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ORDNANCE FIELD GUIDE

VOLUME II

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ORDNANCE FIELD GUIDE

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Edited by

LT. COL. Wm. C. FARMER

MILITARY SERVICE PUBLISHING COMPANY
HARRISBURG 1944 PENNSYLVANIA

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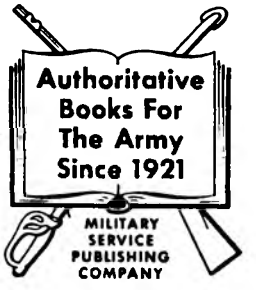

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Dedication

This manual is dedicated to our comrades-in-arms of the Ordnance Department who have gone into the combat zones all over the world in support of the Arms and Services in their struggle against the Axis.

Their resourcefulness, initiative, and devotion to duty through month after month of arduous labor under difficult and hazardous conditions should serve as 'Guide' to the Ordnance Department for many years to come.

It is especially dedicated to those Ordnancemen who left their families to serve their country on Bataan, in Africa, Italy, France, Germany, Burma, China, and many other far-flung battlefields, and who will never return.

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The Ordnance Field Guide

In the years to follow the defeat of Germany and Japan, the United States must play a major role. Regardless of what particular plan for the maintenance of security and peace may finally be adopted, one thing, at least, is certain: Our army must be ready to do its part in the great work. This work calls for an army flawlessly equipped, and thoroughly trained. Ordnance is both determined and prepared to do its part by insuring to that army the finest ordnance equipment and the best trained ordnance personnel in the world.

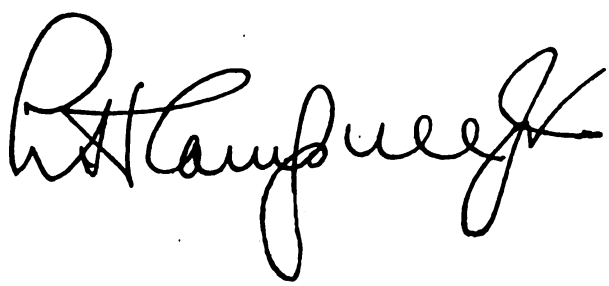
The experience of World War II has shown, to even the casual observer, the prime importance of that mobility and firepower which modern ordnance provides. And to the trained military mind ordnance now, as never before, spells the difference between success and failure.

The myriad changes in ordnance during World War II complicate and increase the study and the work of our ordnance officers to a vast extent. The training of our ordnance officer corps, one of the prime charges of the Ordnance Department, must not only be effective but it must be complete. Each man must possess, in addition to a mastery of his own special subject, a sweeping knowledge of modern weapons, a working acquaintance with all automotive practice and a comprehensive understanding of an officer's duties and responsibilities.

To provide for this training, many have felt the need of a supplement to the hundreds of Technical Manuals and Training Courses, each of which treats exhaustively of a single subject. Not only is it desirable to have the outlines of many manuals, course texts, and training aids in one book but this book should incorporate the military knowledge and experience which could be compiled only from all available sources.

To prepare this compendium of modern ordnance a large group of ordnance officers and enlisted men volunteered to work on such a project. Lt. Col. William C. Farmer, a member of the Staff and Faculty of the Ordnance School, Aberdeen, Maryland, headed the group. Their material has been drawn from very many sources: Textbooks, manuals, service magazines, directives, dispatches, reports of observers from every battlefront and throughout the world, and last, but not least, their own vast store of experience.

How well Colonel Farmer and his associates have accomplished the important work with which they were entrusted, is revealed in the pages which follow.



Major General, Chief of Ordnance

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Preface

After several years of service with ordnance troops and staffs, both in the United States and overseas, it was the feeling of the editor that a definite need existed for a 'manual' of such broad scope that it would serve as an encyclopedic 'guide' and 'self-educating' text for ordnance officers in the field. The "Ordnance Field Guide" has tried to meet this challenging assignment.

This manual covers a wide range of material. Principal sources appear in the bibliographies which are appended to the various subjects discussed, and which also furnish a ready guide to the many War Department publications that cover in greater detail the various matter pertaining to the organization and administration of the Army, the technical and military subjects, and the materiel, functions and operation of the Ordnance Department here presented. Other sources are: Ordnance School and industrial textbooks, service magazines, standing operating procedures, ordnance plans, administrative orders, and other data obtained from overseas theaters, reports, conference notes, lectures, observers' reports, and the combined knowledge of some 200 Ordnance officers and enlisted men who have compiled and written the original manuscripts for the various sections of the manual.

Each officer and enlisted man who has contributed to this book is a specialist in some particular phase of ordnance operations or materiel. Many of them have served in the field, in Alaska, the Aleutian Islands, Australia, the Caribbean Area, the Far East, Guadalcanal, the Hawaiian Islands, Italy, the Middle East, New Guinea, New Hebrides, North Africa, Sicily, and the United Kingdom. Practically every type of ordnance field duty, with troops or staffs, is represented by their experiences. The Silver Star, the Legion of Merit, the Purple Heart, and the star-studded campaign ribbons worn by various contributors attest to their wide range of field activities. Every specialized course of instruction on ordnance materiel and operation offered by the various Ordnance schools is represented by a contributor to this work. Many of these officers are also graduates of the Command and General Staff School (in either the general or service staff course) or of other service schools.

The contributors have donated their services with no other remuneration than the satisfaction of aiding in a work that should help many ordnance officers to assimilate more quickly many of the complexities of their profession, thereby contributing to the efficiency of the entire Army and the war effort of the Nation.

The royalties from the sale of this book will be donated to the Army Emergency Relief Society.

In re-writing and editing the work of the various contributors, there has been no attempt to conform to a single standard of writing, and naturally many styles will be encountered due to the large number of contributors. All have attempted to treat the subject matter assigned to them in a 'down-to-earth' manner, and have tried to cram as much 'meat' as possible in the space allotted.

The data contained herein is *not* to be considered official. In using this manual, the reader must bear in mind that the composition, size, and duties of units and the quantities and types of equipment allotted to units are subject to constant change. In making field use of the data contained in this book, a check should first be made as to whether the then existing units and equipment are based on T/O & E's which are later than those upon which the discussions in this manual are based.

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Similarly, ordnance materiel is subject to re-design and improvement and operational technique improves with added experience.

All ordnance equipment charts, tables of organization and equipment, and similar material reproduced herein, in whole or in part, bear the official War Department designation and the date of issue.

It is suggested that the reader post any changes or revisions which might be later issued from official sources in his copy of the "Ordnance Field Guide." In this way, the book can be kept up-to-date and will retain its value as an accurate source of information.

The editor felt that in a work of this nature continuity of subject matter was most important. Therefore, there are no cross-references on minor subjects, although larger subjects have been cross-referenced when deemed necessary. It was believed, however, that the repetitions of information in the Guide would serve a useful purpose.

A study of this Guide cannot be expected to make the reader an expert in any one subject, but it should give a useful background for nearly every situation with which the ordnance officer can reasonably expect to be confronted in the field. It should also lay the groundwork for any specialization the reader might wish to pursue at a later date.

The original intention of the editor was to prepare an ordnance textbook of broad scope as a guide for training purposes. Due to the advanced state of Ordnance Training for World War II, a compromise between a textbook and a field reference guide has been compiled to serve for the duration of the present conflict.

The editor contemplates a revision of the "Ordnance Field Guide" shortly after the termination of the present war. It is expected that the experience gained in the editing of this edition, coupled with the many ordnance lessons of the war which will be available at that time, should enable the preparation of a much more comprehensive and cohesive textbook. A standardized set of books of this type would in the opinion of the editor be of extreme value in the post-war training of ordnance officers and troops, whether at ordnance schools, ordnance training centers, civilian colleges, or in the field. Criticisms, suggestions, and contributions from ordnance personnel, both in the garrison and in the field, will therefore be welcome at any time, and will be used to the fullest extent in the contemplated future revisions of this manual. They should be sent to the editor at the address below noted.

Special acknowledgment is made to Col. Willis R. Slaughter, Commandant, The Ordnance School, for making available the facilities of The Ordnance School during off-duty hours for research, illustrations and typing. The "Ordnance Field Guide" would not have been possible without his encouragement, appreciation and whole-hearted support.

Col. L. A. Codd, Executive Assistant to the Chief of Ordnance who took a personal interest in the Editor's idea for such a Guide, did much to make the project possible.

The Editor cannot conclude this preface without stating that he has been most effectively assisted by Major John B. Scott in the overall and detailed planning, editing, rewriting and coordinating of the material for the volumes of this work.

WILLIAM C. FARMER,
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Staff and Faculty
The Ordnance School
Aberdeen Proving Ground, Maryland
December 15, 1944.

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The following officers and enlisted men of the Ordnance Department have written articles on the various subjects contained in this volume. The amount of work done by each ranges from one to two hours in the case of some of the smaller contributions, to many, many hours spent in writing the longer articles. This time has been contributed by the writers out of their limited off-duty hours.

No attempt is made to give special credit to a particular writer, But all contributors are listed under the pertinent chapter heading. In some cases an article or a portion thereof was prepared by the Editor or those assisting him.

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CHAPTER 1

SMALL ARMS

INTRODUCTION

In the development of weapons from primitive times to the present day, the history of small arms is interwoven in a truly romantic and enthralling pattern. Early man could scarcely have appreciated that his employment of rocks, bludgeons, and stone axes in hand-to-hand encounter represented relations which, today, we have come to construe as a combination of weapon and ammunition employed in close-in fighting. From these savage, improvised 'tools of war' small arms weapons have progressed through evolutionary stages, reflecting with an illuminating accuracy the dominant motives during each period or era in which they appeared until this present war in which our soldiers, equipped with modern weapons, are enabled to deliver large volumes of fire over great distances.

Following the discovery of gunpowder, matchlocks, wheel locks, and miquelet locks in that order, appeared in various European countries during the fifteenth century. Our ingenious ancestors shrewdly turned to the innovation of grooved or rifled barrels even during this early period as shown by the presence of, "one iron gun with a twist (inside) like a Snail's Shell" in the Fortress of Gautalla on July 28, 1476. Probably the inconveniences of transporting powder, shot, and primers separately, and the unwieldy operations of loading these early weapons, accounts for steady trends forward in the development of our present mechanical loaded fixed rounds of ammunition.

Armament inventors have been confronted continuously, in a basic sense, with the problems of: a satisfactory chamber design for holding and feeding ammunition combined with a suitable barrel for directing the projectile toward the target; a device for igniting or otherwise obtaining the maximum usable energy from powder used to propel the projectile; and a mechanical arrangement providing repetition of the aforegoing so as to produce a rapid rate of fire.

It is quite fitting that the names of General George Washington and his advisor, Colonel Knox, be associated with small arms development in the United States. The foresight and planning of these men in 1777 resulted in the establishment at Springfield, Massachusetts, of that truly great small arms plant, Springfield Armory. In the days of the American Revolution a desire to protect the arsenal against British Naval attack, to utilize water power from the Connecticut River, and to provide reasonable land and water accessibility were prime considerations in selecting the site of the arsenal. The practical application of utilizing powder combustion pressure to force a ball projectile through a grooved barrel of slightly smaller inside diameter than the ball was first realized at Springfield Armory about 1854 in a single shot musket and a pistol carbine produced at that time. The effect of these weapons upon the outcome of the Civil War is as certainly reflected in history as the important relation of the Garand rifle and bazooka to an allied victory in World War II. Springfield Armory is the home of extensive small arms research and design. Many famous weapons (including the Springfield and Garand rifles to mention only a few) have originated there.

John Browning's automatic small arms weapons are today rounding out a most successful performace in the second great world war of their experience. The forbearers of this efficient type of modern automatic weapon are to be found in medieval multiple crossbows, the French Montigny Mitrailleuse of the nineteenth century and numerous small caliber artillery weapons including the Requa and Lowell battery guns and the Gatling gun. Recognition for automatic weapons development and successful use will appropriately include such famed inventors as Hotchkiss, Maxim, Gardner, Lewis, Colt and Chauchard for the fine quick-firing weapons produced by these men.

Small arms lessons learned during and after World War I and subsequent ideas which have been developed by the War Department are reflected in the refinements and improvements to weapons already in use during that period and the production of several newer types. Government surveys conducted during the early

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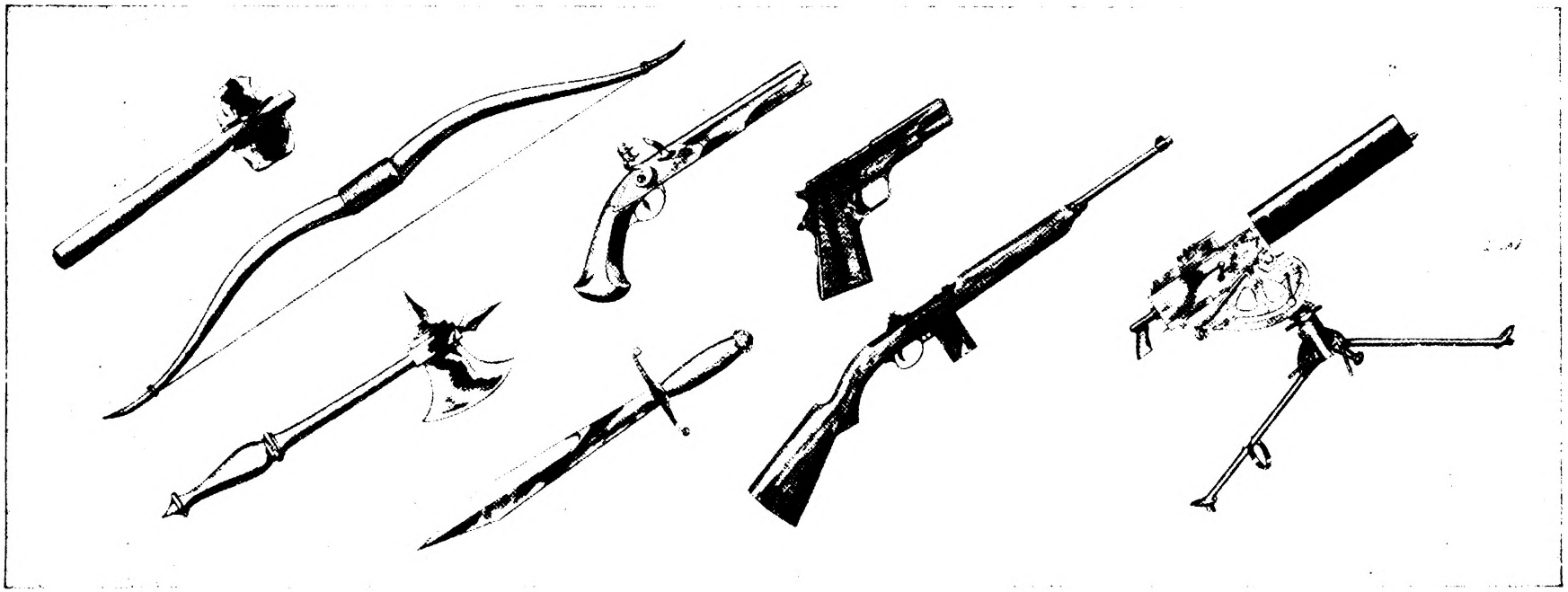

Figure 1. The Development of Small Arms.

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1930's laid the groundwork for converting peacetime industrial machines to the production of war materiel. Envisioning and recognizing the tremendous small arms requirements which would be occasioned in the course of speedily drafting a citizen army, extensive plans were formulated and later put into operation by the Ordnance Department. The result of these actions has enabled our nation to mobilize industry as needed, produce armament as required by the army, and put into the hands of our own soldiers and those of the allied nations a phenomenal quantity of finest quality small arms weapons to an extent unsurpassed by any other nation.

In noting the scope and generous treatment accorded small arms weapons herein, readers may well observe lessons so far taught in World War II. Consummation of victory results rather from close-in direct enemy contact by ground forces culminating in the occupation of territory than solely from fire power, mobility, and aerial warfare. Considered in this light the importance of small arms weapons to modern conflict may be justly appraised.

Description, functioning, stripping, assembly, adjusting, inspection, and care of small arms is covered in detail. Maintenance from the viewpoint of the small arms technician is considered a subject of such broad scope as to preclude its coverage in a field guide of this nature. Particularly, the reader's attention is invited to the material at the close of this chapter dealing with the principles of small arms preventive maintenance, care, and preservation under the widely varying circumstances and climatic conditions frequently encountered when working in the field with small arms weapons.

General Definition and Terminology

This glossary has been compiled to assist the reader to understand better the mechanical definitions and phrases used when referring to small arms. To make this glossary complete would require a separate volume; hence definitions will be confined to those most frequently used.

Accelerator. A part designed so as to act as a timing device and a transmitter of energy.

Ammunition. The various articles used in the discharge of small arms such as cartridges, shells, powder, shot, bullets, and primers.

Aperture. An open passage, such as rear sight with either a small or large opening or a peep sight.

Assembly. Consists of two or more parts which are either permanently or semi-permanently assembled and should not ordinarily be taken apart.

Automatic. Weapons in which the force of the explosion of the first shot is utilized to continue the mechanical operation of the weapon. The weapon continues to fire as long as the trigger is depressed, ammunition is left in the magazine or belt, and the gas is generated to perform the eight phases of a complete cycle of operation.

Adjustment. Placing the parts and sub-assemblies in proper working relationship to each other.

Band. A metal strip encircling and holding the barrel and stock of a weapon together.

Barrel. Metal tube of a weapon through which the bullet is given velocity and direction in its line of flight, and to concentrate the gas which is generated by the explosion of the powder on the base of the bullet.

Blowback. See 'Principles of Operation of Small Arms Weapons'.

Bolt. The working part of the mechanism that locks the cartridge in the chamber.

Bore. The interior of a barrel through which the projectile passes.

Breech. The rear end of the barrel where normally a type of locking mechanism fits to close the rear of the barrel at the time of firing so that the gas pressure created by the explosion will be utilized in driving the bullet through the bore.

Breech Block. That part of the mechanism which receives the backward pressure of the explosion and closes the breech opening of the bore against the force of the charge.

Breech Lock. The mechanism that locks the breech at the time of firing.

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Bullet. A small projectile for use in weapons and made in various forms and weight.

Butt. The part of the gun stock that fits against the shoulder.

Butt Plate. A plate of metal, horn, or vulcanite placed on the butt to protect the wood against damage.

Caliber. The diameter of the bore, expressed as a decimal in inch units. Caliber is the diameter distance across the lands in the bore. It is also the measurement of the diameter of the projectile. It is expressed in millimeters in continental Europe.

Cam. A surface designed to change the direction of movement of a moving part.

Carbine. A type of rifle made with a short barrel.

Cartridge. The fixed ammunition for small arms.

Cartridge Case. The metal case which contains the explosive charge.

Chamber. The enlarged portion in the rear end of the barrel where the cartridge is placed when in position to be fired.

Choke Bore. A shotgun bore slightly constricted at the muzzle.

Cleaning Rod. A rod used to clean the bore of a weapon.

Clip. A device used to hold several cartridges together so that they may be loaded simultaneously in the gun.

Cocking. The process of retracting the hammer or firing pin to the rear and holding it by the sear so that it may later be released to fire a new cartridge.

Creep. Any movement of the trigger that can be felt by the fingers after the slack is taken up and before enough pressure is applied to release the sear.

Counter Recoil. The forward movement of the mechanical action.

Cut-off. A mechanical arrangement which temporarily cuts off the feeding from the magazine into the chamber.

Cycle of Operation. The mechanical sequence of operation consisting of eight phases: firing, unlocking, cocking, extraction, ejection, feeding, loading, and locking.

Double Action. Cocking and firing the revolver by pressing the trigger.

Ejector. A mechanical device by which the fired cartridge is expelled from the receiver.

Ejection. The process of expelling the empty cartridge case from the receiver after the case has been withdrawn from the chamber.

Extractor. A hook shaped part which withdraws the empty cartridge case from the chamber.

Extraction. The process of withdrawing the empty cartridge case from the chamber. This process occurs as the bolt moves to the rear.

Feeding. The process of drawing a cartridge into the receiver and aligning the cartridge with the chamber of the barrel.

Firing. The process of igniting the propelling charge of the cartridge in the chamber. When this charge is ignited, it forces the bullet through the barrel and toward the object at which the gun is directed.

Fire Control. That part of the mechanism which prevents accidental priming of the cartridge until the mechanism is in the firing position.

Firing Pin. The part of the firing mechanism which strikes the primer, thereby exploding the powder charge.

Flare Pistol. A large pistol used to fire flares for illumination or signaling.

Fore Arm. That portion of the wooden stock located under the barrel and forward of the trigger guard.

Fixed Arm. A weapon that is attached securely on fixed installations in tanks, vehicles, or planes and is aimed only in the path or flight of the tank, vehicle, or plane.

Flexible Gun. A weapon mounted on a flexible mount which can be moved horizontally or vertically permitting the gunner to direct the line of fire irrespective of the path or flight of the tank, vehicle, mount, or plane.

Gage. The term used for the diameter of the bore for shotguns.

Grip. The hand of the butt-stock. It also applies to the grip of a revolver and pistol.

Guard. A loop or rectangle made of metal protecting the trigger.

Groove. The cutaway portion between the lands into which the bullet or

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rotating bands of projectiles fit, giving them a rotary motion as they travel through the bore.

Group. A number of parts or assemblies or both which either function together in the gun or are intimately related to each other.

Gas Operation. See Section II (Principles of Operation of Small Arms Weapons).

Hair Trigger. A trigger requiring only a light touch for firing.

Hammer. That part of the trigger mechanism which strikes the firing pin or strikes the primer directly.

Hang Fire. A delayed ignition.

Ignition. Setting the powder on fire.

Headspace. The headspace of a military weapon with a cartridge fully seated in the chamber is the distance between the base of the cartridge and the face of the bolt.

Lands. The raised spiral portion of the rifling. This is the surface of the bore that cuts into the bullet or rotating band to give the bullet the spinning motion.

Locking. The process of closing the breech end of the barrel and locking the cartridge in the chamber. This process occurs on counterrecoil.

Loading. The process of placing the cartridge in position for firing.

Line of Sight. The line followed by the sights or eye of the operator. This line is not the same as the line of the bore.

Magazine. The receptacle for the cartridges in a repeating weapon from which the cartridges are fed automatically into the receiver by the action of the mechanism.

Malfunction. An improper or incomplete action of some part of the weapon or its ammunition.

Muzzle. The forward end or mouth of the barrel.

Overtravel. The distance that the firing pin notch will override the sear notch in cocking to insure positive engagement of the two.

Pistol. A small arms weapon with a relatively short barrel, so made as to be easily carried, aimed, and fired with one hand.

Primer. The percussion cap used to ignite the powder charge.

Pawl. A part designed to prevent movement of another part until the desired time; or a part, usually pivoting and under spring tension, which is used to change a unit, causing the unit to move in a definite sense and prevent movement in an opposite direction.

Receiver. The part of a weapon which houses the working parts of the weapons.

Recess. A cutaway surface made either for locking purposes or to allow another part to be positioned properly.

Revolver. A repeating weapon with a revolving cylinder carrying the cartridges.

Recoil. The rearward movement of the mechanical action.

Recoil Operation. See 'Principles of Operation of Small Arms Weapons'.

Rifle. Any shoulder weapon that has spiral grooves or rifling in the bore designed to impart a spinning motion to the projectile.

Rifling. Spiral grooves in the bore of a rifle designed to give a spin to the projectile for greater accuracy and carrying power. Rifling includes both the grooves and the ridges between called 'lands'.

Rifle Twist. There are two main types of rifling. That first, which is most common to small arms, is the uniform twist. In this type there is no variation in the degree of pitch in the rifling from one end to the other. The second type is the progressive or increasing twist, which is more common in artillery pieces. In this type the degree of pitch will increase as it nears the muzzle end of the barrel.

Rate of Recoil. The rate of recoil is governed by the resistance offered by the projectile in relation to the resistance offered by the recoiling parts.

Sear. A pivotal pawl or latch in the trigger mechanism operated between the trigger and the hammer or firing pin.

Smooth Bore. An unrifled bore. Example: the bore of a shot-gun barrel.

Striker. A firing pin or hammer.

Sling. A leather or heavy canvas strap used either to carry certain shoulder weapons or to assist in steady holding of the piece in deliberate shooting.

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Stoppages. Cessation of fire as a result of malfunction in the weapon.

Slow Initial Extraction. Slow initial movement of loosening the cartridge case from the chamber.

Small Arms. The accepted dividing line is six-tenths of an inch or Cal. 60. However, in application there are exceptions to this rule: A small arms mechanic should be qualified to maintain all weapons carried in aircraft. This has brought into the small arms units of the Air Forces such weapons as the 20mm (.787 inch), 37mm (1.44 inches) aircraft cannon, and the 75mm (2.94 inches) gun.

Sight Radius. The distance between the front and rear sight. For accurate shooting the longer the sight radius the better.

Semi-Automatic. Weapons in which the trigger must be pressed for each successive shot. The force of explosion is utilized in operation of this type to extract and eject the empty cartridge, to feed the new cartridge from the magazine into the chamber of the weapon and to re-cock the piece.

Trajectory. The path traveled by the bullet while in flight.

Trigger-Pull. The amount of pressure on the trigger required to release the firing pin.

Trigger. That part of the trigger mechanism pulled manually to release the cocked hammer and fire the weapon.

Unlocking. The process of opening the breech of the barrel. In most types of operation this process occurs as the recoiling parts move rearward.

Windage. A term used for sight correction laterally, either right or left. It is used in making adjustments for wind.

Principles of Operation of Small Arms Weapons

All small arms weapons are based on one of four general principles of operation or upon some modification or combination of these principles.

Manual-Operated Weapons. Bolt or slide action, manual operation of the bolt to perform all phases of operation except feeding and firing.

Recoil-Operated Weapons. In recoil-operated weapons, the bolt, barrel, and barrel extension, locked together, recoil to the rear until the bullet has left the barrel. This movement to the rear is independent of any rearward movement of the receiver. After the bullet has left the barrel, the moving parts (barrel, barrel extension, and bolt) separate, and, the bolt travels to the rear independently of the barrel and barrel extension. The distinguishing feature of recoil—operated weapons as contrasted with weapons operating on different principles is the independent motion of the barrel with respect to the receiver.

Long Recoil-Operated weapons differ from short recoil-operated weapons in the time of locking of the barrel and barrel extension to the bolt.

In *Short Recoil-Operated* weapons, locking is accomplished on the forward movement of these parts before they reach the firing position. Thus, the barrel, barrel extension, and bolt move into the firing position locked together. In long recoil-operated weapons, the recoiling parts move forward into the firing position independently of each other, and are not locked together until the firing position is reached.

A second distinguishing difference between short and long recoil-operated weapons is the distance of recoil of the barrel and barrel extension as compared to the distance of recoil of the bolt. In short recoil-operated weapons the distance of recoil of the bolt is much greater than the distance of recoil of the barrel and barrel extension. In long recoil-operated weapons, the distance of recoil of the barrel and barrel extension is almost the same as the distance of recoil of the bolt.

A third difference between long and short recoil-operated weapons is that, in long recoil-operated weapons, the bolt is caught and held to the rear while the barrel goes forward to the firing position. This is not true with short recoil-operated weapons.

The Automatic Pistol M1911A1 and all Browning machine guns are short recoil-operated weapons. The 37mm M4 and M9 aircraft cannons and the automatic shotguns are long recoil-operated weapons.

Gas-Operated Weapons. Weapons operated solely by gas utilizing a portion of the powder gases to act on some form of piston and cylinder arrangement. The piston is connected to the bolt and is driven to the rear with sufficient force to un-

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lock and open the breech. The gas may be taken from the barrel through a hole drilled in the barrel at any point between the chamber and the muzzle, or as in some weapons, the gas is taken at the muzzle of the barrel itself.

If the hole through which the gases pass into the gas cylinder is very small, the gases striking the piston will be at a lower pressure than the gases still in the barrel. This is true since the very small hole will admit such a small quantity of gas that it cannot occupy the space within the cylinder at the pressure within the barrel. The gas, therefore, which is admitted to the cylinder expands against the piston and gives very smooth action. Weapons operating on this principle are 'expanding gas' arms.

If the hole admitting gas is larger, enough gas will pass into the cylinder so that the pressure against the piston will equal the pressure within the barrel. This gas iterally knocks the piston back and gives a rougher, harsher action.

A gas-operated weapon may be quickly identified by the gas piston and cylinder which lie parallel to the barrel.

Guns employing only this principle of operation are: Carbine M1; U. S. Rifle Cal .30 M1; and Browning Automatic Rifle Cal .30 M1918A2.

Blowback-Operated Weapons. Weapons operated by the blowback principle utilize the pressure of the powder gases to force the bolt to the rear independently of the barrel which does not move relative to the receiver. The gasses produced by the propelling charge act against the cartridge case which in turn acts to force the bolt to the rear.

All weapons operated by the blowback principle must be kept from unlocking while the pressure in the barrel is still too high for safety of personnel. The manner of insuring that the breech is kept closed may be either positive or not positive. If positive, the operation is commonly known as 'delayed blowback.' If not positive, the operation is called 'straight blowback.'

Straight Blowback-Operated weapons generally have a very heavy bolt, backed by a powerful spring, and the round is fired before the bolt is fully forward. The blowback force must overcome the final forward momentum and inertia of the bolt before opening the breech and ejecting the fired shell. There is no positive lock in this system and the delay is provided by the forces mentioned above.

Delayed Blowback-Operated weapons are locked by some mechanical means so that the breech is not opened until the pressure in the barrel has partially subsided. This is done in a number of ways: rotating bolts, locking cam surfaces, lever systems, etc.

The new M3 submachine gun, and the Thompson submachine gun M1 operate on the straight blowback principle. The 20-mm AN-M1 or AN-M2 and the Thompson submachine gun M1928A1 operate on the delayed blowback principle.

Shoulder Weapons—Non-Automatic

U. S. RIFLE, CAL .30 M1903, M1903A1, M1903A2, M1903A3, M1903A4

At the beginning of this century the War and Navy Departments felt the need for a more modern magazine loading rifle. The standard rifle at that time was the excellent, but old-fashioned, Krag-Jorgensen, which was rapidly falling behind the times as newer, stronger, and more powerful weapons were being developed by various foreign nations.

Development. Military and sporting rifles of all nations were constantly being tested as well as rifles submitted for trial by our own gunsmiths. Of the many types submitted and tested, the German Mauser proved to be the best combination of safety, durability, dependability, and simplicity. To the Mauser rifle, after paying royalties, our military gunsmiths in Springfield Armory made several modifications to better suit it to our needs. They submitted the first modified Mauser for test in 1901. The tests were so satisfactory that they were continued, and in 1903 the model of that year was approved and designated U. S. Magazine Rifle, cal .30 M1903.

By 1905 a sufficient quantity of these rifles was completed, and they were issued to infantry troops to be subjected to all types of climatic conditions. As a result many improvements were suggested. To name a few, the construction of both front and rear sights was completely changed to their present form. The com-

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bination ramrod and bayonet, a one-piece ramrod lying in the stock directly below and parallel with the barrel and which could be pulled forward a short distance for use as a bayonet or pulled all the way out for use as a cleaning rod, was scrapped in favor of the present M1905 knife-type bayonet and present stronger upper band. A trap which accommodates the combination thong and oiler was added to the butt, and the butt plate was fitted with a butt plate cap for access to this trap.

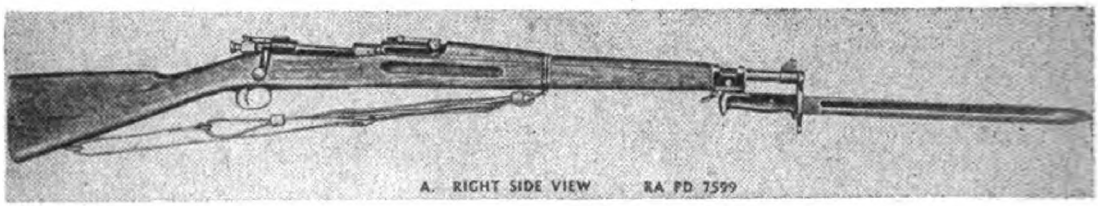
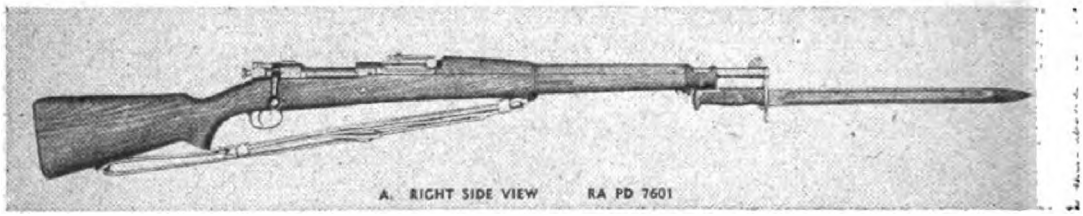


Figure 2. U. S. Rifle Cal. .30 M1903. Right Side View.

In 1906 the German 'Spitzer' type of bullet was tested and found superior to our heavy 220-grain, round-nosed projectile, then in use. The 'Spitzer' projectile, being pointed, was lighter and more streamlined, which gave longer range, flatter trajectory, less bore wear, etc. We adopted the 150-grain 'Spitzer' type of projectile, shortened the length of the neck of the cartridge case, and designated this round Cartridge, ball, cal .30 M1906. To use this shorter round in the rifles already manufactured, it was necessary to remove the barrel, cut one additional thread at the breech, move the rear sight forward, screw the barrel back into the receiver taking up the one additional complete turn, and to rechamber them for the M1906 ammunition. This was done to all '03 rifles issued up to that time.

U. S. Rifle, Cal. .30 M1903A1. With the exception of changes in manufacturing procedure, types of steel used, and hardening processes, there were few changes made to the weapon until January 1930 when a pistol grip was added to the stock. This change, because it did not make obsolete the rifles already manu-



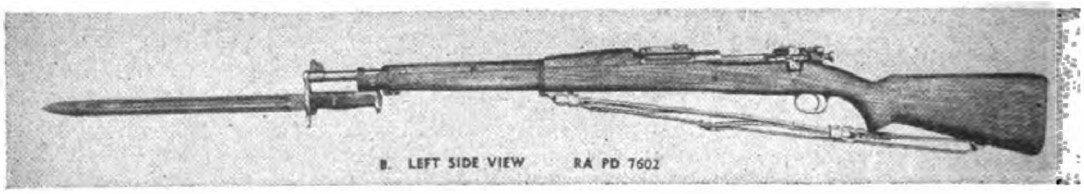


Figure 3. U. S. Rifle Cal. .30 M1903A1 With Bayonet M1905 and Sling M1907.

factured, required the addition of 'A1' to the nomenclature of the rifle. It was about this time that the finger grasping grooves, commonly called 'hog-wallows' because they could be used for nothing else, were eliminated from the front end of the stock. The butt plate was checkered to eliminate slipping from the shoulder and the bolt handle in 1918 was bent slightly rearward for easier operation. These changes made it easier for the riflemen to fire more accurately and faster.

U. S. Rifle, Cal. .30 M1903A2. The Armored Force, for training purposes, needed a subcaliber gun which could be fired through the tube of a tank's own artillery piece. A complete rifle could not be mounted on top of the tube as it would be

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inaccessible to a tank gunner from within the tank. The idea of an assistant gunner being mounted in a McClellan saddle, strapped around the tank's artillery tube, riding outside a moving tank, loading and firing the '03 rifle, was short-lived and unpopular.

Designers first inserted an '03 barrel, the complete receiver extending rearward into a solid shell casing. An improvement over this early model was the inserting of the barrel only into a length of 1¼ inch pipe and securing it at the breech end, then the adding of a metal flange around the pipe both at the muzzle and the breech to center the pipe and seal the artillery tube. The complete receiver extended rearward within the open breech of the tank's artillery piece and was easily loaded and fired in this position. This is the Model 1903A2.

U. S. Rifle, Cal .30 M1903, Mark I. The 'Mark I' rifle was a standard '03 rifle altered to accomodate the Pedersen 'automatic pistol' device as well as the regular issue bolt. The left side of the receiver was slotted for ejection of the small expended cases of the 'device'. The sear was replaced by a special sear that would fire both the device and the issue bolt. The cut-off was slotted to engage and secure the device, but not to interfere with regular bolt operation. The rifle, so modified, was stamped on the front bridge of the receiver 'Mark I'. When the Pedersen devices were finally scrapped, the special sears and special cut-offs were eliminated and the rifles reverted to their original nomenclature.

The purpose of the Pedersen device was to provide the riflemen with a dual purpose weapon. For 'close-in' fighting the device could be used to give tremendous fire power within the limits of the 40-round box-type magazine. The principle of operation was blowback with a heavy counterweight to act as a delaying device. The cartridge consisted of a small cal .30 bullet in a small straight case, similar in size and design to the popular cal .32 automatic pistols. The complete device would be inserted into the receiver, the same as the regular bolt. The magazine would be inserted into the upper right of the device, the rifle cocked, as with the M1911 Pistol, by pulling the slide rearward. It would then be ready to fire.

U. S. Rifle, Cal .30 M1903NM. This rifle until the present emergency was manufactured for use in the National Rifle Matches conducted each year at Camp Perry, Ohio. It is the standard M1903A1 rifle with the following characteristics: barrel is star-gaged and selected for accuracy; the bolt is bright; the type C pistol-grip stock is specially selected; ejector is made of nickel steel; extractor, follower, hand guard assembly, mainspring (29½ to 30 coils), firing pin assembly, butt plate assembly, receiver, sear, front and rear sights, magazine spring, sear spring, all specially selected for quality and workmanship to produce better than normal accuracy and performance of the rifle. Earlier models had a headless cocking piece and reversed safety lock, which are changed to the present type when the rifle is issued for use.

U. S. Rifle, Cal .30, Other Models. During peacetime, the National match rifle was one of several models manufactured by Springfield Armory for other than strictly military use. Most of the following models were made commercially available for the promotion of civilian rifle marksmanship. Many of these models are, however, now 'back in service', and the experienced ordnanceman should recognize them. These models have been or are being converted into straight military jobs.

The style NB is exactly the same as the National Match except that it is mounted on a model 1922 stock, style M.T., cal .30, formerly known as the style 'B' stock. The rear half of this stock has the same dimensions as the short, sporter style stock used on the cal .22 Springfield, but is a full length military stock with hand guard and upper band assembly.

The style 'NM Special' is exactly the same as the regular National Match except that it is mounted on a model 1922 stock, style M.T., cal .30. This stock is a full length model, but has the conventional pistol grip found on the M1903A1 rifle, and also a rounded 'shotgun style' butt plate.

The style SB is the regulation service rifle M1903, mounted on the model 1922M1 stock, style M.T., cal .30.

The style N.R.A. is the popular Springfield Sporter. It has a model 1922 stock, cal .30, which is of the short sporting variety with no hand guard and with a

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'shotgun style' butt plate. The exterior of the exposed barrel is of the same dimensions as the cal .22 M1, and is polished and 'browned' to a smooth, dark color. The receiver is also browned to match. The front end of the stock is fitted to the barrel by a special lower band. In place of the standard military rear sight, it has a Lyman 48, micrometer adjustable, rear sight located on the right side of the rear bridge of the receiver.

The style N.B.A. is exactly the same as the N.R.A. except that it has the model 1922M1 stock, cal .22, with stock screws added. This stock has an odd-shaped pistol grip as have all the M1 versions of the M1922 stock. This, as on the N.R.A. model, is also a short, sporting style of stock, except that the front end has the undesirable finger grasping grooves.

The style 'T' is a heavy barrel target model mounted on a stock similar to the N.R.A. It is furnished with 26,- 28,- or 30-inch barrels which are 1.250 inch in diameter at the breech, and taper to .860 inch at the muzzle. The complete rifle is specially selected, as is the N.R.A. and the National Match, for accuracy and performance. It has telescopic sight bases attached to the top of the barrel, a Lyman 48 receiver sight, and a special Winchester Globe front sight. Its weight is approximately 12 lbs., 4 ozs.

The style, US Rifle, cal .30, special target, international match type A is similar to the style 'T' heavy barrel target model; however, it has a Swiss style adjustable butt plate, 28-inch barrel only, and weighs about 1 pound more.

The style US Rifle, cal .30, special target international match type 'B' is similar to the style 'A' above except that it has in addition a Swiss type check piece, Garand-type fast-firing pin, Woodie-type double set triggers, and weighs about 14 lbs., 12 ozs. This model is commonly referred to as a 'Free Rifle'.

U. S. Rifle, Cal .30 M1903A3. This latest model of the service rifle was developed in 1941 from the standard M1903A1, with the principal idea in mind of speeding up production and cutting down on expense without sacrificing any of the qualities of the M1903A1.

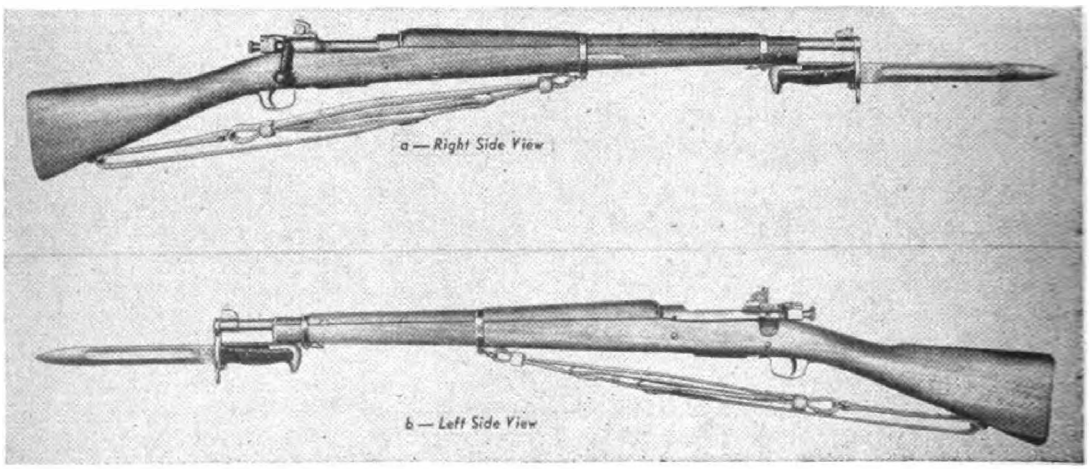

Figure 4. U. S. Rifle Cal .30 M1903A3 With Bayonet M1 and Sling M1907.

At first glance, the '03A3 looks the same as the '03 or the '03A1, the pistol grip being optional. Noticeable is the one great improvement over the '03 and '03A1—the elimination of the cumbersome battle sight from the breech of the barrel, and the addition of a new and simply designed rear sight on top of the rear bridge of the receiver. The rifleman now has the advantage of a maximum sight radius as well as a sturdy, simple, aperture sight close to his eye. Missing the old battle sight, you would notice covering that area the longer hand guard, now called a barrel guard.

The Springfield manufactured by Remington Arms Co. does not have complete interchangeability of parts with the older '03A1; therefore, replacements should be made according to parts listed in SNL B-3. Some parts, although they vary in design, may be found in recently manufactured M1903A1 rifles because they are

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interchangeable. The following is a list of changes made in designing this 'war baby'.

Stock. Similar to the '03 except that a pistol grip is optional. Earlier '03A3's had stock screw pins running laterally through the central portion of the stock to reinforce the trigger guard and magazine hole. Later models had stock screws and nuts as on the M1903 and M1903A1 models.

Rear Sight. Assembled to the rear bridge of the receiver, consists of a dovetailed base, windage yoke, slide aperture, spring, and windage knob. The range scale on the windage yoke is graduated in 100-yard divisions and has 50-yard adjustments. The slide aperture can be moved up and down this scale from 100 yards to 800 yards. Turning the windage knob moves the yoke to the right or left, each click representing a change of 1 minute of angle or a change in the point of impact of 1 inch for each 100 yards of range. Each division on the windage scale represents 4 minutes of angle or a change of 4 inches per 100 yards of range in the point of impact.

Barrel Guard. Replaces the hand guard of the '03 and '03A1 and also covers the area formerly occupied by the rear sight of the older model.

Upper Band Assembly. Is made of sheet metal stampings. The bayonet stud band, which replaces the upper band of the '03 rifle, is shorter, solid on top, and has two bayonet mounting stud bands on the bottom. The stacking swivel and stacking swivel band are stampings. They are secured to the forward end of the stock just to the rear of the bayonet stud band.

Lower Band and Lower Band Swivel. Made from flat metal stampings. The swivel of the '03 rifle is of round wire and the lower band is grooved for reinforcement.

Trigger Guard Magazine Assembly. The new nomenclature for the stamped. staked, and welded magazine, trigger guard, and floor plate. In the '03 rifle the magazine and trigger guard is an intergral machined piece with a separate and detachable floor plate. In the '03A3 the magazine spring is not clipped to the floor plate.

Front Sight Group. Composed of a flat front sight pinned in a slot in a ring-type sight base which is keyed and pinned to the muzzle. The sight is furnished in five heights from 0.537 to 0.477 inches. The front sight group of the '03 is composed of a flat front sight and a moveable stud fitted ino a ring-type fixed stud which is splined and pinned to the muzzle.

Butt Plate Group. Same as the '03, but made of stampings and the butt plate cap is not as easily removed.

Butt Swivel Group. Made of two plates with the swivel between, welded together, and secured with two butt swivel screws.

Bolt Group. Parts are basically the same as those in the '03, but differ slightly in design and are not all interchangeable. SNL B-3 should be referred to before attempting to fit parts from one model to the other.

Follower Group. In the '03A3 is made of sheet metal stampings. It has a straight ridge running longitudinally on its top side. A portion near the narrower front end is bent downward and inward on both sides to seat the magazine spring, and there is a projection on the rear end to hold it in position. The follower on the '03 gives the same results, but is a machined piece. Followers are completely interchangeable.

U. S. Rifle, Cal .30 M1903A4 (Snipers. This is the only remaining Springfield rifle that is classified as 'limited standard'. All models previously described are classified as 'obsolete' and are no longer being manufactured. However, they will, because of their accuracy and dependability, be used for many years to come and it will be necessary for an ordnanceman to have thorough knowledge of all of these models.

The '03A4 is identical with the '03A3 with the following exceptions:

A telescopic sight is mounted in a bridge type mount over the receiver. The front and rear mountings for the sight base are secured on the top of the front and rear bridges of the receiver respectively. The telescope is secured to this base, both front and rear, by two ring mounts. The rear mount has an adjustment for zeroing the rifle for windage, while metal shims are used to elevate or depress the front mount for zeroing the rifle for elevation. After the zero has been obtained, adjustments will be made within the telescope by moving the reticle.

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Both front and rear metallic sights are eliminated.

The stock will have a pistol grip and a notch for the altered bolt handle.

The bolt handle curves downward and is cut away on the outside to clear the scope when it is raised.

Cartridges must be inserted into the magazine by hand, one at a time, because the standard 5-round clip cannot be positioned above the receiver.

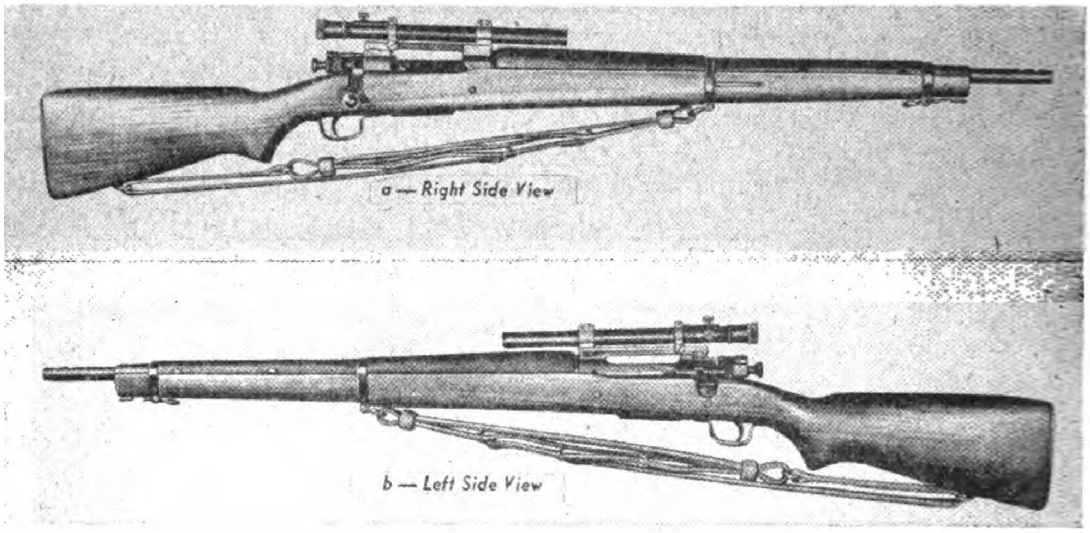

Figure 5. U. S. Rifle Cal .30 M1903A4 With Sling M1907.

At present, the Weaver commercial telescope model 330 C, designated M73B1, is being issued with this rifle. The telescope has a magnification of 2.2 power and has an internally adjustable reticle for elevation and windage. It may be elevated to a maximum of 1,200 yards.

A bayonet can not be used on this rifle.

Operation and Functioning

General. The operations to fire one round and reload all occur at approximately the same time. Therefore, to adequately explain the complete cycle of operation, it will be necessary to divide this cycle into various phases. The loading of ammunition into the magazine and the bolt's remaining open after the last round is fired are not a part of this cycle since they occur only once in the operation of the rifle.

Primary Loading. The loading of the magazine will be known as primary loading. This will be done with the 'cut-off' turned up and showing 'ON' and the bolt drawn fully to the rear. The loaded five round clip will be placed in its seat in the top of the rear bridge of the receiver and the five rounds pushed down into the magazine until the last round is caught by the right edge of the receiver. The follower has been forced down and the magazine spring compressed. If so desired, the rifle can be kept loaded by inserting additional rounds by hand, forcing them down in the same manner. An extra round can be loaded, making the gun capacity six, by inserting this extra round in the chamber while holding the rounds in the magazine downward and easing the bolt forward so that it will ride over the top of the uppermost round in the magazine. Then continue to close and lock the bolt.

With the cut-off at 'OFF', the magazine will be cut 'off' in that the bolt cannot be pulled back far enough for the front end to completely uncover the top round in the magazine or to uncover the rib on the follower should the magazine be emptly. With the cut-off at 'OFF, a completely loaded magazine can be kept in reserve and the rifle used as a single shot weapon by inserting one round at a time and closing the bolt behind that round. It will also be used that way for drill purposes so that the bolt can be opened and closed without the rib on the follower moving up and blocking the forward movement of the bolt.

Firing. With the bolt closed and locked, a live round in the chamber and the

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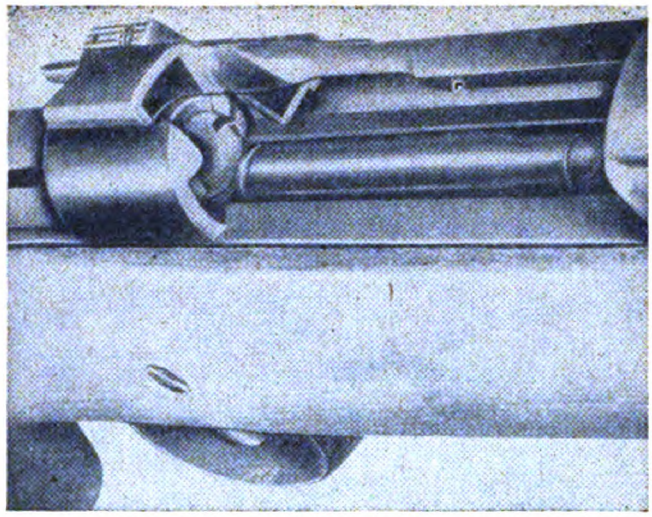
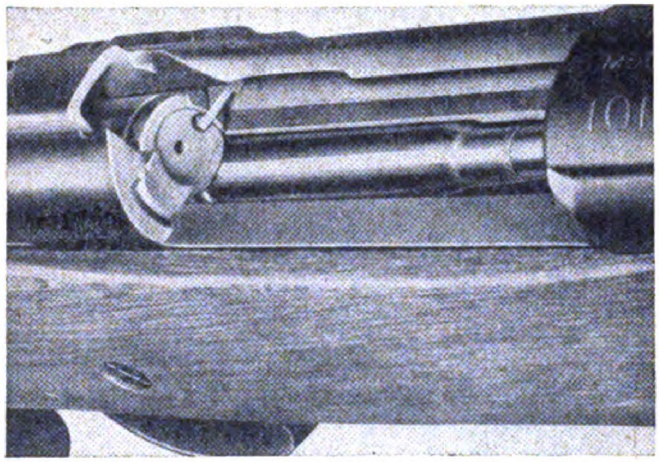
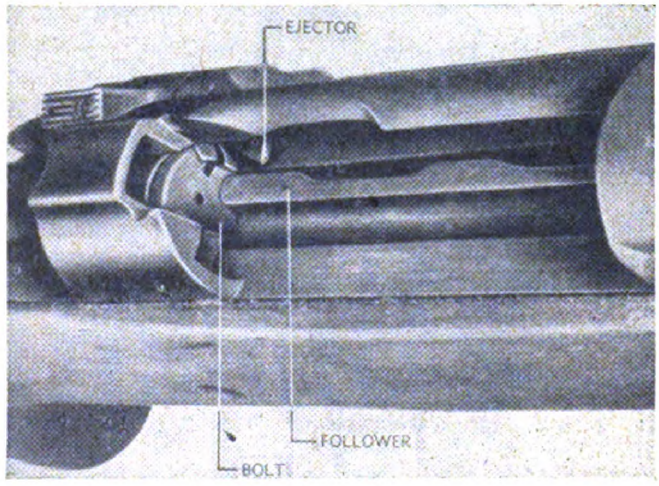


Cartridge in Magazine.



Cartridge in Magazine.



Position of Follower.

Figure 6. Primary Loading Operation for the Cal .30 M1903 Type Rifles.

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piece cocked, we are ready to squeeze the trigger and fire the weapon. The rearward movement of the trigger while the 'hump' or normal bearing surface is in contact with the receiver and until the 'heel' or rearward surface comes up and contacts the receiver, is known as the 'slack.' During the time that the slack is being taken up, the distance from the trigger pin to the hump is short; therefore, the leverage obtained is very great; the movement of the trigger will be longer but the force required very slight. After the slack, the pull will become heavier and the movement of the finger shortened because we are now using a longer line of leverage, the distance from the trigger pin to the heel of the trigger. In addi-

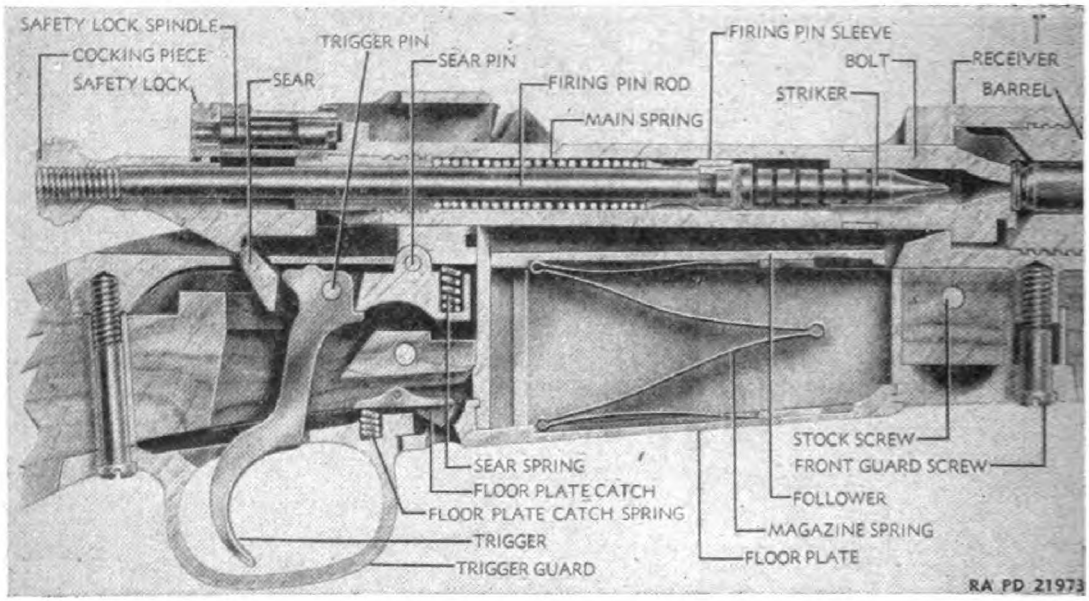

Figure 7. U. S. Rifle Cal .30 M1903A3. Section Through Receiver. Vertical View.

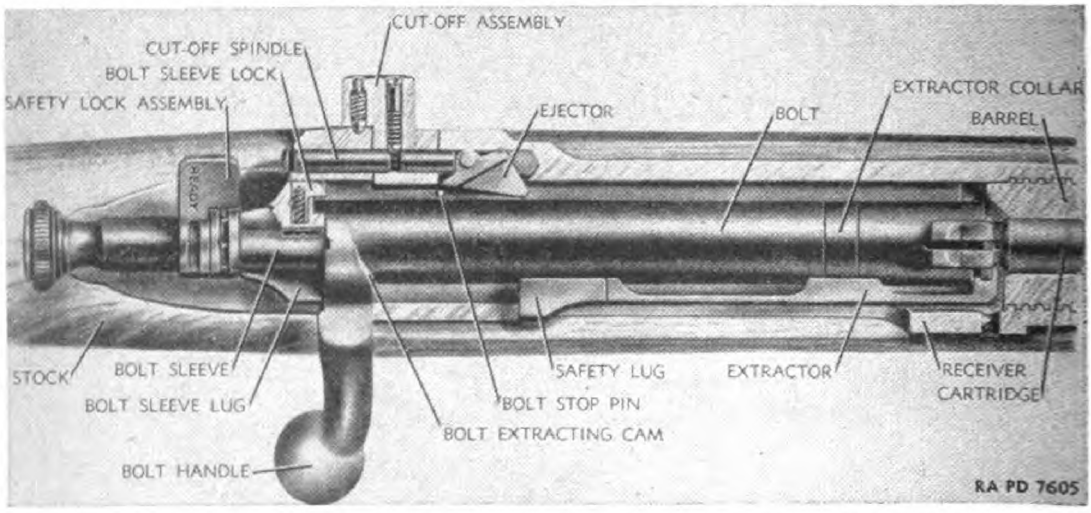

Figure 8. U. S. Rifle Cal .30 M1903A1. Section Through Receiver. Plan View, Etc.

tion, the sear spring will require greater force to further compress it. During the time that the trigger is being rotated, its rotation is causing the rear half of the sear to move down and become disengaged from the sear notch in the cocking piece. The forward half of the sear is moving upward, compressing the sear spring, and building up the force to return the trigger when released.

As soon as the sear is forced down low enough, the cocking piece will be released and will fly forward due to the tension of the compressed mainspring. The main-

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spring is compressed between the threaded forward end of the bolt sleeve assembly (which is immovable while the bolt is closed) and the firing pin sleeve seated against the striker. The striker, in turn, is hooked onto the firing pin rod, a part of the cocking piece in which the sear was seated. Therefore, when the sear releases the cocking piece, all these moving parts within the bolt sleeve and bolt body will fly forward and the tip of the striker will protrude through the face of the bolt, indent the primer, ignite it and cause the piece to be fired.

To eliminate dangers of firing unless the bolt is completely rotated and locked, the cocking piece has a forward projection which will drop into the deepest portion of the cocking cam, provided the bolt is completely closed. However, if the bolt were not completely closed this forward projection would strike the camming surface and stop further forward motion of the firing parts, or, the tension of the mainspring might continue moving them forward; but, as it does so, the bolt would be caused to rotate completely.

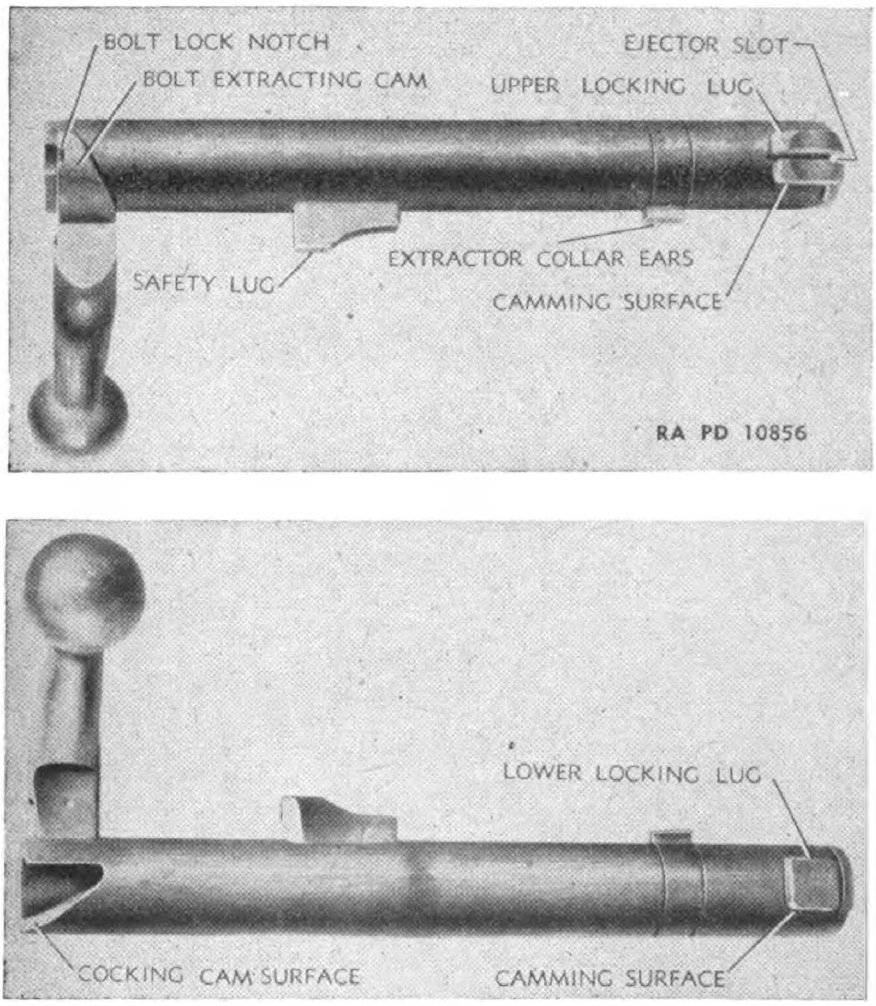

Figure 9. Bolt Assembly. Top and Bottom Views.

Unlocking. After the weapon has been fired the first step is to raise the bolt handle causing the two locking lugs on the forward end of the bolt to become unseated from their locking recesses in the receiver so that the bolt will be moved rearward.

Slow Initial Extraction. During the last half of the bolt's rotation while unlocking, a rearward force will be imparted to the bolt by the extracting cam on the upper forward surface of the bolt handle bearing against a mating cam in the receiver. This will free the fired cartridge case from the chamber and extract it slightly.

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Extraction. As the bolt is pulled rearward after unlocking, the hook of the extractor, which is engaging the rim of the cartridge case, will cause the case to be extracted from the chamber.

Ejection. Just before the bolt is drawn fully to the rear, the (slotted) locking lug strikes the heel of the ejector, throwing its forward point to the right and into the slot in the locking lug. As the bolt moves further rearward, the base of the cartridge case strikes the ejector which tends to knock it forward and to the right. The extractor, still gripping the case, will act as a pivot point and cause the ejection to be in a right hand and slightly upward direction.

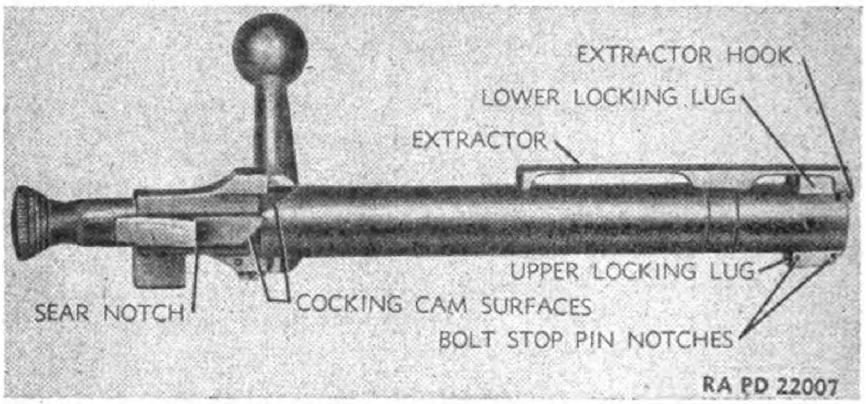

Figure 10. Bolt Group Assembled.

Feeding. The last half inch of the rearward movement of the bolt uncovers completely the rounds held down in the magazine by the rounded under surface of the bolt. This frees the rounds which then move upward and contact either side of the receiver, depending upon their staggered position within the magazine. The tension of the compressed magazine spring forces the rounds upward and holds the top round in position so that its base will block the forward movement of the bolt.

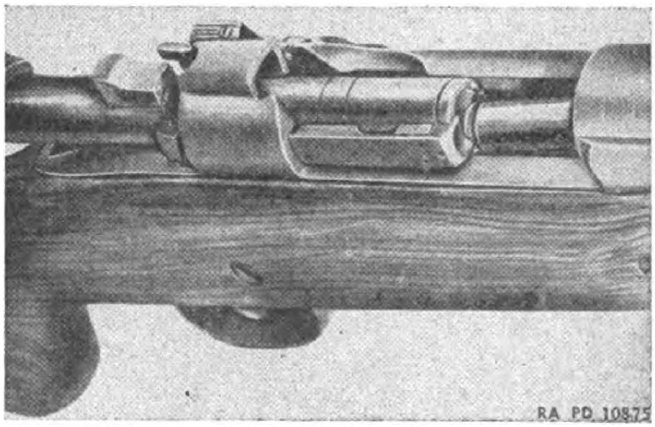

Figure 11. Cartridge Being Pushed Into Chamber.

Loading. As the open bolt is shoved forward, the lower part of its face strikes and pushes forward on the base of the round held in the top of the magazine. As the bolt continues forward, the round will rise slowly, the nose of the projectile will strike and ride up the bullet ramp portion of the receiver and enter the chamber and the base of the round will slide under the rounded lower edge of the hook portion of the extractor. The right side of the end of the barrel is cut away to allow the forward end of the extractor to move completely forward with the bolt so that loading and locking, may be completed.

Locking. After the bolt arrives at the forward position, the turning downward of the bolt handle causes the locking lugs to become engaged into the locking

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recesses in the receiver. The locking lugs and recesses are so designed that when the closing of the bolt is begun, their camming surfaces will cause the bolt to be pulled forward slightly. This will force the round forward, seating it very snugly in the chamber, the projectile engaging the lands in the barrel.

Cocking. Cocking begins with the unlocking action but is not completed until after the bolt is again closed and locked. Therefore we mention it now in this cycle of operation.

As the bolt body is rotated in unlocking, the cocking cam surface in the rear underside of the bolt will cause the cocking cam portion of the cocking piece to be cammed rearward and compress the mainspring to its maximum degree, since the cocking piece cannot be rotated with the bolt. After it is cammed rearward and up onto the rear end of the bolt body, it will drop into the cock notch portion of the bolt and will remain there throughout the extraction, ejection, feeding and loading operations. At the end of loading and as locking is begun, the bolt will be far enough forward so that the sear notch portion of the cocking piece will be engaging the released and elevated rear end of the sear. The slight forward movement of the bolt, caused by the bolt's locking lugs and shoulders in the receiver, will cause the cocking piece to be held stationary while the cock notch in the bolt moves forward and then rotates to the locked position. This rotation aligns the nose of the cocking piece with the deepest portion of the cocking cam notch in the bolt. The weapon is now cocked and again ready to be fired.

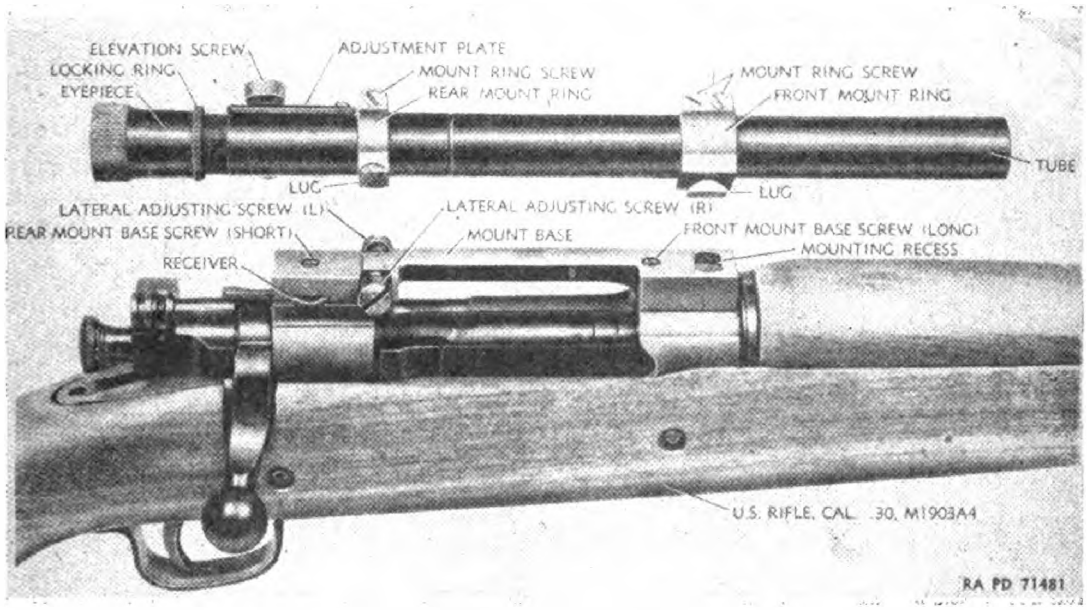

Figure 12. Telescope Sight M73B1 (Weaver).

Safety Lock Assembly. The safety lock has three positions, left or 'Ready', 'Intermediate,' and right or 'Safe.' When the safety lock is to the left, it is inoperative and the rifle can be fired. In the intermediate position, its cams enter the recesses in the top of the cocking piece, cam the cocking piece rearward and out of contact with the sear and lock it rearward. All the way over to the right, the locking action of the cocking piece continues, and in addition, the uncutaway position of the safety lock spindle is rotated into the safety lock spindle notch in the bolt; thereby locking the bolt sleeve to the bolt body and preventing rotation or unlocking of the bolt.

Disassembly and Assembly

Field Stripping. The first portion of this disassembly will be the breakdown of the weapon only as far as authorized and necessary for normal care and cleaning by the using arm. Further breakdown will be known as 'detail disassembly.'

In removal of the telescopic sight from the M1903A4, first remove the right lateral adjusting screw from the mount base, grasp the sight just to the rear of

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the front mount ring and swing the rear end away from the receiver toward the right, until the sight is at right angles to the receiver. Lift sight straight up from the mount base. Do not disturb the left lateral screw as it is staked in position for proper alignment of sight.

Bolt Group. Place cut-off in the intermediate position, cock the rifle, turn the safety lock to the intermediate (vertical) position, raise bolt handle, and draw to the rear. With the bolt group removed, depress the bolt sleeve lock and unscrew the bolt sleeve from the bolt body, thereby exposing the mainspring, firing pin sleeve, striker, and bolt sleeve.

Floor Plate, Magazine Spring and Follower. With the bullet end of a cartridge or some similar pointed object, press upward on the floor plate catch (through the hole in the rear of the floor plate) at the same time sliding the floor plate and the magazine spring and follower back. The floor plate and follower can then be removed from the magazine spring by simply lifting the rear ends of the spring slightly and sliding these parts forward.

Where the M1903 type follower and magazine spring are assembled in an M1903A3 or M1903A4 rifle, it will be necessary to remove the front and rear guard screws and pull out the trigger guard magazine assembly together with the spring and follower. The '03A3 type of follower may be removed as stated above, but can, if necessary, be removed by following very carefully the following step-by-step procedure: With the cut-off set at 'ON' and the bolt rearward, insert a pointed object directly in front of the ejector and against the left side of the follower rib. Push downward and to the right until the front left side of the follower emerges through the magazine slot at front of the receiver and rests on the lip of the receiver. Move the bolt forward slowly against the rear face of the follower to disengage the follower from the magazine spring. (Do not allow the front end of the follower to strike the mouth of the chamber.) Pull the bolt to the rear and lift out the follower and magazine spring.

Assemble all parts in the reverse order of disassembly.

Detail Disassembly

The Bolt. To further disassemble the bolt, turn the extractor to the right, forcing its tongue out of the groove in the front of the bolt. Force the extractor forward and off of the extractor collar which is bent into position during manufacture of the bolt and should not be removed. Hold the bolt sleeve between the forefinger and thumb of the left hand, draw the cocking piece back with the middle finger and thumb of the right hand, and turn the safety lock from the intermediate position to the left to the 'Ready' position with the index finger of the right hand. This allows the cocking piece to move forward in the bolt sleeve, and partially relieves the tension of the mainspring.

With the cocking piece held against the breast, draw back on the firing pin sleeve, and, holding it in this position, remove the striker with the left hand. The firing pin sleeve will slide off with the mainspring. Pull the firing pin rod out of the bolt sleeve assembly.

Turn the safety lock assembly to the dismounting bevel on the bolt sleeve assembly, which is half way between 'ready' and the vertical position. Remove it by striking the front face of the safety lock thumb piece a sharp blow with a brass or wooden hammer. The safety lock assembly cannot be further disassembled. Drive out the bolt sleeve lockpin from the top, and the bolt sleeve lock and spring will fall out to the left. The firing pin rod is screwed and riveted together at the factory and cannot be disassembled.

To reassemble the parts of the bolt group follow the reverse order of disassembly, taking care to do as follows: compress the bolt sleeve lock and spring before driving in the bolt sleeve lock pin. Insert the safety lock assembly as far as the spring and plunger will permit; then insert a small screwdriver (or the specially designed safety lock assembling tool) between the spindle and plunger and force the plunger upward into the thumb piece until it slips over the edge of the bolt sleeve, at which time, a shove from the rear of the safety lock assembly will seat it in place. Engage the extractor in the extractor collar, and by a slight pressure toward the bolt on the rear half of the extractor while lifting slightly on the forward end, the tongue can be lifted onto the bolt, slide rearward, and then rotated into the extractor groove on the bolt.

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Stock Group. Remove the upper band screw and slide the upper band forward. Unscrew the stacking swivel screw and remove stacking swivel (on the M1903A3, loosen but do not remove this screw). Press in on the lower band spring and slide the lower band forward and off the stock.

Draw the hand guard slightly forward and remove it. This also applies to the barrel guard of the M1903A3.

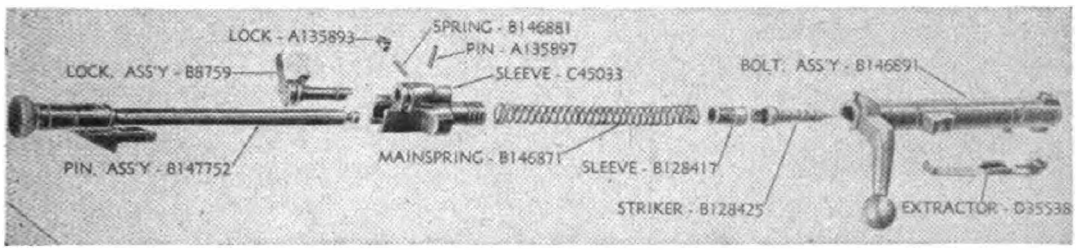

Figure 13. Bolt Group Parts for U. S. Cal .30 M1903M3.

After removing the front and rear guard screws, the trigger guard group can be pulled down and out. The floor plate catch may be removed by driving out the floor plate catch pin from either side. The trigger guard magazine assembly will be removed in the same manner as the M1903A3 and A4 but there is no floor plate catch, etc., to be removed.

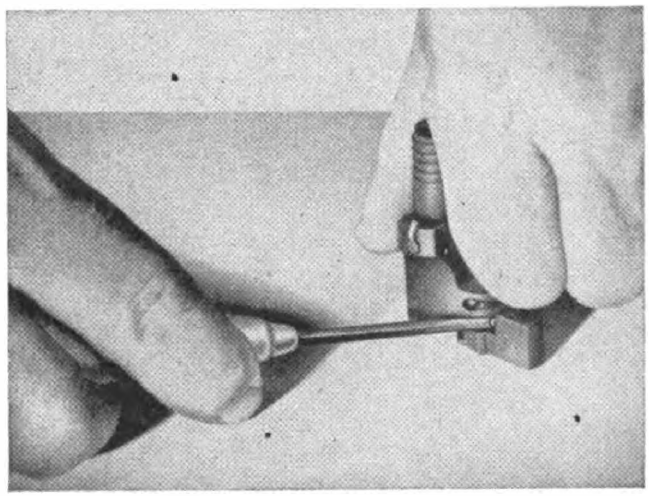

Figure 14. Assembling Safety Lock to Sleeve.

Lift out the barrel and receiver group from the stock. The barrel and receiver will not be unscrewed except in an ordnance establishment equipped and authorized for such work.

To remove the lower band spring, drive it out from the left side.

To remove the rear guard screw bushing, drive it out from top or bottom, taking care not to burr it.

Unscrew the butt swivel screws and lift out the butt swivel assembly.

Unscrew both large and small butt plate screws and remove butt plate assembly. Unscrew butt plate cap spring screw and remove screw and spring. Drive out the butt plate pin and remove the butt plate cap. Do not disassemble the butt plate pin from the M1903A3 or A4 as the ends of the pin are upset at the factory.

The front and rear stock screws (or pins) serve merely to reinforce the stock, and should not be removed unless necessary for repairs or replacements.

Assembly of the stock group is merely the reverse order of disassembly except that the stacking swivel band must be assembled to the stock and barrel guard before the bayonet stud band. Also, if removed, the barrel guard ring must be assembled to the barrel before the above parts are assembled. (See Figures 15 and 16.).

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Barrel Group. Remove the front sight pin by driving it out from the left and remove the front sight. Unscrew the front sight screw and remove the moveable stud by tapping it out laterally. The fixed stud, which should not be removed, is held by a pin through its body and a spline on the top of the barrel.

The front sight base of the M1903A3 corresponds to the fixed stud of the '03' and is keyed and pinned to the barrel.

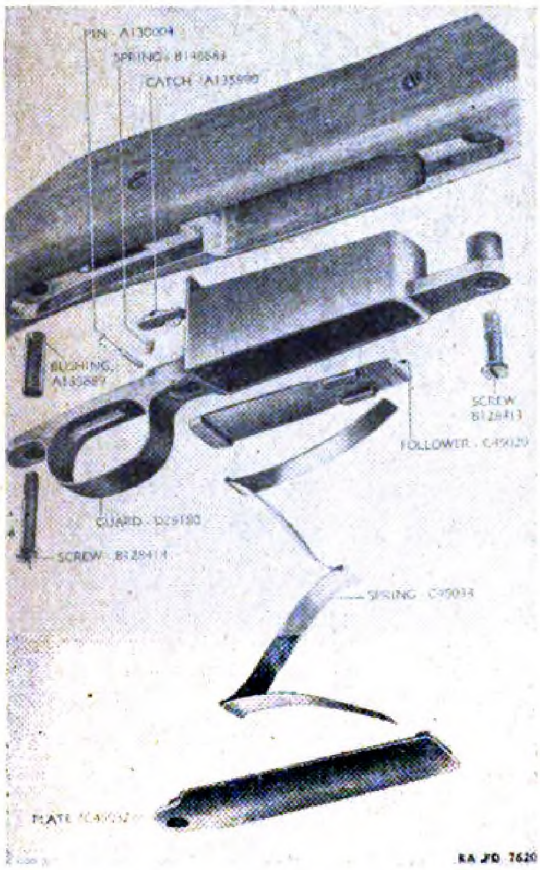

Figure 15. Trigger Guard and Floor Plate Group.

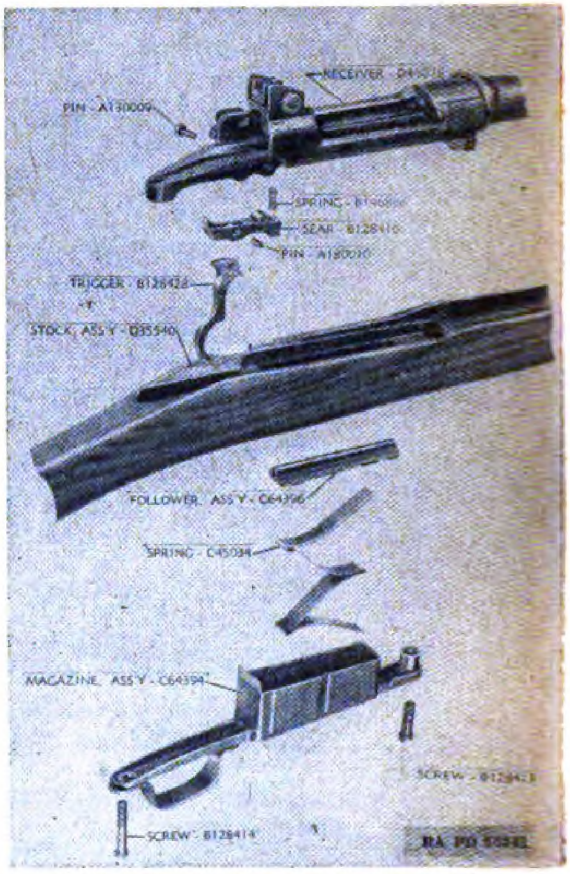

Figure 16. Trigger Guard Magazine and Trigger Group.

To remove the rear sight assembly from the fixed base of the '03' A1 rifles, turn the windage screw until the moveable base has been revolved far enough to disengage the worm gear on the base lip from the screw threads on the windage screw, and until the front and rear lips of the moveable base are not held by undercuts on the fixed base. Lift the moveable base off the pivot lug on the fixed base.

Turn rear sight leaf to the rearmost position, hold the rear of the rear sight base spring away from the leaf, drift out the rear sight leaf joint pin and remove the leaf. Remove the base spring by forcing it rearward with a punch inserted in the hole in the spring.

Unscrew the rear sight slide cap screw from the rear sight slide cap and drive out the rear sight slide cap pin. Unscrew and take out from the right the rear sight slide binding screw. Drive the rear sight slide cap very gently to the left out of the mortise in the rear sight slide. Remove the slide and cap from the sight leaf and slide the rear sight drift slide to the top of the leaf and out of the groove in the leaf. The drift slide pin is riveted in place and will not be removed.

To remove the rear sight windage screw from its position in the fixed base, compress the windage screw spring by forcing the screw collar toward the windage screw knob so as to allow as much play as possible, and tap the taper head and screw knob alternately toward the breech until it becomes unseated. The windage screw assembly is made a permanent assembly in manufacture by having the end of the pin spun over after the knob has been put on.

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The fixed base should never be removed unless necessary. However, to remove it, drive out the fixed base pin and drive the base forward by striking it with a hard wood block, taking care not to damage the overhanging lugs. Remove the spline that prevented rotation of the base.

To reassemble, follow the reverse order of disassembly and be sure to place the upper and lower bands on the barrel before attaching the front sight. With the 03A3, be sure to include the barrel guard ring and stacking swivel band before assembling the front sight.

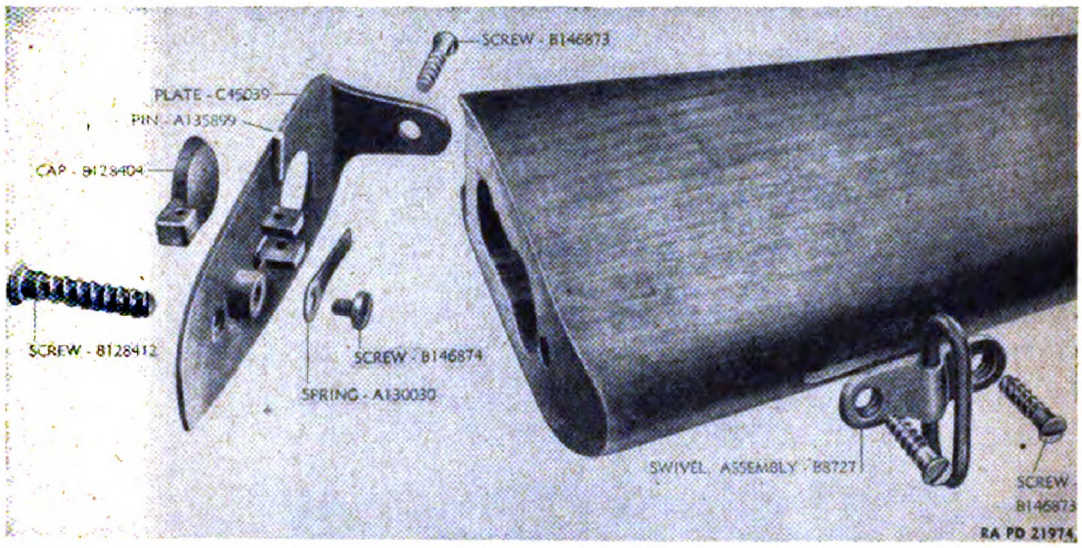

Figure 17. Plate and Butt Swivel Group.

Receiver Group. Remove the cut-off by loosening the cut-off screw in the end of the thumb piece until it disengages the groove in the cut-off spindle, insert the blade of a small screwdriver into the notch in the protruding rear end of the spindle and pull it rearward and off. Lift out the cut-off spring and plunger and the cut-off screw.

Remove the ejector by driving the ejector pin out from top to bottom.

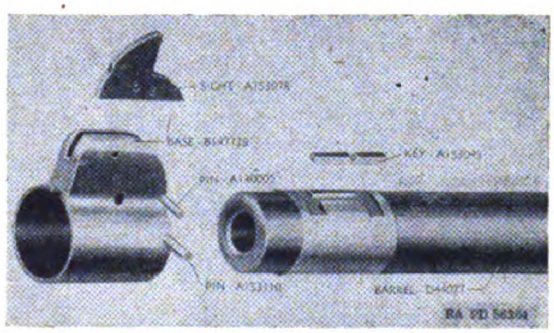

Figure 18. Front Sight Group (Exploded View).

Remove the sear, sear spring, trigger, and trigger pin by tapping out the sear pin from the right. Remove the trigger from the sear by driving the trigger pin out from either side.

Remove the bolt stop assembly by inserting a small punch in the hole in the end of the spring and draw it from its pocket until the pin is free to be pulled out. The bolt stop pin and spring are a permanent assembly.

M1903A1 rifles of recent manufacture and all M1903A3 and A4's will not have a bolt stop assembly as it is no longer considered an essential part of the weapon. Broken, worn, or missing bolt stop assemblies will not be replaced.

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The rear sight of the M1903A3 rifles, located on the rear bridge of the receiver, will be disassembled as follows:

(1) Loosen the windage index knob screw located in the knurled edge of the windage knob and pull the knob from the yoke screw.

(2) Turn out the windage yoke screw from the left side of the sight base, at the same time holding the remaining parts to keep them from springing out.

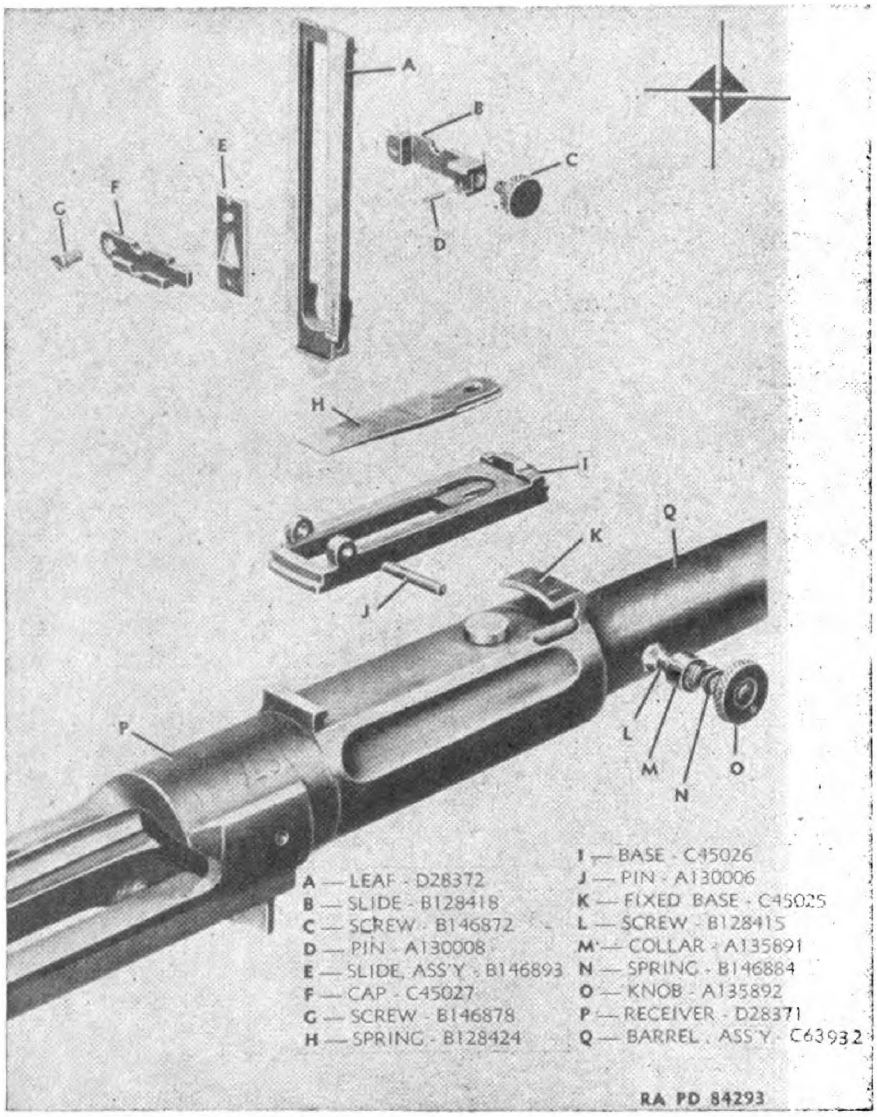

Figure 19. Rear Sight Group (Exploded View).

(3) Lift the windage yoke and aperture group out of the base, and lift out the windage yoke plunger and spring and the index knob spring from the right side of the base.

(4) Loosen the aperture slide screw and pull it, with the screw and slide aperture spring attached, forward out of the windage yoke. The spring and screw can be removed from the aperture if necessary.

The sight base should not be removed, but, if necessary, turn out the base screw and drive out the base from the left. More recent models do not have a base screw, but the sight is staked in place.

Reassemble completely in the reverse order of disassembly.

To remove the telescopic sight mount base of the M1903A4, drive back the staking of the front and rear mount base screws and remove the screws. Lift the base

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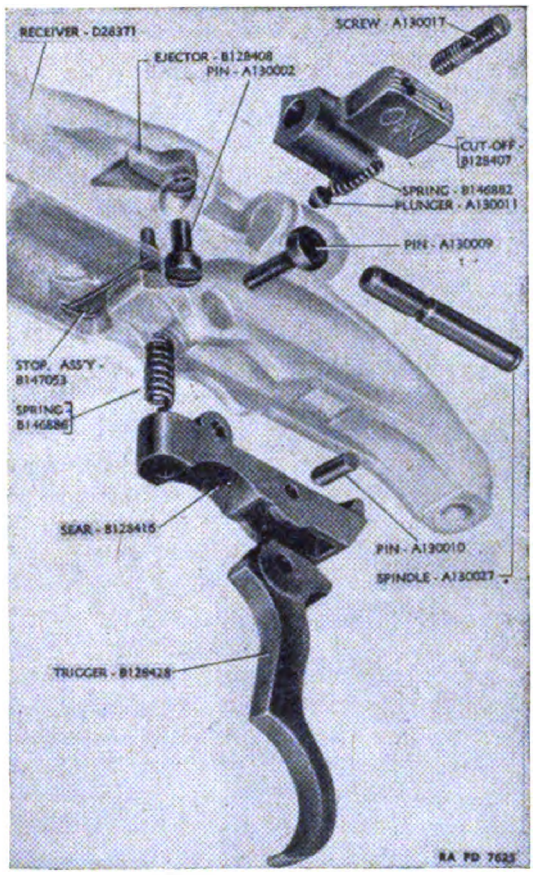

Figure 20. Receiver Group (Exploded View).

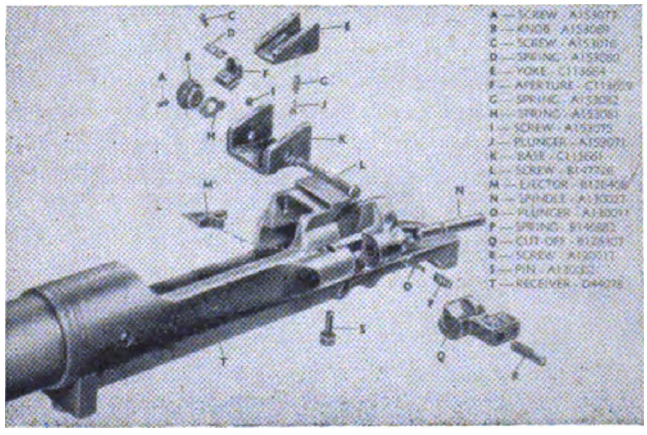

Figure 21. Rear Sight and Cut-off Group.

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from the receiver. Note the shim which may be positioned under the front or rear end of the mount base. This shim is used for leveling the base with respect to the bore line of the barrel when assembled at manufacture. It is obtainable in four thicknesses ranging from 0.005 to 0.020 inches. The only precaution to be taken is to note the shim's location and thickness for reassembly purposes.

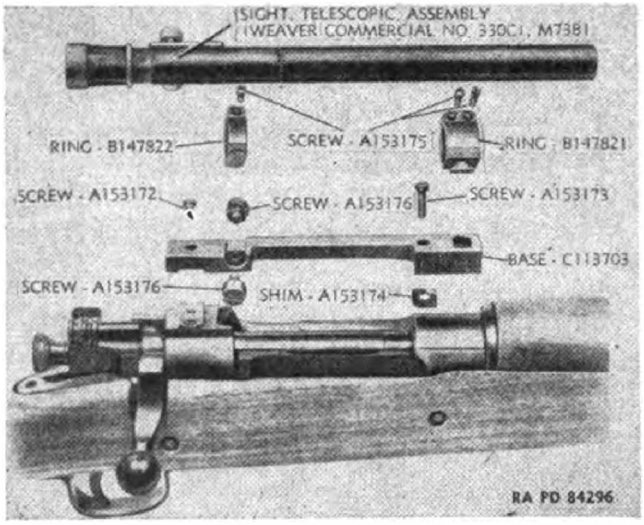

Figure 22. Mount Base and Scope Sight

Inspection

Inspection of the rifle will be divided into two phases, visual and gaging—for the purpose of determining its condition and whether or not repairs or adjustments are needed for continued serviceability. Before inspection is begun, the weapon must be thoroughly cleaned to remove any foreign matter that might hide a flaw or interfere with operation.

Inspect visually the rifle's general appearance. Is it dark and lusterless? Are there any shiny spots, rust, wear, or mutilated or damaged exterior parts? Is the stock cracked or damaged? Is it well saturated with raw linseed oil or treated with 'China' or Tung oil at the arsenal? Check the hand or barrel guard for similar faults. Does the barrel float properly? That is, does the barrel bed in such a manner that it is resting on the wood of the stock surrounded by the upper band; and can it be lifted upward with a force of approximately four pounds to touch the under side of the top forward portion of the upper band (bayonet stud band)? Check screw heads for mutilation. Test the operation of the complete rifle with dummy rounds and the operation of the safety, cutoff, magazine spring, floor plate catch, rear sight, butt plate cap, etc.

Completely disassemble the rifle and inspect the surfaces of all parts for cracks, dents, burrs, wear, mutilation, rust, and serviceability throughout.

Check the sight alignment and security of the sights. Will the rear sight movable base spring move back into alignment when forced to the left about 1/8 inch? Is there any backlash in the windage screw and can it be turned easily?

Visually inspect the barrel for serviceability. Accuracy is materially reduced by bulges, erosion, and pits. In order to inspect the barrel, it must be clean of all foreign matter, especially metal fouling, oils, etc. Place a bore reflector in the receiver with the muzzle pointed at a source of light. Turn it end for end and look into the muzzle, the reflector pointed at a source of light. If it is free of bulges, pits, and erosion, and if the bore is straight, it is probably serviceable. Small or fine pits will not cause a barrel to be unserviceable, but any pit that would allow the escape of gas (⅜ to ½ inch long or longer and as wide as a land, regardless of size), will cause the barrel to be declared unserviceable and scrapped. Pits in the chamber that cause the cartridge case to stick will cause the barrel to be scrapped.

Inspect all springs either visually or by measurement. A visual inspection con-

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sists of testing the spring's operation within its group; a gaging inspection would be to measure its over-all free length.

Gaging will be necessary to measure the headspace, breechbore diameter, and trigger weight.

There are three headspace guages available today: one, the minimum gauge, measures 1.940 inches long; the other two are minimum gauges, and measure 1.946 inches and 1.950 inches long respectively. They should be inserted in the magazine and loaded into the chamber like a round of ammunition in order to prevent the possibility of the extractor breaking the brittle extraction rim on the gauge if it snaps around that rim. The minimum (1.940 inch) gauge should be inserted first. The bolt must close on this gauge or it will be evident that there is less than 1.940 inches between the face of the bolt and the shoulders in the chamber. If the bolt, after determining it is satisfactory, fails to close on this minimum gauge, the chamber must be reamed.

To determine the maximum headspace, use the 1.946 inch gauge in an arsenal or depot, or the 1.950-inch gauge in the field. The reason for these differences being that the arsenal or depot has the facilities to correct headspace, and is, therefore, held to closer tolerances. Because the field does not have these facilities, more wear is allowed before sending the rifle to an arsenal or depot for rebarreling or scrapping of the receiver.

With the maximum gauge in place the bolt should not close when the handle is shoved forward and down. Extreme care must be taken not to force, but rather 'work' the bolt handle to see if it will close. 'Work' it lightly with the index and second fingers only.

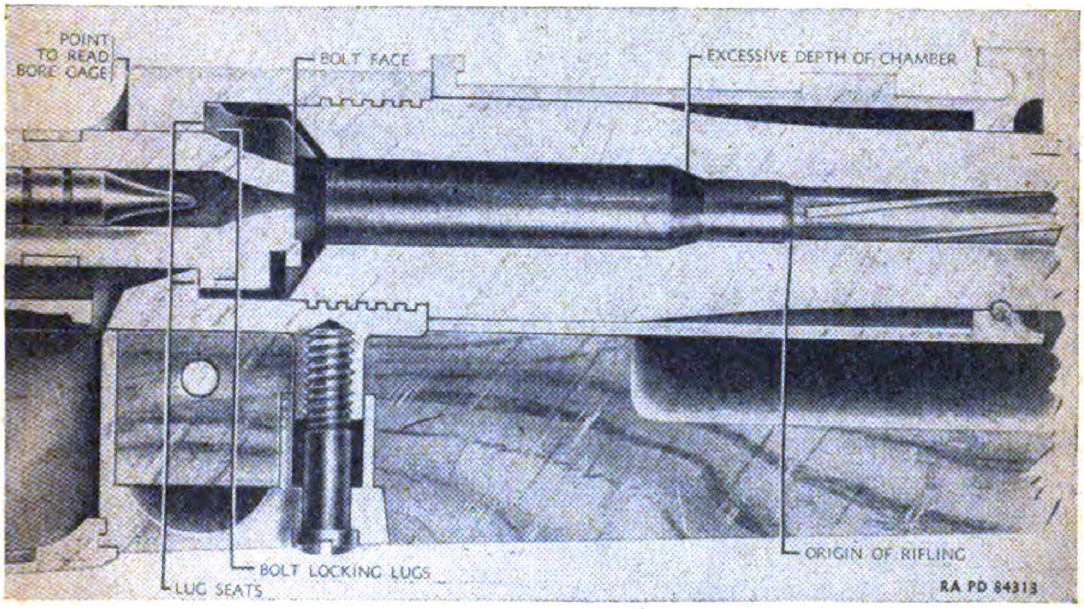

Figure 23. Points of Wear.

Should the bolt close with either maximum gauge or fail to close with the minimum gauge, it is easy to determine if the bolt is unserviceable due to its locking lugs being worn or oversize, or its face being too worn. Merely replace the issue bolt, using the same headspace gauge, with a Field Test Bolt which is known to be of the correct dimensions. If it still closes or fails to close, as it did before, the wear will lie either in the receiver (the locking lug seats) or in the shoulders of the chamber. However, if it now fails to close on the maximum gauge or does close on the minimum gauge it can be assumed that the receiver and barrel are satisfactory and a new bolt should be used as a replacement. Of course, the headspace gauges should be used to check this new bolt.

The breech bore gauge is used to determine wear of the bore at the origin of the rifling and has a scale graduated to read in thousandths of an inch. It has the

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form of a tapered rod and is inserted into the receiver and chamber from the extreme rear. There are two breechbore gauges available one of which was graduated incorrectly in that there were only eight spaces instead of nine between the rejection line for machine gun barrels and the rejection line for rifle barrels. This incorrect gauge is being used, however, and the inspector must determine which gauge he has and subtract one one-thousandths from readings obtained on the incorrect gauge. Insert the gauge through the rear of the open receiver, preferably with the magazine spring and follower removed.

Ease the gauge into the chamber until it stops and read the graduation parallel with the top rear edge of the front end of the receiver. If the reading is 0.308 inch or more, with the correct gauge, or 0.309 inch, with the incorrect gauge, the barrel will be declared unserviceable. If it reads 0.306 inch or more the rifle would not be sent overseas but retained in the U. S. for training purposes.

The trigger pull for rifles in the field must be between 3 pounds minimum and 6 pounds maximum. In an ordnance shop the minimum would be 3½ pounds to allow for wear. Test the trigger weight with a mass of 3 or 3½ pounds suspended on a wire rod with a hook. The weight should sit on table or floor with the rod sticking upward. Engage the hook of the rod onto the trigger of the cocked rifle and slowly lift the rifle. The trigger should carry the weight. If it fails, try it several times, you may have jarred the rifle. If it still fails, the pull is less than allowable and the rifle must be repaired. If it carries the minimum weight, add to the weight to bring it up to 6 pounds. Try lifting the weight again. This time it should fail. If the trigger carries the six pound maximum weight, the pull is

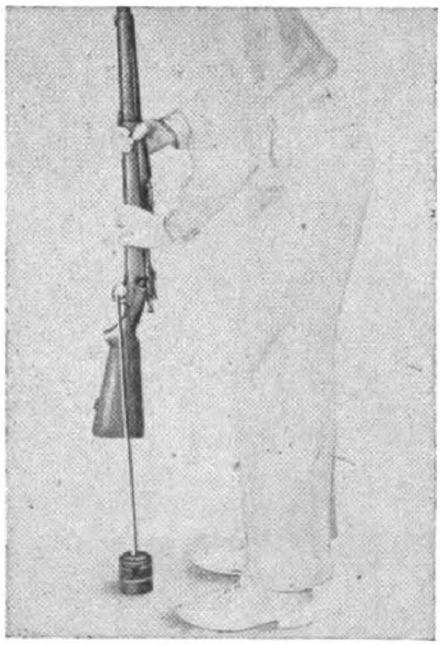

Figure 24. Testing Trigger Pull.

too heavy and must be reduced. Extreme caution must be observed not to jar the rifle or weight, and not to let the rod rub on the trigger guard or stock while testing the pull.

The inspection of the rifle is not complete until after all accessories pertaining to the rifle have been thoroughly inspected in the same detailed manner as the rifle itself.

Maintenance and Repair

Maintenance and repair consists primarily of replacement of parts. These parts are listed in SNL B-3, and symbols are used to indicate whether they are supplied for replacement purposes to the using arms, ordnance maintenance companies, field service shops, or other ordnance establishments. Quite often only parts of

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assemblies need replacement, but when this takes more time than the parts are worth, the whole unit assembly will be replaced.

The maintenance of the rifle is normally performed by the lower two or three echelons and is of a 'first-aid' nature. Tools for this maintenance are listed in SNL B-3 as company accessories for the rifle. Besides replacing parts, maintenance also includes: the removal of burrs by stoning and finishing with crocus cloth, the 'working-in' of new bolts with valve grinding compound (SNL K-2) applied to the cocking and extracting cams, 'freeing' of the bolt's extractor collar by clamping it between two boards and revolving the bolt while applying lubricating oil, the discarding of bolt stop assemblies when using a new bolt, the proper fitting of new stocks, the adjusting of the trigger pull by stoning or replacement of parts into various combinations until a desirable pull is obtained, etc. All these corrections and many more fall to the lot of an ordnance repairman and must be met by him.

Care, Cleaning, and Lubrication

Rifles should be cleaned and oiled not later than the evening of the day on which they were fired, (preferably, immediately after the cessation of firing) and should be inspected, cleaned and oiled daily for 3 days following firing.

Special precautions that apply to the M1903 rifle for care and cleaning are: field strip the rifle and wipe off and lubricate all surfaces that have been or might have been subjected to the burning powder gases, clean the bore with the approved cleaning solutions from the breech end with the long cleaning rod. Failure to clean from the breech causes excessive wear on the lands at the muzzle. The long rod is necessary because the handle of the short rod will strike the rear of the receiver before the patch protrudes from the muzzle, thus 'hanging up' the rod and patch so that they can't be moved.

The same special care required for all weapons in extremes of cold, heat, dryness and humidity applies to the '03 rifle as well.

U. S. RIFLE, CAL .30 M1917

History and Development

The U. S. Rifle, cal .30 M1917 was a World War I emergency weapon. When we entered the war in 1917, there were not enough M1903 rifles to equip the newly expanded army, and increased production failed to meet requirements at that time. The Ordnance Department decided in favor of having the three private arms manufacturing companies, then in production of the M1914 British Enfield rifle, to so modify that rifle as to adapt it to our cal .30 M1906 ammunition, rather than to wait for those and other companies to change their tooling in order to manufacture the M1903 rifle. Furthermore, it was felt that these several private companies would be unable to produce parts for the M1903 that would be interchangeable with the government-manufactured rifle parts. The British Model 1914 was being manufactured for cal .303 ammunition, which was a rim-type of cartridge and larger in diameter than our cal .30 ammunition. Therefore, new barrels had to be manufactured and chambered for our cartridges; the face of the bolt was altered to fit the base of our round, and the magazine was altered to accommodate the difference in over-all length between the two rounds.

This conversion changed the nomenclature from M1914 British to U. S. Rifle cal .30 M1917. Some of the early bayonets, which had already been produced in 1917, had the British designation "1913", and a cancelled British property mark stamped on one side with "U. S." markings on the other. There were two issues of bayonet scabbards, the first had a leather hangar, while the second and later type had the conventional double hook held by a metal extension formed on the mouthpiece.

The rifles were manufactured under contract first for the British, and then for the War Department by the following firms:

Eddystone Rifle Plant, Pennsylvania, owned by Remington Arms Co. and later owned by Midvale Steel and Ordnance Co. This company made 1,181,908 rifles up to November 9, 1918.

Remington Arms and Union Metallic Cartridge Co., Olean, N. Y., which produced 545,541 rifles up to November 9, 1918.

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Winchester Repeating Arms Co., New Haven, Conn., which made 465,980 rifles up to November 9, 1918.

None of these rifles has been manufactured since 1918, but subsequently they have seen plenty of service as training rifles and even combat weapons. They were made available to civilians during peacetime through the National Rifle Association for the promotion of civilian marksmanship. They were sold at the absurdly low price of $7.50 used, or $12.50 in new condition. Thousands were sold and have been converted into beautiful sporting rifles and are now valued at between $60.00 and $200.00 depending upon the amount of conversion.

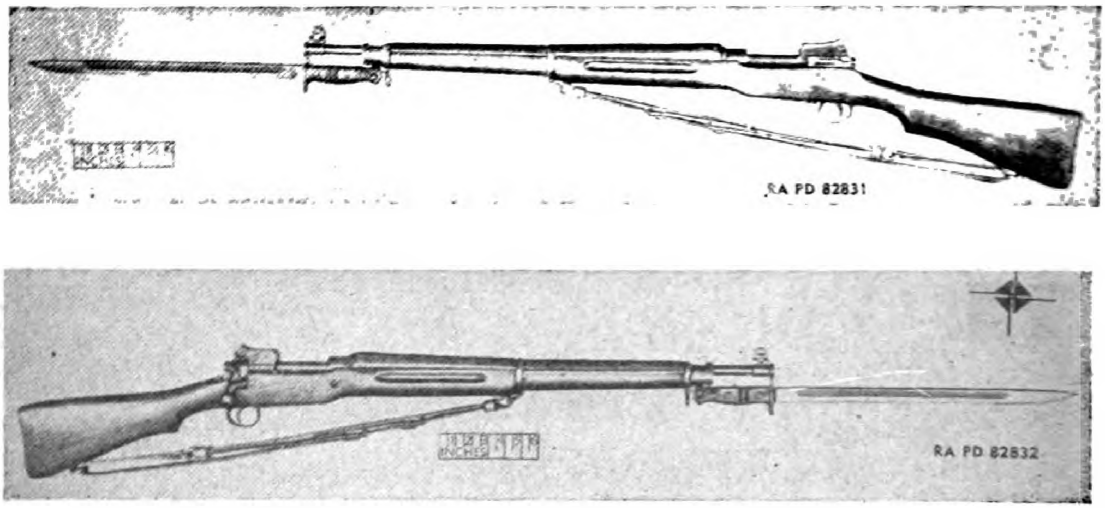

Figure 25. U. S. Rifle M1917. Right and Left Side Views.

The Rifle, U. S. cal .30 M1917, commonly called the Enfield, is a manually bolt operated, repeating, shoulder weapon, air cooled, loaded with the standard Springfield 5-round clip, magazine fed, and with a total capacity of seven rounds (one in the chamber and six in the magazine). Its weight with sling M1907 and bayonet is 11.66 pounds.

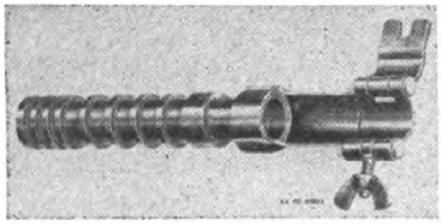

Figure 26. Launcher Grenade M2, '03 Rifle.

Disassembly and Assembly

Field Stripping. The disassembly authorized for normal care and cleaning consists of a breakdown of the rifle for proper care and maintenance. This enables one to reach all surfaces that may have been affected by the burned powder gases or other foreign matter. Further disassembly is performed under the supervision of competent Ordnance personnel.

For field stripping remove the following:

(1) Floor plate, follower, and magazine spring.
(2) Gun sling, oiler, and thong case.
(3) Bolt.

To remove the *floor plate:* insert the nose of a round of ammunition or some similar pointed object into the hole in the rear of the floor plate; push upward to depress the floor plate catch; slide the disengaged floor plate to the rear and

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remove it; disassemble the follower and floor plate from the magazine spring by sliding them forward off the leafs of the spring. Reassemble these parts and insert them into the weapon in the inverse order.

To remove the *bolt:* force the bolt stop to the left, raise the bolt handle and pull rearward to remove it from the receiver. Hook a loop of strong string on the dismounting hook of the cocking piece and pull rearward while rotating the string so as to unscrew the bolt sleeve from the bolt body.

An alternative method of disassembling is to open the bolt, push the safety lock all the way to the rear, close the bolt, insert a small piece of metal between the cocking piece and sleeve, pull outward on the bolt stop, remove the bolt from the weapon, then merely unscrew the bolt sleeve and firing pin assembly from the bolt body.

Detail Disassembly. To further disassemble, place the point of the striker on a wooden table or similar object; push downward on the bolt sleeve, compressing the mainspring until the nose of the cocking piece clears the bolt sleeve so that it can be rotated a quarter turn counterclockwise and removed; release the bolt sleeve slowly, remove it and the mainspring. Rotate the extractor one half turn counterclockwise and push it forward out of the extractor collar and off the bolt.

Reassemble in the inverse order of disassembly, taking special care properly to engage the extractor in its collar, and then lift and slide in onto the bolt.

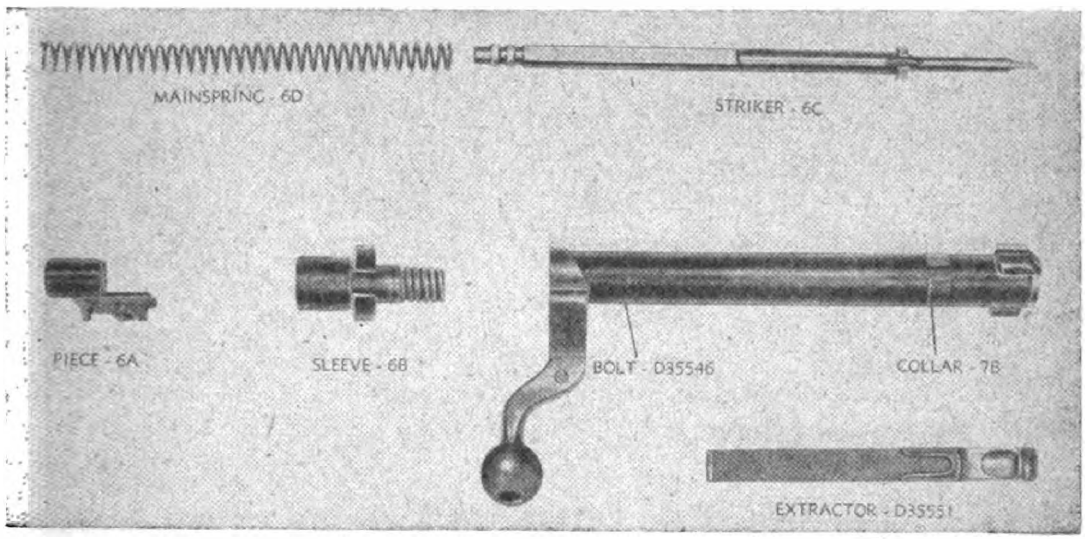

Figure 27. Bolt Group Parts for U. S. Rifle Cal .30 M1917.

The Stock Group. Loosen the stacking swivel screw, remove the upper band screw, and slide the upper band forward. Slide the front hand guard forward and remove it. Loosen the lower band screw, drive out the lower band pin, and slide the lower band forward. Slide the rear hand guard forward and remove it. Remove the floor plate, magazine spring, and follower as described in field stripping. Unscrew the front and rear guard screws and remove the guard. Drive out the floor plate catch pin and lift out the floor plate catch and spring. Pull the stock away from the barrel and receiver and then slide out the magazine. Slide the hand guard ring forward off the receiver and barrel.

Removal of the butt plate and butt swivel is done in the same way as on the M1903A1 rifle described elsewhere.

The Barrel and Receiver Groups. Bolt stop assembly and ejector will be removed as follows: remove the bolt stop screw and lift off the bolt stop assembly. Pull the bolt stop spring rest outward to remove it. Pull downward on the free end of the bolt stop spring to remove it, and then the released ejector can be taken out of the bolt stop.

The *safety lock* may be disassembled by unscrewing and removing the safety lock holder screw, safety lock holder, turning the safety lock downward and

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pulling out to the right. The safety lock spring and plunger will fall out of the rear end.

The *trigger, trigger pin, sear, sear spring, and sear pin* will be removed by drifting out the sear pin from the right. Note: the stud on the forward end of the sear prevents rotation of the sear unless the interlock slot of the bolt is directly above. This will prevent the weapon from being fired unless the bolt is rotated completely locked.

The *rear sight* will be removed and disassembled as follows: unscrew the rear sight base spring screw and remove the rear sight base spring; insert a drift into the hole in the front end of this spring and drift the spring forward and remove it; unscrew the rear sight joint bolt and nut, remove the bolt and lift out the rear sight leaf assembly; remove the rear sight slide stop screw from the leaf and slide off the rear sight slide assembly.

The *front sight* should be removed by drifting out the front sight carrier pin from either side and driving the carrier forward off the muzzle. The key may then be lifted out of its slot in the barrel. The front sight itself is supplied in eleven different heights and may be removed from its staked-in location in the front sight carrier by tapping it from left to right.

Assembly. Assemble the weapon in the inverse order of disassembly, carefully noting the proper step-by-step procedure and precautions mentioned in disassembly. Be sure the hand guard ring, lower band assembly, and the upper band assembly are placed properly, and in that order, onto the barrel before reassembling the front sight carrier.

Operation and Functioning

The Enfield rifle has almost the same operation and functioning, the same steps or phases, which occur in the same order as already described in detail in the M1903 portion of this chapter. Therefore, it will not be repeated here. The following are the few points in operation that differ and should be described:

The *bolt stop assembly* and ejector: the bolt stop is held protruding inward adjacent to the bolt body by tension of the bolt stop spring and is squared on its forward end to strike the rear surface of the slotted locking lug of the bolt. This prevents the removal of the bolt. The outer forward lip provides a surface for the operator's thumb to hold the bolt stop outward and away from the locking lug so as to allow removal of the bolt from the receiver.

The *ejector* presses against the side of the bolt and will move inward into the slotted locking lug to cause ejection due to the constant tension of the spring portion of the ejector.

Safety Lock Assembly is attached to the rear right portion of the receiver and has a portion that engages into a slot cut into the underside of the cocking piece. Rotation of the safety lock causes this surface to engage, force rearward, and lock the cocking piece away from engagement with the sear. Rotation also causes the safety lock plunger to move forward because of an eccentric and fit into a hole cut in the rear surface of the bolt handle, locking the bolt in the closed position.

Cocking Cam and Cock Notch in the bolt produce the same results as in the M1903. but they are cut differently so that raising of the bolt handle will cause the cocking piece to be cammed a short distance rearward, leaving the remainder of the cocking action to be completed by the operator on the closing of the bolt after the cocking piece engages the sear and is held stationary.

Safety Stud on the sear and the interlock slot in the bolt are described in the disassembly of the trigger and sear from the barrel and receiver groups.

Inspection

The procedure and gages used for inspection of the M1917 rifle *differ* from the M1903 rifle as follows:

The minimum headspace gage or no gage at all should allow the bolt to close completely, and the inspector should note the distance between the underside of the bolt handle and the stock. Either maximum gage, depending on the location of the inspector ('shop' or 'field'), should not allow this distance to be normal The maximum gage should hold the bolt slightly open and this distance, therefore, should be greater. If excessive headspace is apparent, its cause can be

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determined by using a new bolt that is known to be correct, since no 'field test' bolt is obtainable for this rifle.

Since the operation of the bolt is such that it requires a force of approximately 18 pounds to close the bolt, it is well to remove the mainspring before gaging headspace.

Oversize stocks are found in some cases which may interfere with the estimating of distance between the bolt handle and stock. This being the case, the stock must be removed and the distance between the underside of the bolt handle and the receiver must be used.

The breechbore diameter rejection point, using the M1903 gage, is one one-thousandth inch greater than the M1903. Using the correct gage, it would be 0.309 inch; the incorrect gage—0.310 inch.

The protrusion of the striker must lie between 0.058 inch and 0.068 inch. There is no gage obtainable to test this, but a depth micrometer can be used.

The free length of the mainspring is approximately 5.75 inches.

Maintenance, Malfunction and Cleaning Notes

Maintenance and Repair. Refer to the same sub-division under the M1903 rifle. The following parts are those most commonly replaced:

Ejector	Mainspring
Extractor	Rear hand guard assembly
Floor plate	Sear spring
Front hand guard assembly	Stock assembly
Magazine spring	Striker

Check especially the following points as they lead to the most common malfunctions of this rifle: tightness of the floor plate to the trigger guard; proper function of the safety stud. Test to see that the rifle will not fire unless the bolt is completely locked and that the bolt cannot be opened if the trigger is held rearward. Check to see that the barrel is completely floating in the stock and does not touch or bind except at the breech, and that it merely rests at the muzzle end. Test the proper function of the bolt stop assembly and ejector.

The M1917 rifle is officially classified as 'limited standard,' and it is expected that it will be recalled and declared obsolete in the near future. For that reason, as well as due to the shortage of, and no manufacture of, new parts, 'cannibalization' is authorized. The repair of these rifles is constantly being performed by fewer and fewer field service depots and arsenals.

Care, Cleaning, Lubrication and special climatic maintenance for small arms generally are explained elsewhere and apply to the M1917 rifle.

U. S. RIFLE CAL .30 M1

The M1 rifle is a semiautomatic, self-loading, shoulder weapon, which affords greatly increased fire power as compared to the former 1903 cal .30 rifle. It was designed by John C. Garand and developed by the Springfield Armory shortly before the outbreak of World War II. It is, perhaps, a distinct understatement to say the M1 rifle has proved to be in the present war, a most formidable and effective weapon which has greatly increased the fire power of American troops.

The weapon is composed of four main groups: the barrel and receiver group, including the bolt and operating mechanism; the gas cylinder group; the trigger housing group, and the stock group.

Functioning

The weapon is loaded with an eight-round clip and the loading should be performed with the piece locked, that is, with the safety in the rearmost position. When the loaded clip is forced down into the receiver, it depresses the follower. As the follower nears the bottom of the receiver, the front end of the follower arm contacts and rotates the accelerator. The accelerator in turn bears on a lug on the bullet guide and forces down the front end of the operating rod catch, thus releasing the operating rod which moves forward from pressure of the operating rod spring. At the same time the rear arm of the operating rod catch swings upward, releasing the stud on the front end of the clip latch. The clip

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latch then rotates under the pressure of its spring so that its rear lug moves inward to engage the clip and retain it in the magazine.

Simultaneously with the forward movement of the operating rod, a cam surface in the operating rod handle contacts the operating lug on the bolt, causing the bolt to move forward. As the bolt moves forward it engages the uppermost round in the clip, pushing it forward into the chamber. Cams cause the bolt to rotate clockwise as it reaches its battery position, causing the locking lugs to seat themselves in the locking recesses of the receiver.

Now that the weapon is loaded, the hammer spring is compressed and the trigger lugs are engaged in the hammer hooks, holding the hammer in the cocked position. Before the piece can be fired the safety must be released. When the trigger is pulled, the trigger lugs are disengaged from the hammer hooks and the released hammer, moved by its springs, strikes the firing pin which in turn hits the primer of the round.

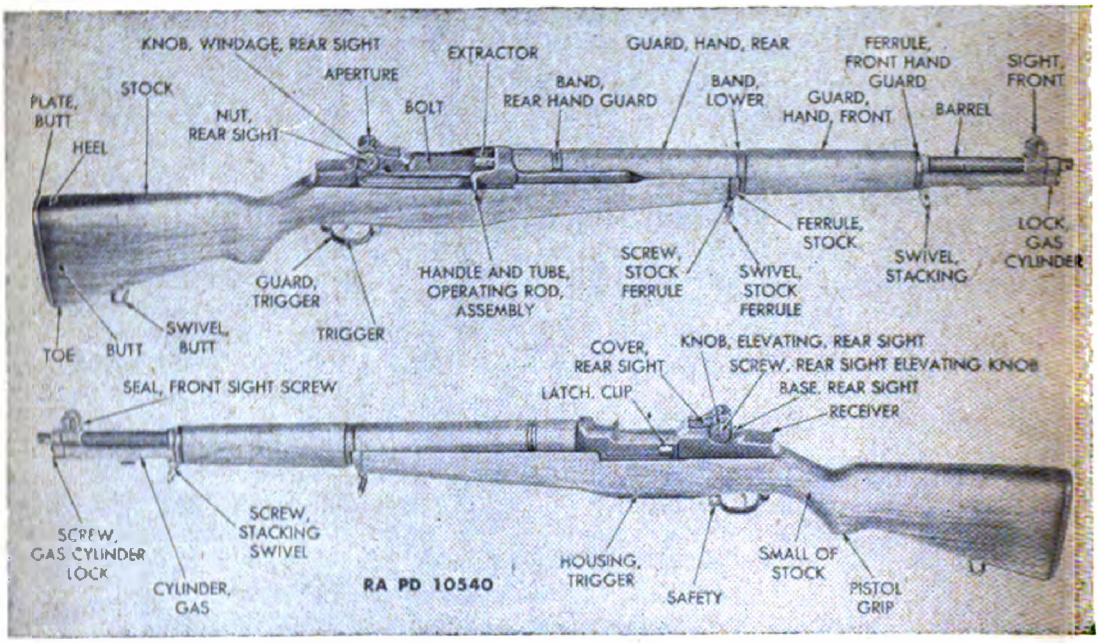

Figure 28. U. S. Rifle Cal .30 M1 (Rifle and Receiver, Sectional View).

When the bullet passes the gas port, located about 1½ inches from the muzzle end of the weapon, a portion of the gas expelling the bullet enters through the port into the gas cylinder, impinging on the gas piston (a portion of the operating rod) with a quick sharp blow of sufficient force to drive the operating rod to the rear. As the operating rod moves rearward it compresses the operating rod spring. There is 5/16 inch free movement of the operating rod before the cams in the handle contact the bolt to allow the bullet to clear the muzzle before unlocking begins and to relieve the gas pressures in the bore.

When the cam surfaces in the operating rod handle contact the operating lug of the bolt, the bolt rotates counterclockwise, disengaging the locking lugs from their recesses in the receiver; then the operating rod carries the bolt rearward. The empty cartridge case is withdrawn from the chamber by the extractor and as the mouth of the cartridge clears the breech, the ejector, which is continually pressing on the base of the cartridge, ejects the case to the right through the action of the compressed ejector spring. The rear end of the bolt forces the hammer back and rides over it, compressing the hammer spring, and finally comes to rest at the rear of the receiver. With the bolt in the rearmost position, the magazine is again uncovered. The follower, actuated by the follower arm, and the follower rod (which transmits pressure from the operating rod spring), forces the topmost cartridge upward in the clip so that it lies in the path of the

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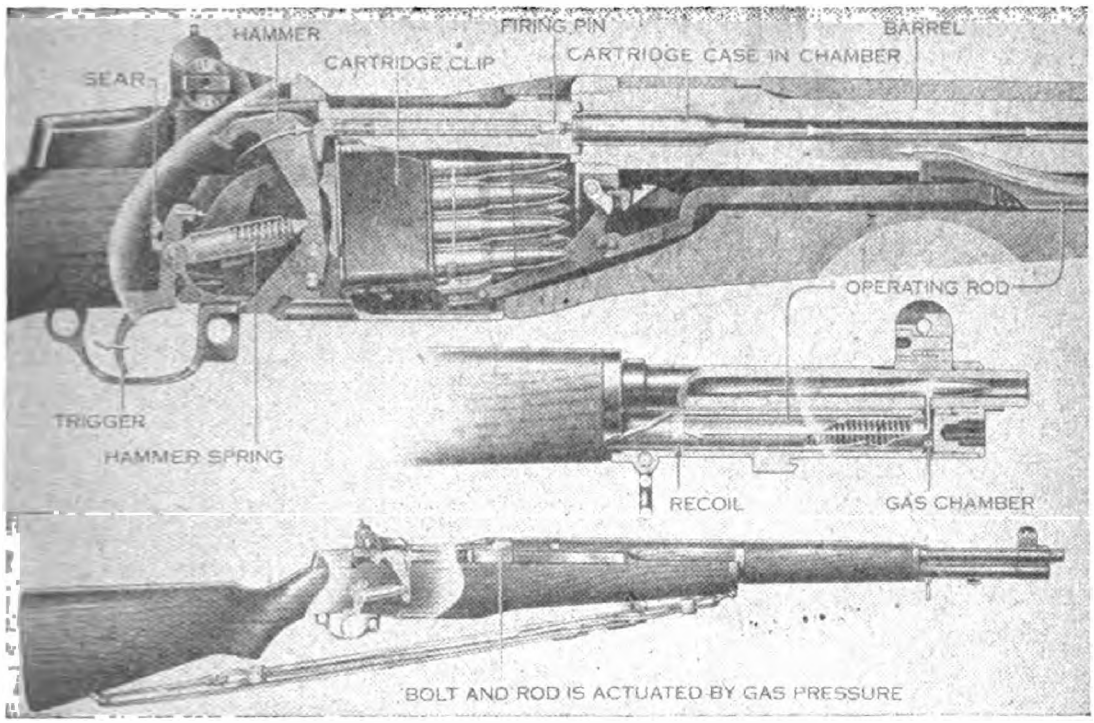

Figure 29. Basic Functioning U. S. Rifle Cal .30 M1.

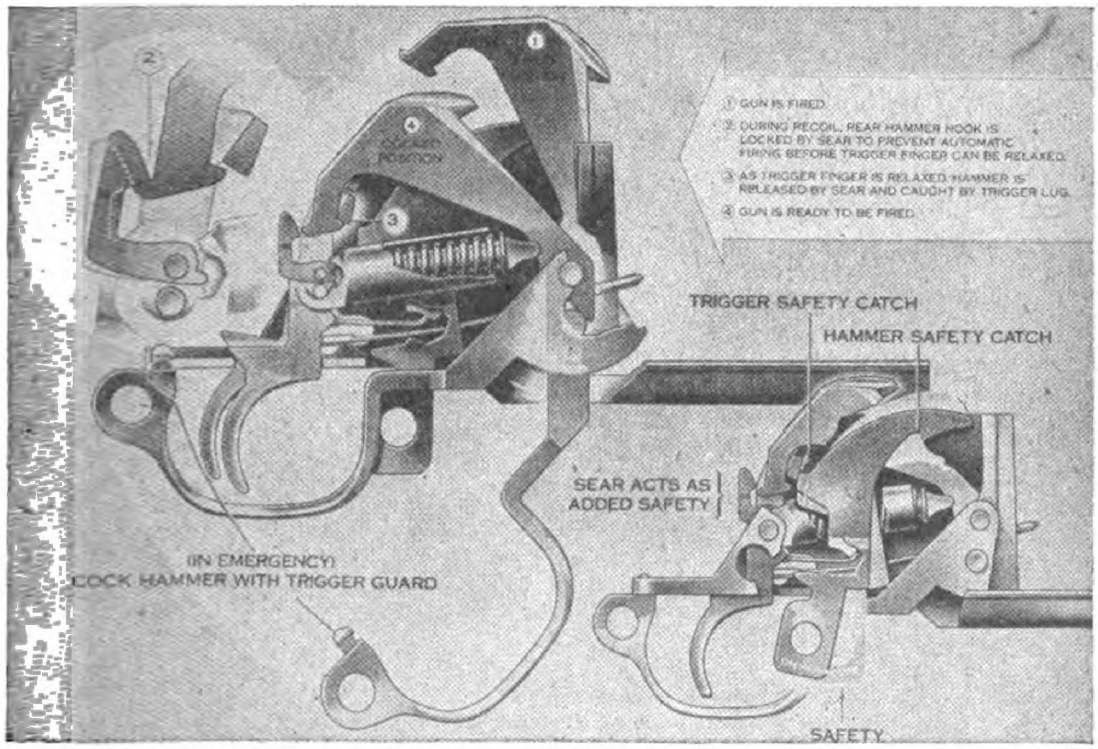

Figure 30. Trigger and Safety Functioning, U. S. Rifle Cal .30 M1.

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bolt and as the bolt moves forward, actuated by the operating rod spring, the round is automatically fed into the chamber. The hammer, under pressure from the hammer spring, rides on the bottom of the bolt and tends to follow it, but it is caught and held by the rear hammer hooks engaging with the sear until the trigger is released. At this time the hammer moves upward slightly and the front hammer hooks engage with the trigger lugs, thus retaining the hammer in a cocked position.

When the bolt approaches its forward position, the extractor groove of the cartridge is engaged by the extractor and the base of the cartridge forces the ejector into the bolt, compressing the ejector spring.

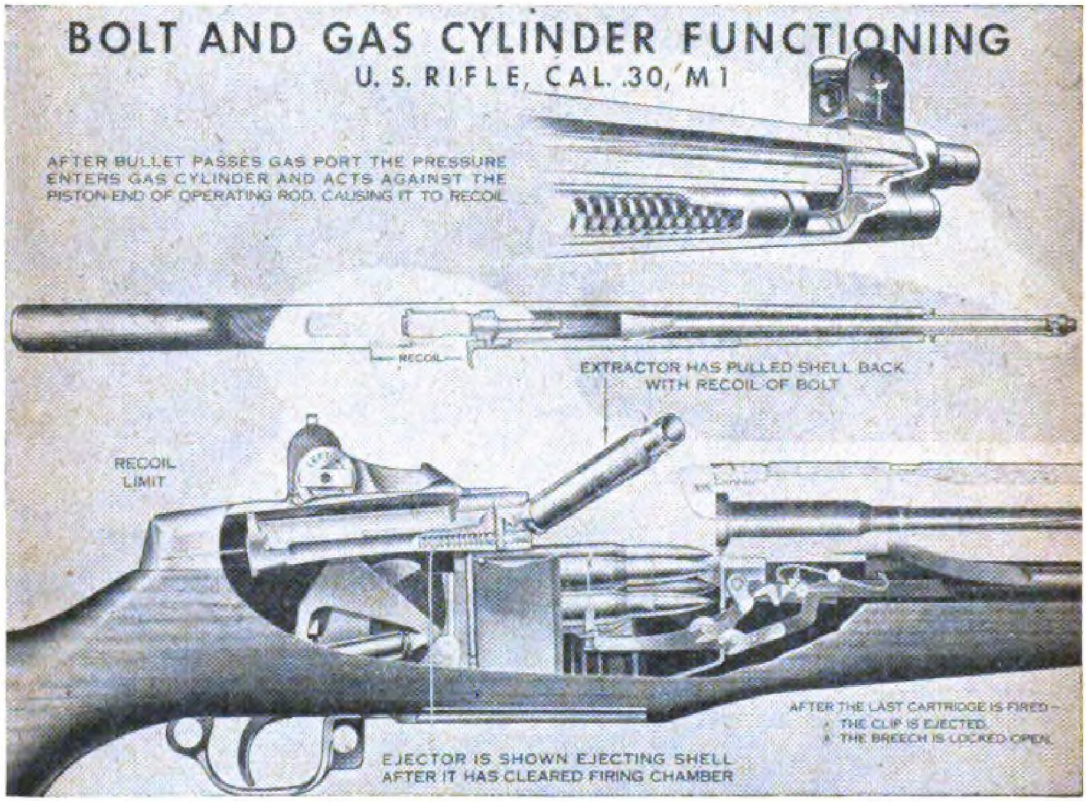

Figure 31. Bolt and Gas Cylinder Functioning, U. S. Rifle Cal .30 M1.

The operating lug is cammed downward by the rear surface of the cam in the operating rod handle, and the bolt rotates as before to engage the locking lugs in the receiver recesses. This action again locks the bolt.

The cycle described above is repeated each time the trigger is moved rearward, until the last round is fired.

When the last round is fired, the bolt clears the top of the magazine in its movement as before, but since the clip is empty, the follower is pushed to its uppermost position by the action of the follower arm, follower rod, and operating rod spring. (The position of the follower rod is such that it cams the forward end of the operating rod catch and bears on the forward lug of the clip latch, thus rotating the clip latch, disengaging it from the clip, and the empty clip is ejected by the clip ejector which was compressed when the full clip was inserted into the weapon.) With the operating rod held to the rear by the operating rod catch and the magazine empty, another loaded clip may be inserted without delay, and firing resumed.

Loaded clips may be removed by holding the operating rod to the rear and pressing in upon the clip latch. The clip ejector will eject the entire clip and the remaining rounds.

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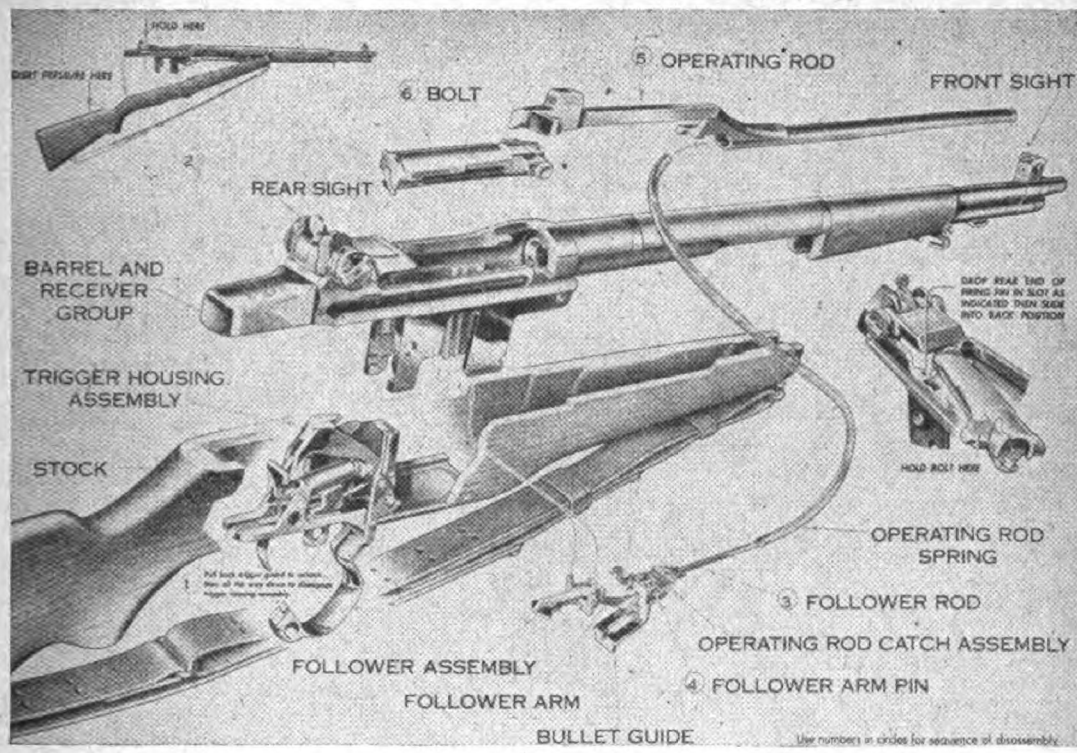

Figure 32. Field Stripping.

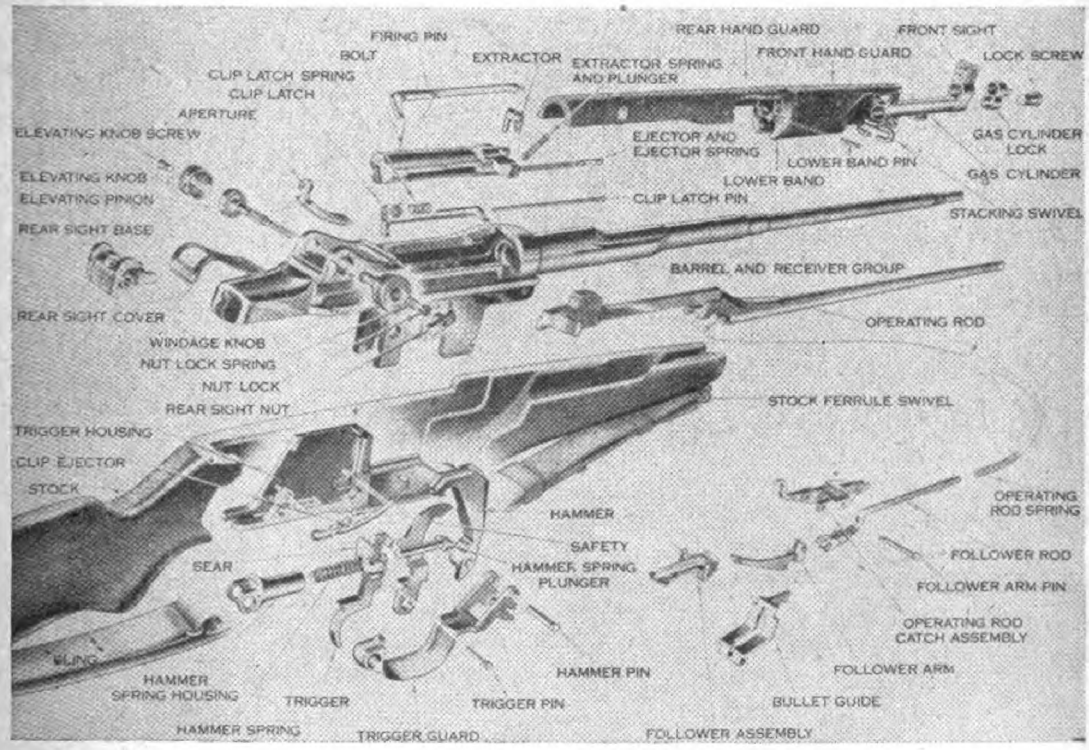

Figure 33. Detail Stripping.

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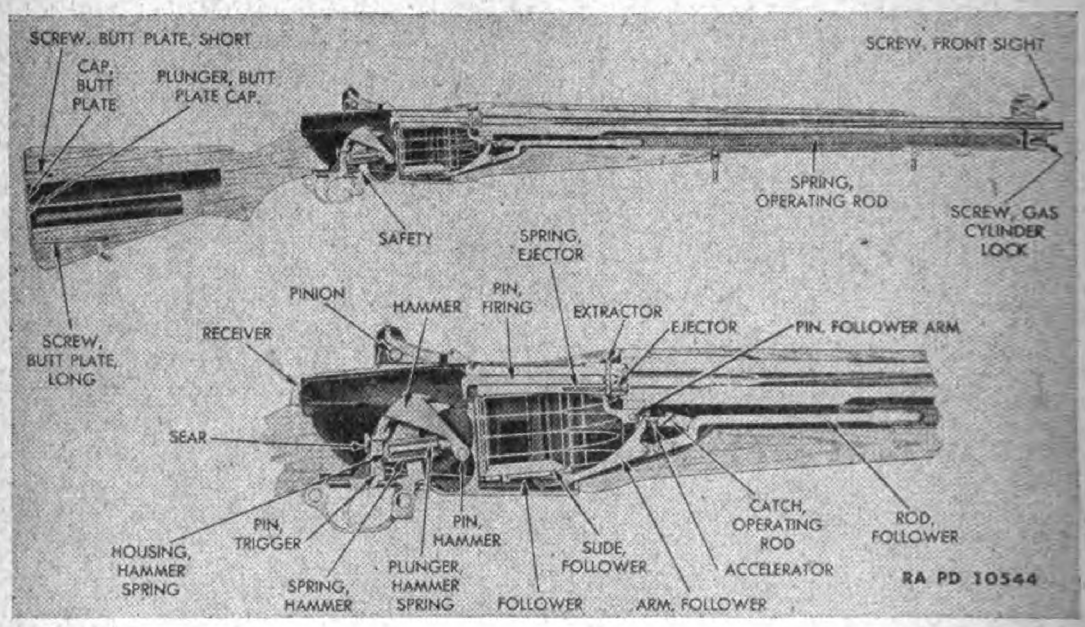
Disassembly

The first step in disassembly is to make certain that the piece contains no cartridges, either in the magazine or chamber.

Turn the weapon upside down, preferably on a wooden bench or on some other clean surface. Grasp the rear end of the trigger guard and pull it back and upwards on the guard. Withdraw the trigger group by pulling directly upward.



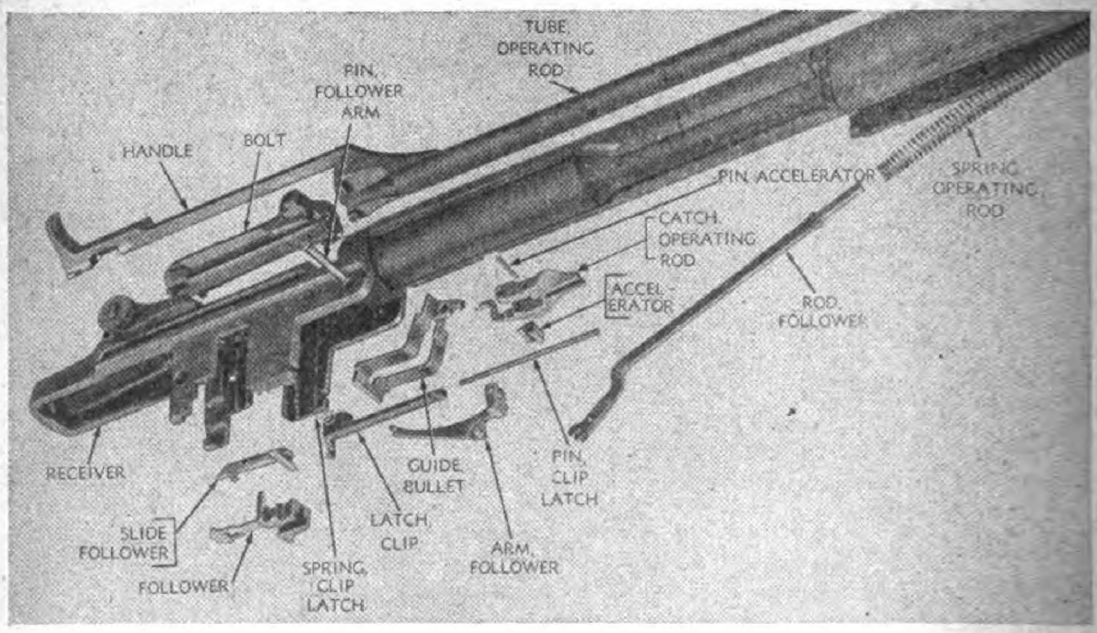


Figure 34. Rifle and Receiver. Sectional View.

Grasp the stock by the butt, raise it slightly, and pull it rearwards away from the receiver. The weapon is now disassembled into three major groups: the barrel and receiver group including the gas cylinder group, trigger housing group, and the stock group.

In disassembly of the barrel and receiver group proceed as follows:

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Remove the follower rod, disengaging it from the follower arm. The operating rod spring attached to the follower rod, will also be removed. Drift out the follower arm pin and remove the follower arm operating rod catch assembly and the bullet guide.

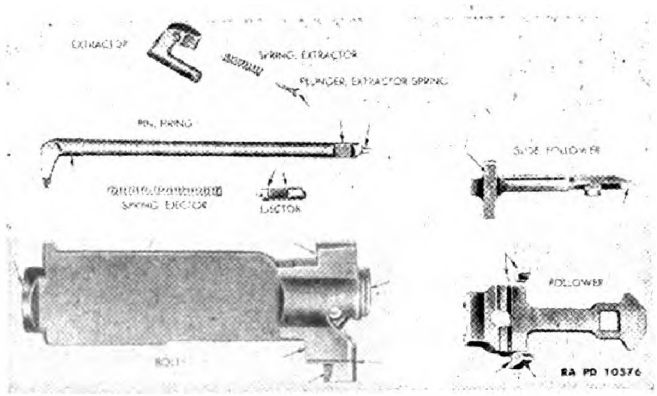

Figure 35. Follower and Follower Slide, Firing Pin and Bolt Assembly Showing Important Points to be Inspected.

Lift the follower assembly (weapon still in the inverted position) out of the receiver slots.

Turn the weapon over so that it is right side up, and pull backwards and upwards on the operating rod. The operating rod guide lug will contact the dismount notch in the receiver guide way, and the operating rod can be removed from the receiver by exerting a slight twisting motion, and, when free, drawing rearward to remove it from the gas cylinder. (The operating rod is intentionally bent. Do not attempt to straighten it). The bolt may be removed from the receiver by tilting it upward and sliding it out forward from the receiver. The clip latch and its spring may be removed by driving the clip latch pin forward out of the receiver.

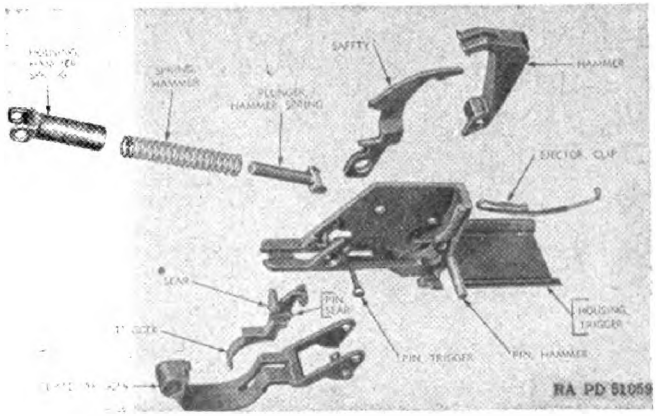

Figure 36. Trigger Housing Group. Exploded View.

To remove the gas cylinder group, unscrew the gas cylinder lock screw and the gas cylinder lock. Remove the gas cylinder by drawing it forward from the barrel. Remove the front hand guard by sliding it forward off the front end of the barrel.

The bolt, not ordinarily disassembled in field stripping, may be taken down in the following manner.

Place the thumb over the face of the bolt to prevent the ejector and ejector spring from flying out when the extractor is released. With a screwdriver blade, pry the extractor from its seat. With the extractor removed, the firing pin, ex-

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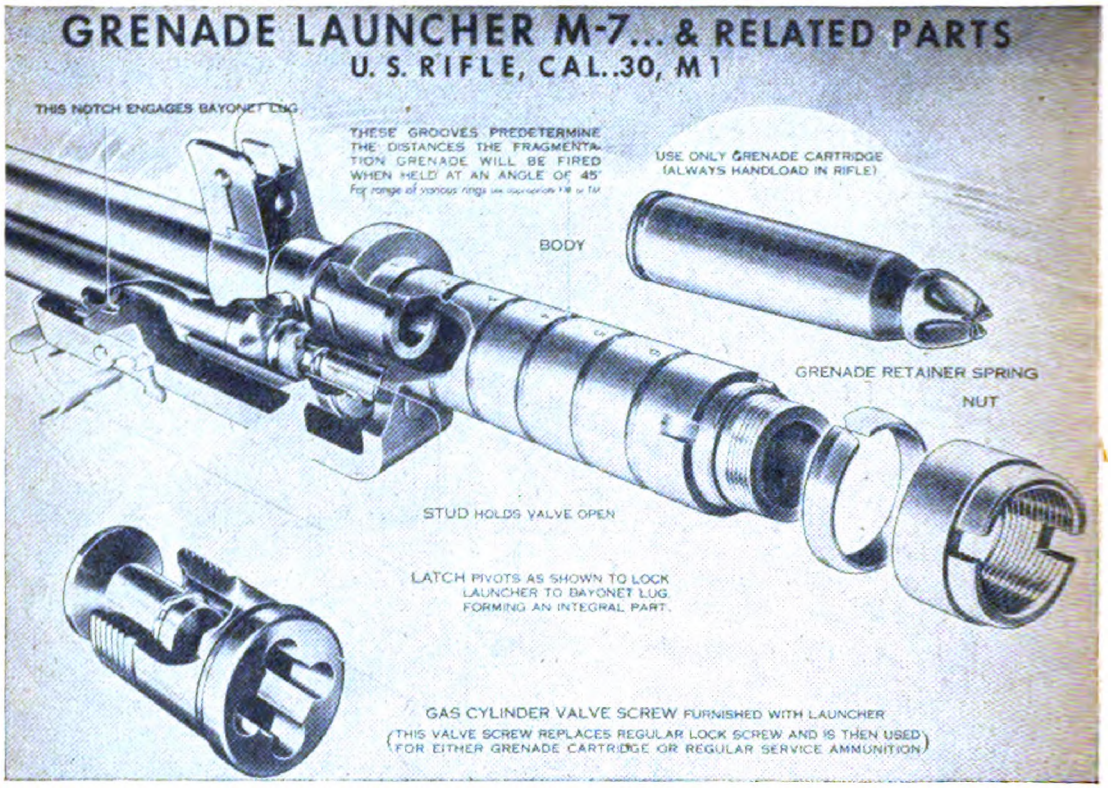

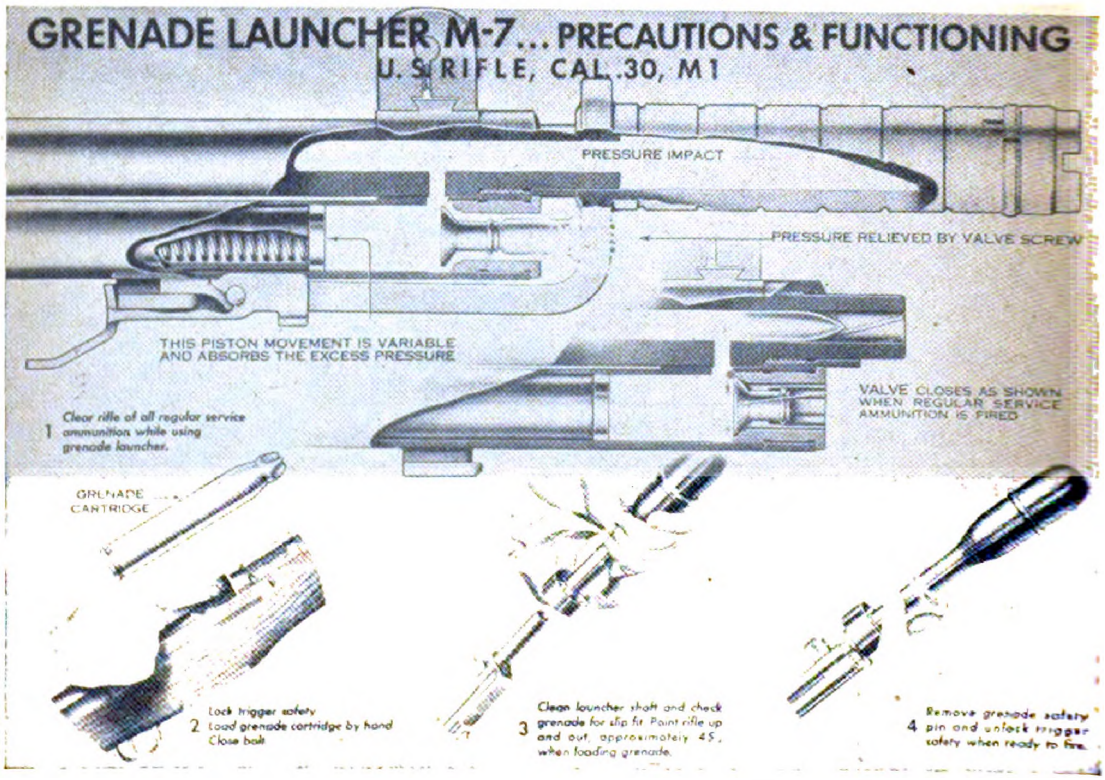

Figure 37. Grenade Launcher M7, U. S. Rifle Cal .30 M1.

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tractor spring and plunger, and the ejector and ejector spring may be withdrawn from the bolt.

The trigger housing group is easily disassembled. With the hammer in the fired position, grasp the group in the right hand, gripping the trigger to release the tension on the trigger pin. Drift out the trigger pin and release the pressure of the hammer spring gradually until extended to its full length. Remove the trigger assembly, hammer spring, and hammer spring housing. Push out hammer pin and remove the safety by pressing its top away from left side of trigger housing until stud snaps out of its seat and lifts from trigger housing. The trigger guard may be removed by sliding it back slightly and rotating counterclockwise. The clip ejector may then be removed by pushing it out from under its retaining lug on the housing.

Assemble is the reverse of disassembly. Special points to observe are listed in TM 9-1275.

Inspection

To inspect any weapon properly, it should be clean and dry. Weapon should be inspected visually for completeness of parts, proper functioning and general overall condition (See Figure 35).

Gage inspection will indicate wear on various parts which would be detrimental to the proper and accurate functioning of the piece and possibly to the operator. The gages used with the M1 rifle are as follows:

Headspace gages: 1.940 inch—Minimum
1.946 inch—Maximum (Shop)
1.950 inch—Maximum (Field)
Breechbore gages: .300 inch—Minimum
.310 inch—Maximum.

Field Test Bolt. Used in conjunction with headspace gages.

Trigger weights: 5-7.5 lbs. (Field)
5.5-7.5 lbs. (Shop).

Accessory tools include barrel reflector to determine condition of bore.

Accessories. Accessories for the U. S. Rifle cal .30 M1 include the following:

Bayonet M1 or M1905
Scabbard, bayonet M7 (for M1 bayonet) or M3 (for bayonet M1905)
Sling, Gun M1 (Web) or M1907 (Leather)
Launcher, Grenade M7

U. S. CARBINE CAL .30 M1, M1A1, M1A3

The U. S. Carbine cal .30 M1 and modifications has been developed since the United States entered the present conflict. Need was felt for a light, accurate weapon to supplement the U. S. Pistol cal .45 M1911A1, for use by personnel below field grade. As a result, the carbine was developed and is very effective up to ranges of 300 yards.

The carbine in a gas-operated, semi-automatic, self-loading, shoulder weapon similar in many respects to the U. S. Rifle cal .30 M1.

Functioning

In the following description it is assumed that the weapon is ready to be fired and that there is a full or partially full magazine in the weapon.

The trigger is squeezed to the rear causing it to pivot on the trigger pin. The rear lip of the trigger pushes upward on the rear end of the sear, causing the sear also to pivot on the trigger pin. This movement of the sear causes its forward end to disengage from the hammer, thus allowing the hammer to pivot under the pressure of the hammer spring, strike the firing pin, drive it forward, and causes the latter to strike the primer of the chambered cartridge, thereby igniting the round.

As the bullet passes down the bore, propelled by the force of the expanding gases, it passes the gas port located about 4½ inches from the breech end of the barrel. As the bullet passes the port a portion of the gases enters through the port into the gas cylinder and strikes the piston a quick, sharp blow. The piston is driven rearward a short distance (about ¼ inch). The rearward movement of the piston is transferred to the operating slide, the forward face of

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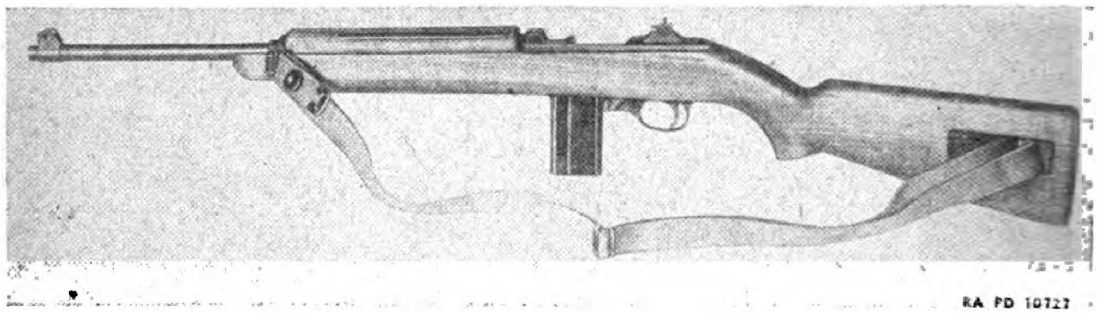
which has been bearing upon the rear face of the piston. The operating slide is thus driven rearward, carrying with it the bolt with which it is engaged by a camming lug on the bolt and a cammed recess on the operating slide handle. The operating slide travels approximately 5/16 of an inch to the rear before it contacts the bolt. This last motion prevents the bolt from opening before the high pressures in the bore subsides.

The cams in the operating slide handle cause the bolt to rotate counterclockwise, rotating the locking lugs from their recesses in the receiver. The slide then carries the bolt rearward.

The empty cartridge case is drawn from the chamber by the extractor, which is a component of the bolt. As the empty case clears the receiver it is ejected by the ejector, which has been bearing on the base of the cartridge. Also as the bolt rotates, the hammer cam on the rear of the bolt engages a mating cam on the hammer and starts the cocking action.



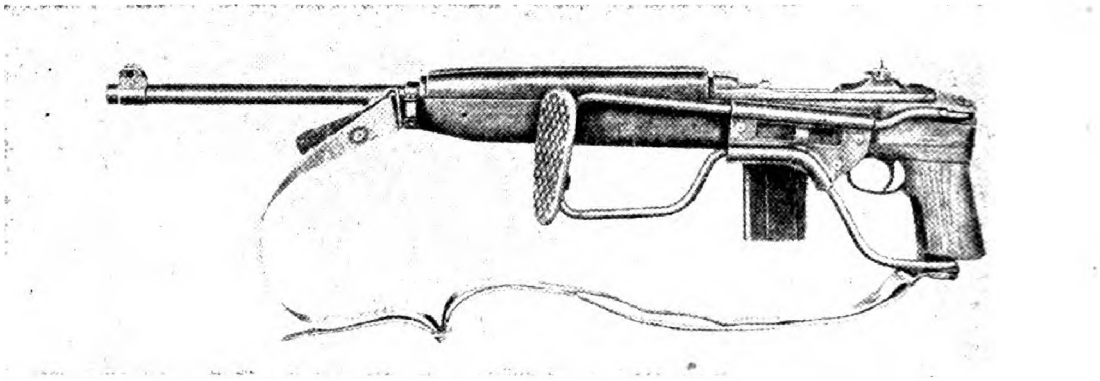


Figure 38. U. S. Carbine, Cal .30 M1 (Top) and M1A1 (Bottom).

The lower rear face of the bolt bears against the hammer and drives it back and down, rotating it about the hammer pin against the force of the hammer spring, until the sear notch of the hammer is in position to be engaged by the nose of the sear. At this point, the nose of the sear engages in the sear notch of the hammer and is held in engagement, due to the elongation of the pivot hole in the sear, by the pressure of the sear spring as the bolt rides over the hammer for a short distance to the end of its rearward movement.

When the bolt has reached the limit of its rearward movement, the magazine is again uncovered and the follower, activated by the follower spring, forces another cartridge up into the path of the bolt. The bolt moves forward, propelled by the operating slide spring, and pushes the top-most round out of the magazine and into the chamber. Cams in the operating slide handle working in conjunction with cams on the operating lug of the bolt cause the bolt to rotate clockwise, thus seating the locking lugs of the bolt in their recesses in the receiver.

The recoil and counterrecoil of the bolt is completed so rapidly that usually the operator has not had time to release the trigger. Thus the trigger is still in its rearmost position when the hammer is rotated back and down by the

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rearward movement of the bolt. In this rearward position, the rear end of the trigger is raised and the trigger spring depressed. The sear spring, however, has forced the sear forward when disengaged from the hammer, since the trigger pin hole in the sear is elongated. The forward movement of the sear has caused the rear end of the sear to drop below the level of the lip on the rear top face of the trigger. As the hammer is forced back and down, the sear notch of the hammer rides over the top of the sear until it is in position to be engaged by the nose of the sear. At this point, the sear spring forces the nose of the sear into engagement with the sear notch in the hammer.

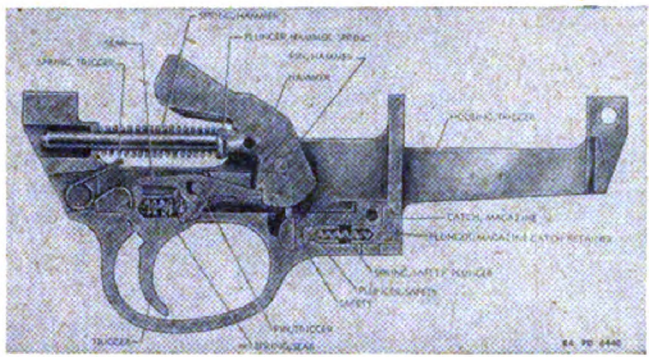

Figure 39. Trigger Housing Mechanism. Hammer in Cocked Position.

When the trigger is released, the trigger spring forces the rear end of the trigger downward; and the hammer spring, acting through the hammer, forces the sear to the rear. This rear movement is made possible by the elongated pivot pin hole in the sear. The release of the trigger has allowed the lip of the trigger to drop low enough for the sear to ride over and rest upon it.

The cycle described above is completed upon each squeeze of the trigger.

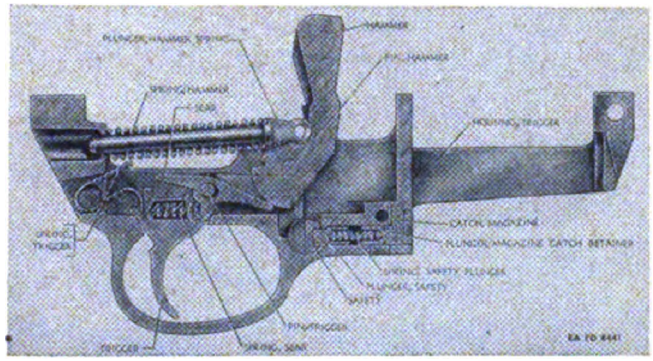

Figure 40. Trigger Housing Mechanism. Hammer in Firing Position.

The magazine, a necessary accessory, is composed of a tube, a base, a follower, and a spring. The spring is positioned in the tube between the base and the follower, so that when the follower is forced toward the bottom of the tube, the spring is compressed. The compression of the spring furnished the force for feeding the cartridges into position at the mouth of the tube. The magazine is held in position in the trigger housing and receiver by the magazine catch.

Disassembly

Before disassembly, remove the magazine, retract the bolt, and check the chamber, making sure that the piece is not loaded.

Loosen the front band by partially unscrewing the front band screw. Depress the front band locking spring and slide the front band forward onto the barrel. Remove hand guard by sliding forward until liner is disengaged from undercut on the receiver.

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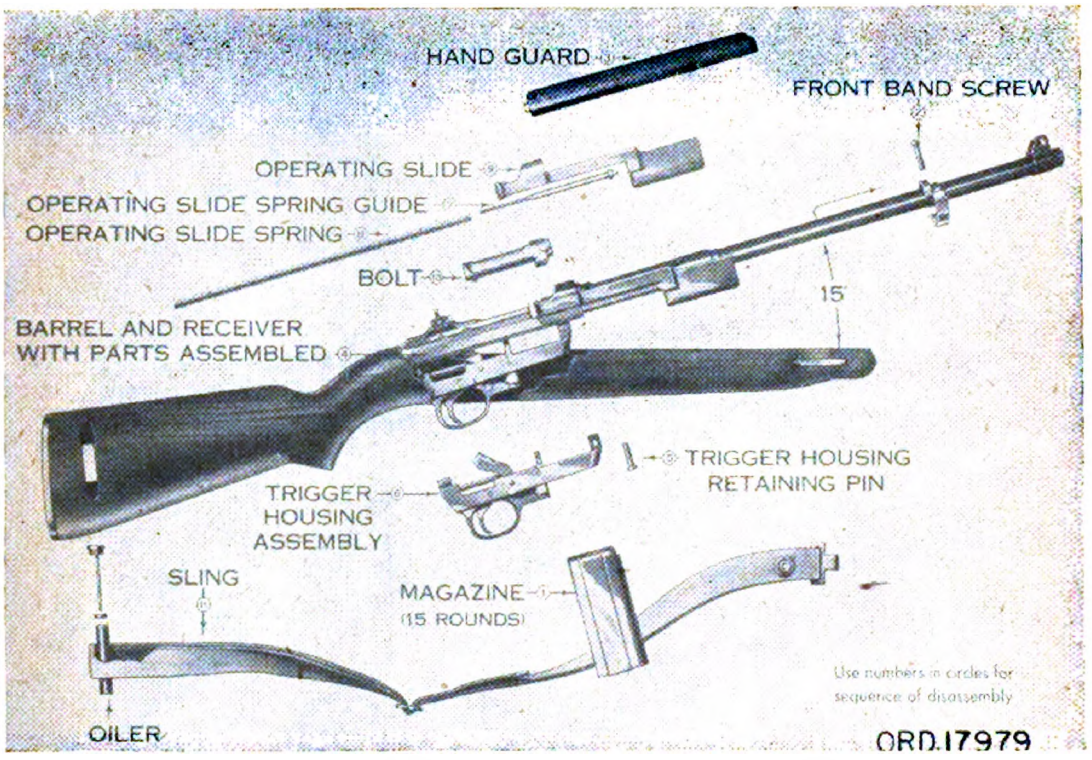

Figure 41. Field Stripping U. S. Carbine Cal .30 M1.

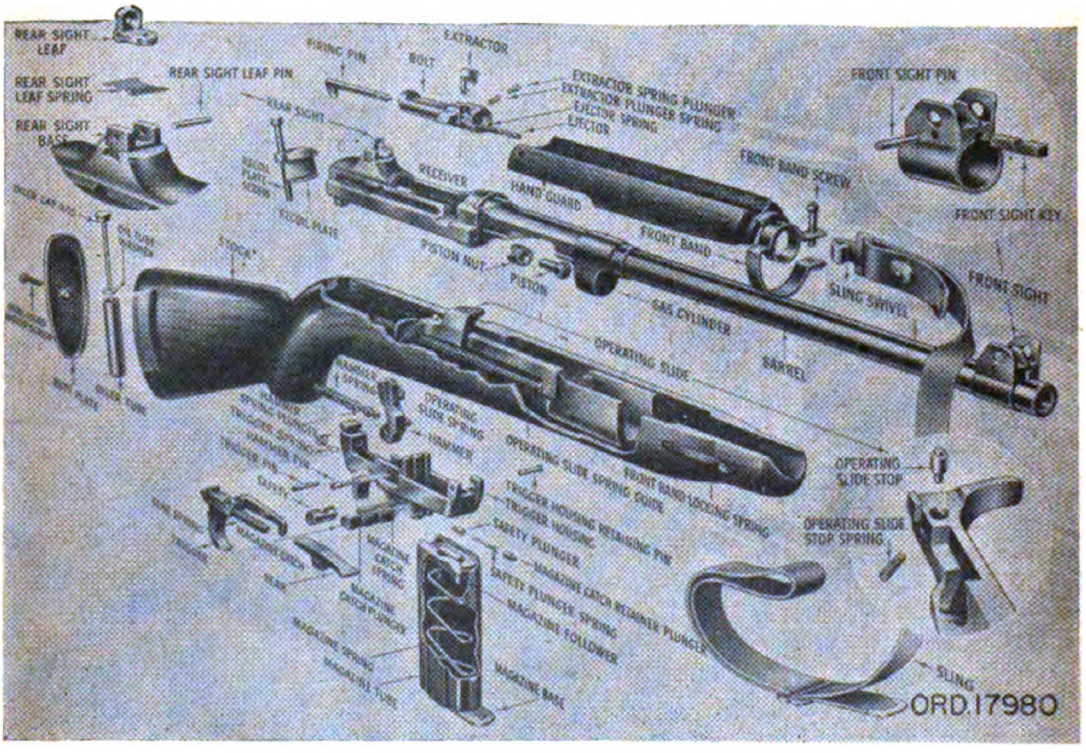

Figure 42. Detail Stripping U. S. Carbine Cal .30 M1.

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Raise the front end barrel and receiver group about 15° until the lug at the rear of the receiver is disengaged from the recoil place, then pull forward and up and lift the barrel and receiver group from the stock.

Push out the trigger housing retaining pin and pull trigger housing forward until rear lug is clear of mating lugs in receiver.

Draw the operating slide spring guide slightly to the rear until it is disengaged from the operating slide; then pull to the right and forward and withdraw the guide and spring from the well in the receiver. In the receiver, where the operating slide spring functions in an operating slide spring housing, remove the housing with the spring and the guide.

Draw the operating slide to the rear until the forward face of the operating slide stop is in line with rear face of the bolt opening in the top of the receiver. Pull the slide handle up and to the right until the operating slide guide lug is free of the retaining groove in the receiver. Then rotate the operating slide body counterclockwise, freeing the lugs by means of the relief cut from the retaining guideways in the barrel.

To remove the bolt it must be rotated counterclockwise and lifted to an angle of 45°, then pulled forward and up, out of the receiver.

The piston and piston nut may be removed, but since the nut is staked in place, they should be only removed at time of Ordnance overhaul, because, if the nut is not properly staked upon assembly, it will work loose during firing and the piece will fail to function properly.

To disassemble the trigger housing group make sure that the hammer is in a fired position. Then insert a small punch into the hole in the hammer spring plunger and pull back and to the right until the plunger is free of the hammer and ease forward against the force of the hammer spring until it is free of the trigger housing. Drift out the hammer pin and remove the hammer.

Drift out the trigger pin and remove the trigger, sear, and sear spring. In removing the trigger spring, remove it carefully to prevent distortion.

In removing the magazine catch, turn the trigger housing bottom up and insert a drift into the hole in the lower face of the trigger housing just forward of the bow. Force the plunger back from engagement with the magazine catch thereby removing the magazine catch, spring, and plunger. After removing the magazine catch, the safety may be removed, as the tension on the safety was removed upon removing the magazine catch.

In disassembly of the bolt, care should be exercised not to lose any of the components. The spindle portion of the extractor locks all of the other components in place. To disassemble, have the thumb over the face of the bolt to prevent the loss of the ejector and ejector spring. Then force the extractor out from its seat. This will free the firing pin, extractor spring, plunger, ejector, and ejector spring.

Assemble the above group in reverse of disassembly. Special points to observe are listed in TM 9-1276. TB 23-7-4 lists all pertinent information on carbine, Cal .30 M2.

Inspection

At present there are few inspection gages available for the carbine cal .30, M1 and modifications thereof other than trigger weights. Trigger weights are: minimum, 4 lbs. and maximum 6 lbs. A maximum headspace gage 1.300 inches (B46619H) only is furnished for testing headspace in the field.

The entire weapon should be checked visually for completeness of parts and smoothness of operation.

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* There has been recently standardized a new carbine which will appear in the field in the near future. The designation of this weapon is U. S. carbine, cal .30, M2.

This weapon is very similar to the U. S. carbine, cal .30, M1, except that by the addition of a few parts it becomes a weapon with selective fire, either semi- or full automatic.

It fires from a thirty round box type magazine and the rate of fire is comparable with that of the Thompson sub-machine gun, M1A1.

There has also been added to all four models of the carbines a front band and bayonet lug assembly which will allow the use of a bayonet.

Accessories for all carbines are: bayonet-knife M4, with scabbard M8A1; sling, carbine, M1 and the oiler which forms the rear anchor for the sling in all full stocked weapons.

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2.36-INCH ANTITANK ROCKET LAUNCHER M1A1 AND M9A1

The 2.36-inch antitank rocket launcher M1A1 and M9A1 does not fit the generally accepted definition of small arms since its caliber is 2.36 inches. If ever a weapon deserved to be called a piece of small arms artillery, this is it. Known as the 'bazooka', it packs the wallop of a 75mm gun, yet it can be carried by any soldier with ease.

It was found in modern combat that the foot soldier's greatest menace is the enemy tank. The only effective and sure way to knock out a tank is to hit it with a projectile that can pierce its armor. Now, as long as infantry can get close artillery support, an attack by tanks can be met and competently handled. Too often, though, it is impossible to bring up sufficient number of antitank guns in time to meet such an attack. There was, then, a definite need for a weapon mobile enough to be carried by an infantry soldier, yet powerful enough to have the effect of an antitank gun upon an enemy tank. The 13-pound bazooka fulfilled these requirements.

The 2.36-inch AT Rocket Launcher M1A1 is an electrically operated weapon of the open tube type. It is fired from the shoulder in the standing position, kneeling position, sitting position, or prone position, Figure 43. Although it is primarily an antitank weapon, it may be used quite effectively against pill boxes and machine gun emplacements. Since there is very slight recoil when it is fired, the tendency for the firer to flinch is greatly lessened.

Disassembly

For ordinary care and cleaning it is not necessary to disassemble the launcher except to remove the two trigger grips. Further disassembly is for the purpose of inspection, maintenance, and repair only.

Flash Deflector. Remove the screw from the flash deflector and remove the deflector. Care should be observed not to lose the screw, nut, and washer.

Sling. Disconnect the web sling from the sling loops on the launcher.

Trigger. Unscrew the sling bracket screws and remove the sling bracket. Unscrew the two screws on the left trigger grip and remove the trigger grips. Remove the cotter pin, withdraw the trigger pin, and then remove the trigger. Break the soldered connection between the wire and the lower switch contact support. Pry the conduit tube with the wire loose from the clips on the left side of the stock support.

Circuit Indicator Cover Bulb. Remove the three screws from the circuit indicator cover. Remove the cover and break the soldered wire connection. Next remove the spare bulb and the socket assembly with bulb.

Stock. Pull the rear part of the hasp down to open it, and remove the two sets of batteries. Remove the hasp, by removing the four screws holding it in place. Break the soldered connection between the wire and the stock support. The last step is to slide the stock off the support.

Tail Latch. Press the front of tail latch body down, remove the cotter pin and the tail latch pivot pin, and then carefully withdraw the tail latch spring.

Assembly. Assembly of the (1) tail latch, (2) stock, (3) circuit indicator cover and bulb, (4) trigger, (5) sling, and (6) flash deflector is merely the reverse of disassembly.

All the electrical connections that have been broken will have to be resoldered.

Loading

The first step is to place the bazooka on the right shoulder and aim it at the target. Squeeze the trigger several times and make certain the bulb lights. It should light only when the trigger is squeezed. (Note: During the operations of loading, sighting and firing, the loader should at all times be to the side of and slightly forward of the breech end of the launcher to avoid the flash back.)

The loader grasps the rocket with his left hand, and inserts the head of the rocket into the breech end of the bazooka, at the same time raising the tail latch clear of the rocket.

(Caution: While the rocket is thus being inserted into the bazooka, the firer makes certain that his finger is off the trigger and that the light is out.)

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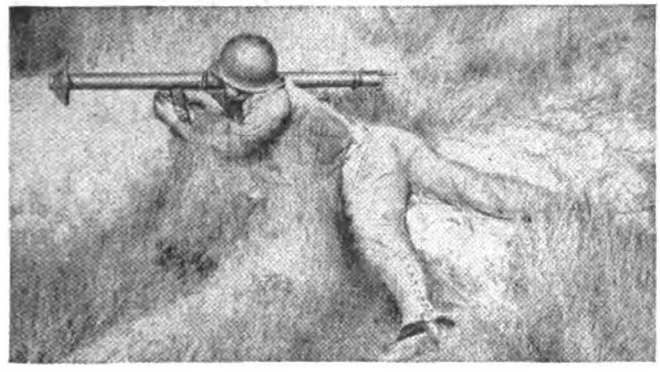

Figure 43. 2.36-Inch Rocket Launcher. Firing Positions.

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After the head of the rocket has been inserted into the breech end, the loader then releases the tail latch and removes the safety pin from the rocket.

(Caution: Since the fuze of the high-explosive rocket is quite sensitive, it is extremely important that the rocket be handled carefully after removal of the safety pin to prevent it from falling. A fall on its nose or a blow of equivalent force after removal of the safety pin will cause detonation.)

The loader next raises the tail latch and carefully pushes the rocket into the launcher until the latch engages a notch on the tail fin.

This is the last and most important step. The loader pulls the end of the

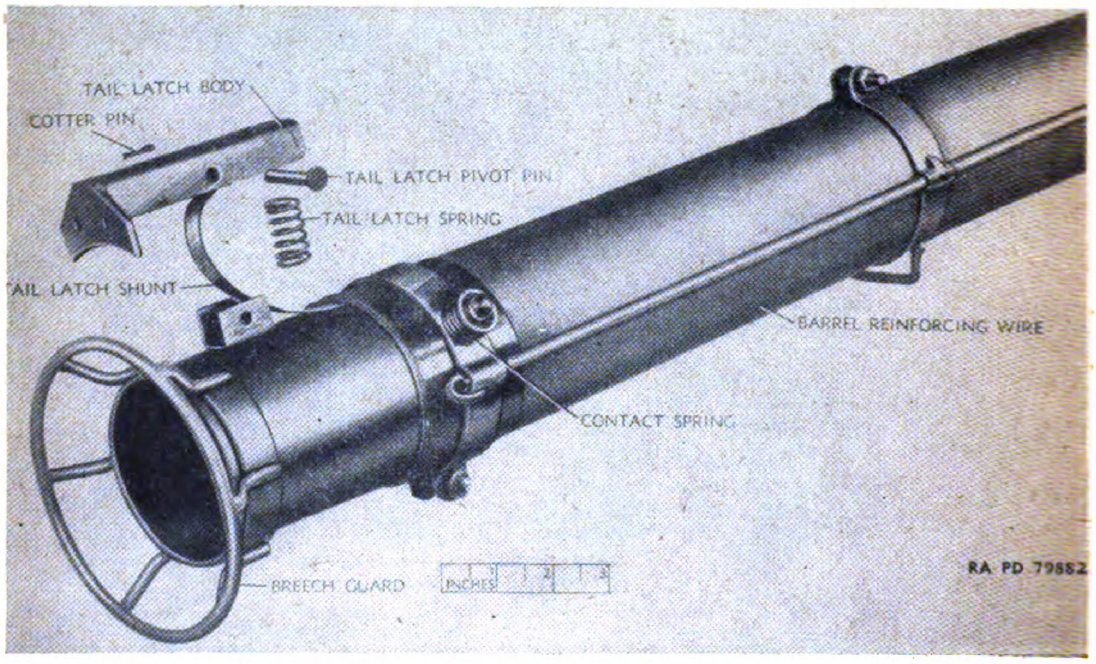

Figure 44. Rear of Launcher M1A1.

Figure 45. Loading Rocket Into Launcher.

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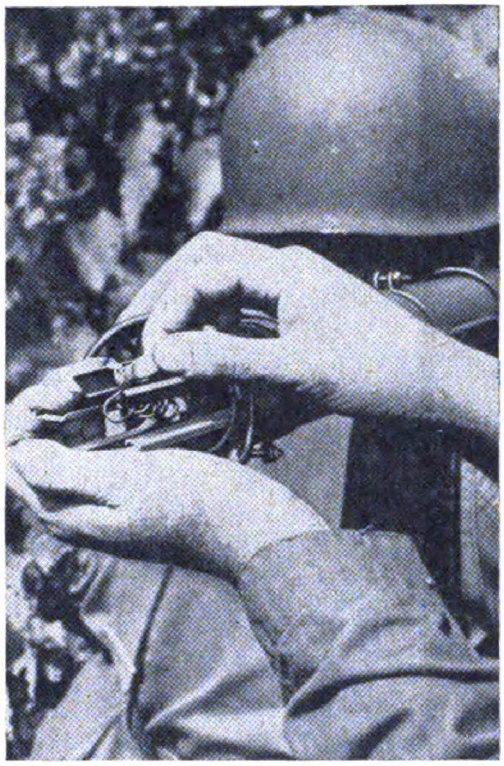
contact wire off the fin, pulls the wire straight back to uncoil it, and then engages the uninsulated part of the wire between the coils of one of the two contact springs. (Note: It is not necessary to wind the wire around the contact spring.



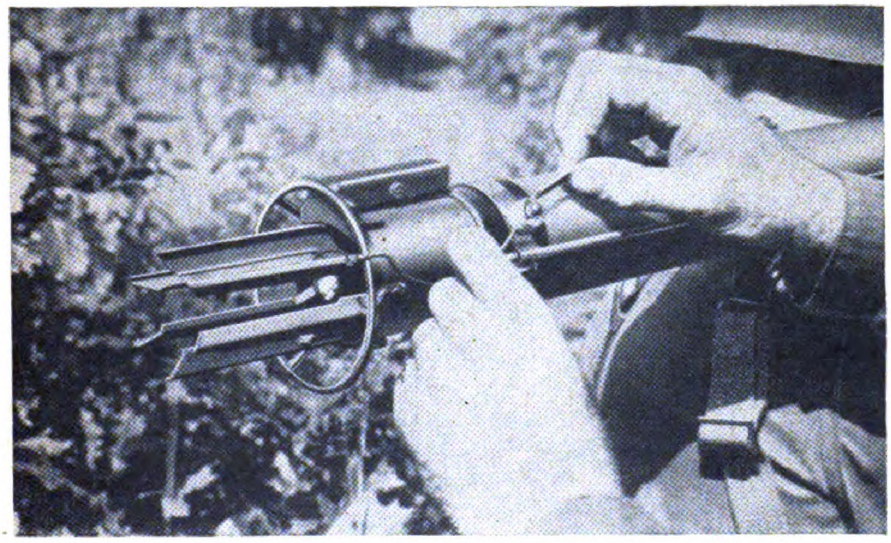


Figure 46. (Top) Disconnecting Wire From Rocket. (Bottom) Connecting Wire to Spring.

Since there is a contact spring located on both sides of the rear of the bazooka, the loader may stand on either side when loading; however, the right side is more appropriate.)

The loader makes certain that he is not in the rear, signals the firer that the rocket is freely loaded into the breech end, and the bazooka is ready to be fired.

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Unloading

If it is desired to unload the bazooka rather than to fire it the loader removes the contact wire from the contact spring, raises the tail latch, and carefully withdraws the rocket until the safety pin may be inserted into the rocket. The rocket is then removed from the breech end of the bazooka. The contact wire is coiled and placed between the fins, and the rocket is repacked.

(Note: Always set the safety of the M9A1 launcher at "SAFE", before unloading the launcher.)

Functioning

The functioning of this weapon is comparatively simple compared to that of other weapons. There is no sear, bolt, or other complicated mechanism.

When the hasp is closed, the coiled battery spring makes contact with the negative pole of the batteries. The coiled battery spring is connected by a short wire to the metal stock support to complete the circuit. The positive pole of the batteries is connected by wire running between the stock and the launcher tube, forward and then down to the lower trigger switch contact. The gap between the lower trigger switch contact is bridged when the trigger is squeezed by the copper contact bar. The wire from the upper trigger switch contact is carried to the rear by a conduit tube mounted on the right side of the launcher tube; in its passage by the stock support it is connected to the circuit-tester-lamp socket. It is then connected to the contact spring mounting clamp at the rear end of the launcher tube.

When the trigger is squeezed it pivots to the rear as it is pinned at its upper end to the trigger support. As the bottom of the trigger moves rearward, it forces the bar contact against the lower trigger switch contact, thus completing the circuit.

The passage of the electric current through the rocket sets off an electric igniter in the rocket, which in turn ignites the propelling charge. The rearward escape of the powder gases through a jet forces the rocket out of the barrel with a muzzle velocity of approximately 265 feet per second. Since propulsion of the rocket is by jet action of the propellent powder, there is very slight recoil. The burning time of the propellant is approximately 0.02 to 0.03 seconds, and combustion is complete before the rocket leaves the muzzle, hence there is no muzzle flash.

When the pressure on the trigger is released, the trigger spring, a part of the trigger assembly, forces the trigger to its forward position, and the electric circuit is broken.

Safety Precautions

It has been previously mentioned that combustion is complete before the rocket leaves the muzzle; occasionally, however, the burning may, for some reason be retarded, creating a backflash as the rocket leaves the muzzle. This occurs during cold weather, but may also occur at other times. The firer should be protected against this by gloves or cloth wrapped around the hands, goggles, or other protective equipment, such as a gas mask. This prevention is especially important in cold climates or when no flash deflector is available. The firer and loader should also wear steel helmets.

When the bazooka is fired from the prone position, the body should be at an angle of at least 45° to the direction of fire, so as to avoid injury from the back blast of the rocket.

No personnel or inflammable material should be behind the launcher within a distance of 20 feet when it is fired. The hot gases can inflict serious burns. When firing from trenches or fox holes, clearances should be provided so that the back blasts is not deflected against personnel.

The dry cells become too weak to furnish enough electricity when operating at temperatures below 14° F. When using the launcher at low temperatures, batteries should be removed from the launcher and kept warm until just before firing. Carrying the batteries in inner pockets in cold climates will keep them sufficiently warm. The spare batteries can be carried in the pockets and alternated with the cold ones every half hour.

The rockets should not be fired at temperatures below 0°F. nor above 120°F.

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Rockets must not be exposed to the sun, except when immediately ready to load. Rockets should be left in their containers and stored in shaded places.

Rockets should not be allowed to remain in hot launchers prior to firing.

If the cardboard plug cemented over the nozzle in the forward end of the fire assembly is missing, do not use the rocket. The plug, which should never be removed, prevents the entry of moisture or dirt into the propellant during storage and handling.

Do not attempt to fire the earlier model rockets M6 and M7 from the M1A1 or M9A1 rocket launcher.

Malfunctions

Proper and intelligent care of the launcher, the same as with all types of small arms, will eliminate most malfunctions. Since the functioning of the launcher is quite different from other small arms, the only two phases of operation we are concerned with are (1) loading and (2) firing.

Immediate Action. If, when the trigger is squeezed, the launcher fails to fire, the following steps of immediate action should be followed:

Squeeze the trigger again to fire the launcher.

If the launcher still does not fire, the firer removes his finger from the trigger, and the loader cautiously makes certain that the uninsulated part of the contact wire engages the contact spring. The firer then attempts to fire the launcher.

If the launcher still does not fire, the loader waits one minute and then carefully removes the rockets, as explained previously. The rocket is set aside for disposal by authorized personnel.

Failure to Load. *Bent Tube.* There is no remedy for this malfunction. The launcher must be replaced.

Bent Breech Guard. The breech guard may be straightened with pliers.

Oversize or Bent Rocket. Any defective rockets should be discarded.

Bent or Defective Tail Latch. An attempt should be made to straighten the latch. If contact between the latch and fin of the rocket is not made, the latch will have to be replaced. (Caution: Never wedge the forward part of the tail latch up to make a contact.)

Failure to Fire. This is usually caused by defective ammunition or a defective firing mechanism.

If the contact wire is loosely connected to the rocket, the rocket may be defective and should be turned over to ordnance maintenance personnel.

A defective firing mechanism may be due to spent or defective batteries, loose electrical connections, or broken parts. Check the batteries by squeezing the trigger and noticing whether the bulb lights. If it does not, replace the batteries and test again. If the bulb still does not light, change the bulb. (Remember, a spare set of batteries and a bulb are always carried in the stock of the launcher.) Remove the two trigger grips and check the trigger switch contacts for loose or broken parts. If the bar contact is deformed, it is permissible to bend it into the correct shape. If the bar is broken the launcher should be turned over to ordnance maintenance personnel. Check and make certain that the battery spring contacts the battery. If the spring is broken, spread it out so that it will contact the batteries. (This, however, should only be done in an emergency.) Remove the circuit indicator cover and check for loose wire. Test by hand for wire being securely connected to the stock contact. If the connection is broken, turn the launcher over to ordnance maintenance personnel for repair.

Inspection

It has been previously mentioned that the purpose of inspection is to determine the condition of the materiel, and the repair or adjustments necessary to insure serviceability and proper functioninig. Through systematic inspection at regular intervals is the best insurance against an unexpected breakdown at the critical moment when performance is absolutely necessary. The following important point should always be kept in mind: Never let your materiel run down; keep it in first-class fighting condition by vigilant inspection and prompt maintenance.

Inspection of the bazooka is of the visual type as no gages are used.

It should be inspected for its general condition, loose or broken components, painting defects, bends, dents, and for obstructions in the bore.

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Squeeze the trigger several times; the bulb should light. If it does not, check the batteries and bulb and replace the defective items.

Check the electrical circuit for loose wire connections.

Remove the trigger grips and check for the following: Deformed or broken switch contact bar. Missing switch contact button. Missing, deformed, or broken bar contact. Missing switch contact lower support unit. Loose connections, particularly between the bar contact and upper switch contact support and between wire and upper and lower switch contact supports. Corroded electric contact points.

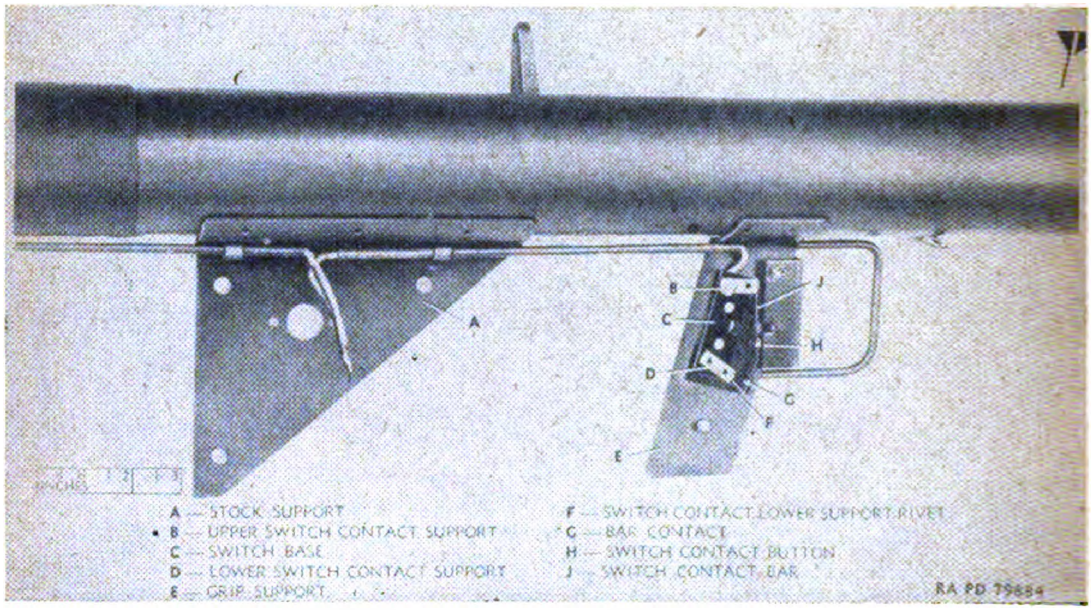

Figure 47. Trigger Group M1A1.

Remove the circuit indicator cover and inspect for loose wire connections. Remove the hasp and check for loose connections between the wire and stock support.

Examine the batteries. If they are cracked, swollen, broken, or do not light the bulb, replace them.

Check the functioning of the tail latch and of the trigger spring.

Inspect the barrel visually for rust, scale, and dents.

Examine the contact springs to see that they are secured to the clamp. They should be clean and free from rust, paint, and grease.

Care and Cleaning

Daily and Immediately After Firing. A cloth, large enough to fill the inside diameter of the barrel, should be wet with rifle bore cleaner and run through the barrel several times. A dry wiping cloth is then run through the barrel until the barrel is dry and clean. Next saturate a clean dry wiping cloth with light, preservative, lubricating oil and wring it out. Oil the bore by running this cloth back and forth through the barrel.

Weekly. Apply one or two drops of light, preservative, lubricating oil to the tail hinge pin. When available special preservative lubricating oil may be used in place of light lubricating oil.

Prior to Firing. A clean dry wiping cloth should be run through the barrel to remove any oil.

Miscellaneous. If the outside of the launcher is rusted, pitted, or chipped, crocus cloth may be employed to clean the surface of those parts. The surfaces thus cleaned should be repainted with lusterless, olive-drab, synthetic enamel. Do not paint the contact springs or the flash deflector. If the launcher is used in wet weather, disassemble the stock and trigger grips and dry all electric contact points and wire with a dry cloth. Clean and oil the rest of the launcher as described previously.

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Modifications

M1A1 Rocket Launcher. The first launcher that was constructed bore the following description: Launcher, Rocket, A.T., M1. It was modified some time later into the M1A1. The following changes constitute the most important modifications.

The gun sling M1 was added to the launcher to facilitate carrying of the weapon.

The outside of the barrel was wire wrapped from the stock to the breech. Its purpose was to provide greater safety in use by strengthening the launcher.

Replacement of the contactor mechanism assembly with a contact clamp assembly. This new assembly simplifies establishing the electrical circuit between the launcher and the rocket. It is also a more dependable method.

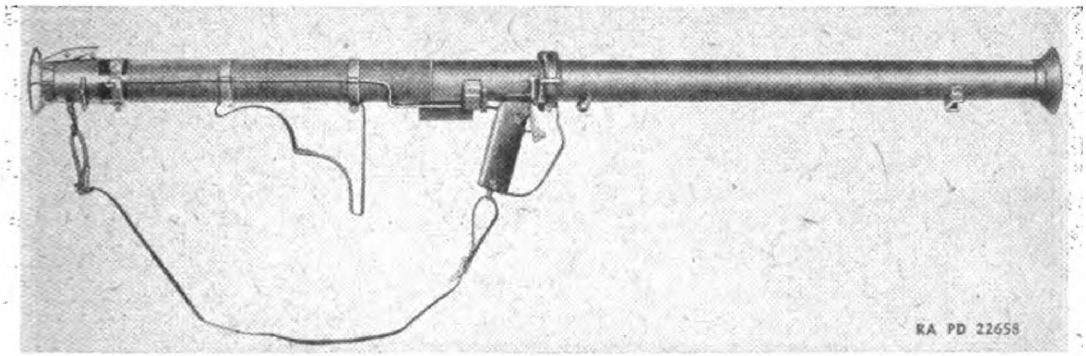
The front grip was removed and the front and rear sights were changed.

The M6 (high explosive) and M7 (practice) rockets were also modified.

ROCKET LAUNCHER M9

Because of the length of the bazookas, it proved a difficult weapon in jungle terrain and paratroops found it unwieldly in jumps from planes. As a direct result, a folding bazooka has been developed by the Ordnance Department. Thus the accordion bazooka came into being and although the M1A1 will still be used, it is no longer being procured.

The M9 rocket launcher weighs a little less than the M1A1, or about 15 pounds. It is 61 inches in length, an addition of 6.5 inches. It has a two-piece barrel; for carrying, the two pieces can be secured sideways to one another. The other main differences between the two models are in the sight, trigger grip, stock, firing mechanism, and flash deflector.



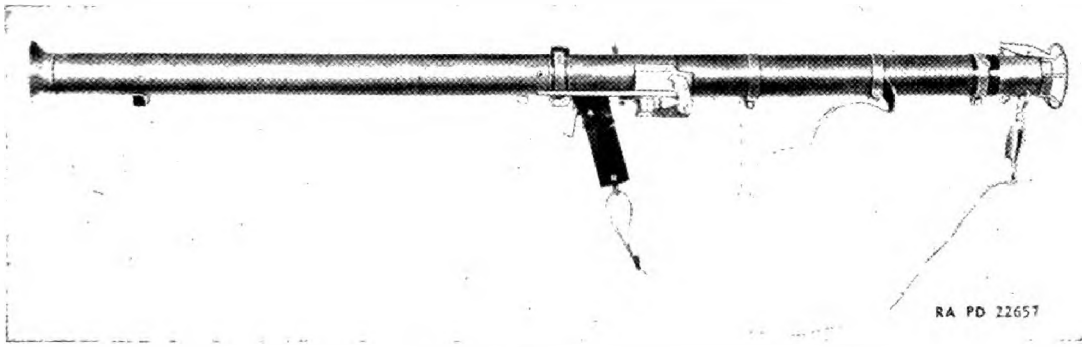


Figure 48. Launcher, Rocket 2.36 in. M9. Right and Left Side Views.

Sight. The bar sight now being used on the M9A1 launcher consists mainly of a fixed stud as the front sight and a peep type rear sight which is mounted on a bar. The range is determined by turning the indicator arm to the appropriate range as indicated on the range plate. The range plate is graduated up to 600 yards. By turning the indicator arm, the angle of the sight bar is changed. The proper sight picture is acquired in a manner similar to that of the M1A1 rocket

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launcher by raising or lowering the muzzle. One important feature of this sight is that it will fold against the side of the launcher to facilitate transportation.

Trigger Grip. The trigger grip houses the firing mechanism which is secured to the trigger grip support on the under side of the rear barrel.

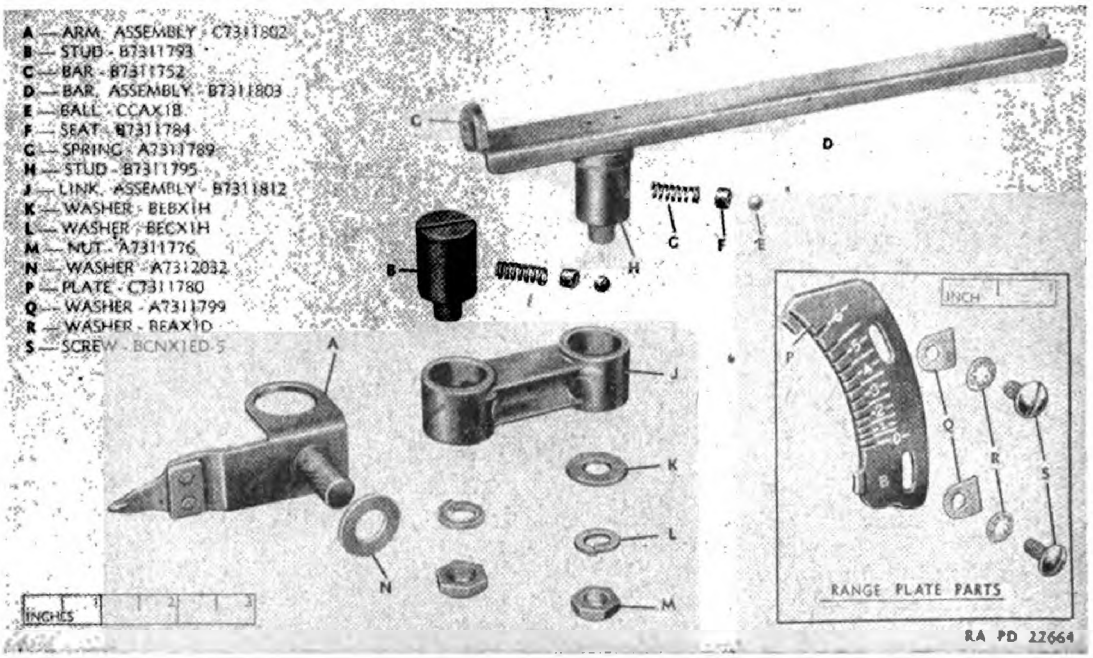

Figure 49. Sight Group Parts. Launcher, Rocket 2.36 in. M9.

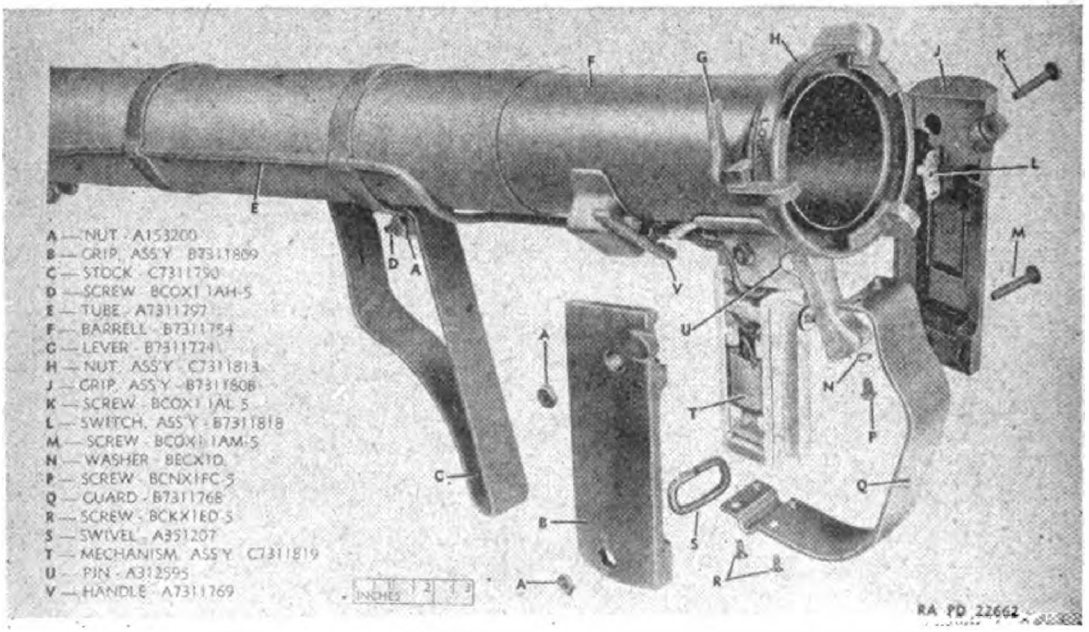

Figure 50. Trigger Grip Group Parts. Launcher, Rocket 2.36 in. M9.

Stock. The metal stock has two shoulder rests. The front rest is used for short range firing, the rear rest for longer ranges and for firing in the prone position.

Firing Mechanism. The firing mechanism consists of magnets housing a coil and a spring actuated bar within the coil. The spring actuated trigger is pinned

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to the trigger grip support and the firing mechanism. The circuit for the passage of the electric current is complete at all times, but when the trigger is in its normal position, no current is generated by the magneto firing mechanism. When the trigger is squeezed, the bar within the coil is rotated and electric current is generated and flows through the circuit. When the trigger is released, the bar magnet is rotated to its original position under the action of the bar magnet spring and during this movement electric current is again generated.

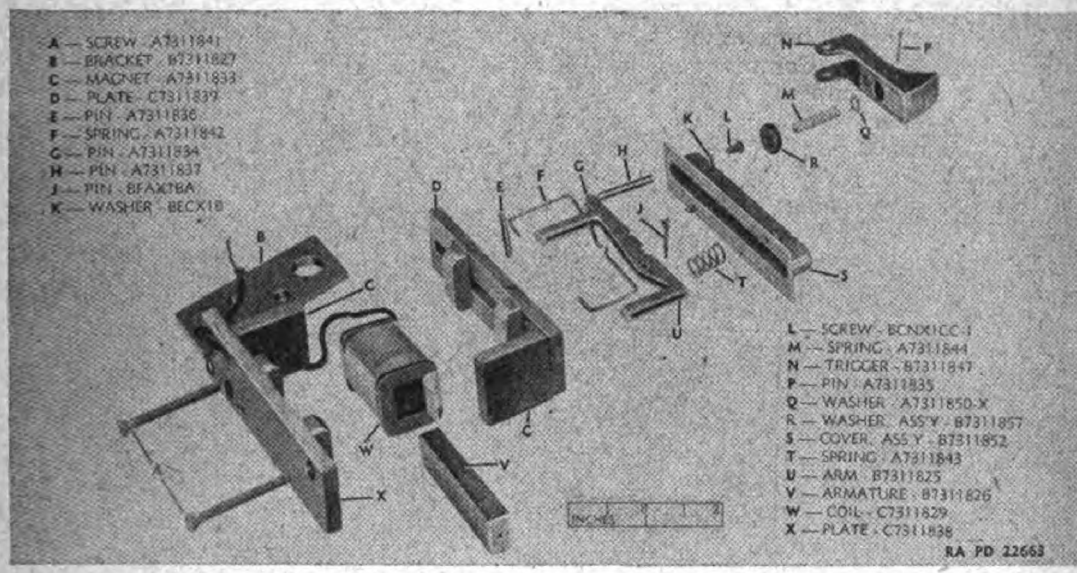

Figure 51. Firing Mechanism Group Parts. Launcher, Rocket 2.36 in. M9.

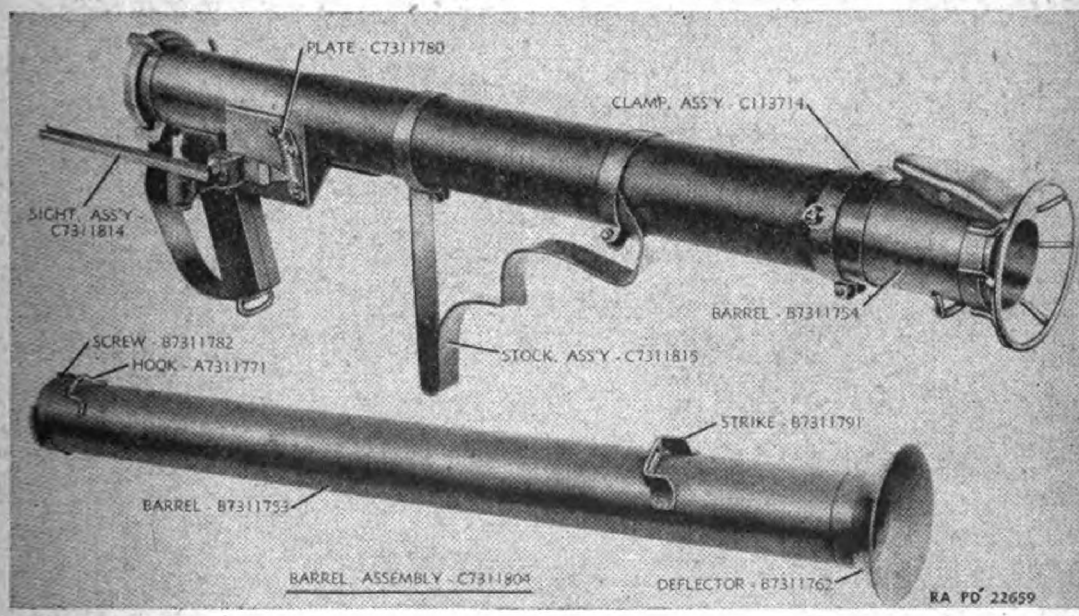

Figure 52. Front and Rear Sections. Launcher, Rocket 2.36 in. M9.

(Note: When firing the M9A1 rocket launcher, squeeze the trigger and release it immediately. Do not move the launcher off the target before releasing the trigger).

The firing mechanism is provided with a safety. When the safety is put at 'safe', the electric current is shunted, and the rocket is prevented from firing.

Muzzle Flash Deflector. This deflector is quite different from the one used

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with the M1A1 launcher. It is of solid metal, spot welded to the tube, with the cone end of the deflector toward the gunner.

Figure 52 shows the front and rear section of the M9 rocket launcher.

The M9 rocket launcher has been recently modified, and it now bears the designation M9A1. The M9A1 launcher differs from the M9 only in a manufacturing difference on the barrel coupling.

THOMPSON SUBMACHINE GUNS

The Thompson Submachine gun, popularly known as the 'tommy gun,' was invented in 1920 by Commander John Blish of the United States Navy and Brig. Gen. John C. Thompson of the United States Army.

Practically every armed force in the world has, during the past 20 years, used this widely known weapon. It is true that it has a comparatively short range, but what it lacks in range it makes up in fire-power. The submachne gun delivers a devastating fire, using the hard-hitting, shock-producing, cal .45 cartridge.

Figure 53. Thompson Submachine Gun Cal .45 M1928A1. Left Side View With 50-Round Drum Type Magazine.

The Thompson submachine gun, cal .45 M1928A1, was the standard submachine gun in the United States armed forces for a number of years. A delayed blowback-operated weapon weighing approximately 10.8 lb., it had a cyclic rate of fire of 650 rounds per minute. As an accessory it used the 20-round box-type or 50-round drum-type magazine. Sometime later a 30-round box-type magazine was designed.

When the M1928A1 model was modified, the new weapon which resulted was designated the Thompson submachine gun, cal .45 M1. The main difference was in the type of operation. The new model was a straight blowback-operated weapon. The small 'H-shaped' bronze lock, which delayed the opening of the breech in the older model, was left out. It was found that the weight of the heavy bolt and the inertia of the 15½ inch recoil spring were sufficient to work the weapon safely and satisfactorily when the locking device was eliminated. Another change was the removal of the Cutts compensator, a device which was screwed onto the front of the barrel and held in place by the front sight pin. The compensator served a two-fold purpose: one, to prevent the muzzle from rising, and two, to cut down slightly on recoil. This was accomplished as follows:

The Cutts compensator was constructed so that the powder gases on coming through the muzzle were coned to higher pressure. These gases were valved through the orifices or slots in the top of the compensator in an upward direction, thus pressing the muzzle downward.

Other changes included elimination of the actuator and breech oiler of the earlier model, and of the cooling fins on the barrel. The rear sight was changed from a movable rear sight leaf to the fixed type of sight. Although the frame looks like the M1928A1 model, it differs in one respect. In the newer model, the butt stock is attached to the frame group by means of two screws. It

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cannot be removed by merely sliding it to the rear, as can the one in the older model (M1928A1). These changes served to cut the cost and the time of manufacturing considerably.

The Thompson submachine gun, cal .45 M1A1, is an air-cooled magazine-fed weapon weighing approximately 10.5 lb. It utilizes the forces of the exploding cartridge to blow the bolt back, thus causing the weapon to function. This type of operation is known as blowback.

The gun is designed to be fired from the shoulder of the individual, similar to a rifle. It uses either a 20- or 30-round box-type magazine. Note: The 50-round drum can not be used with this weapon. The left hand of the individual is protected on the underside of the barrel by a wooden fore grip. A rear grip is also provided for the individual's right hand. Sling swivels are secured to the fore grip and stock for attaching a web sling. On the left side of the weapon just above the rear grip, two small levers are located. The first lever, known as the rocker pivot, enables the weapon to be used for either full automatic or semiautomatic fire. The rear lever, known as the safety, when pointing toward the rear prevents the weapon from being fired.

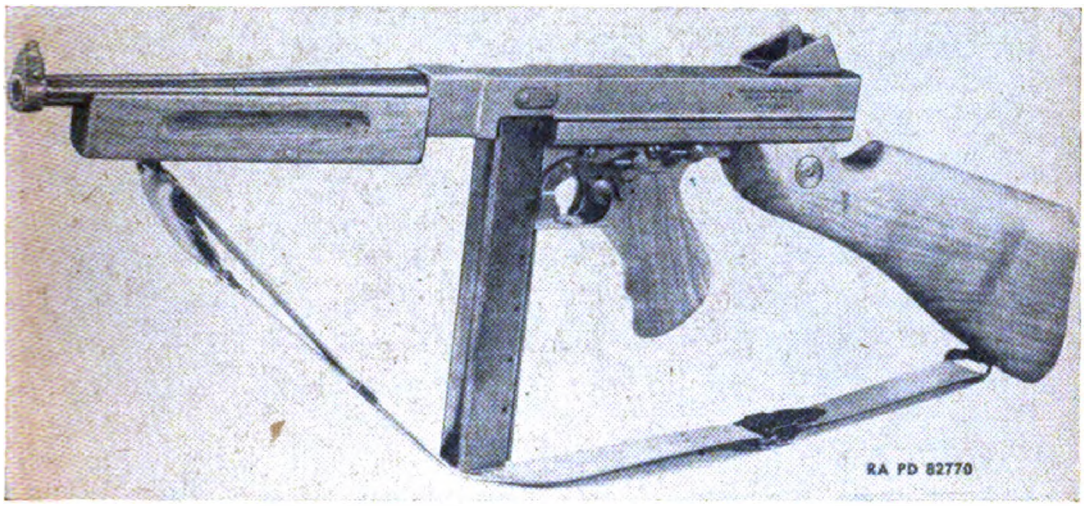

Figure 54. Thompson Submachine Gun Cal .45 M1A1. Left Side View With 30-Round Magazine.

When this weapon was first adopted by the armed forces, it was known as the M1. Sometime later because of a number of modifications the designation was changed to M1A1.

The Thompson submachine guns M1 and M1A1 differ primarily in the design and construction of the bolt. In the earlier model the firing pin slides in a cylindrical hole in the bolt. At the time of firing, the firing pin is struck by a triangular hammer, which rotates on a hammer pin. After firing, the hammer is returned to its orginal position by the firing pin spring. In the M1A1 submachine gun, however, the firing pin is an integral part of the bolt, and there is no firing pin spring, hammer, or hammer pin. A second change is in the design of the rocker pivot and safety. Its operation, however, remains the same. The third change was to add ears to the fixed type rear sight which strengthens it and prevents damage to the aperture.

Field Stripping the Thompson Submachine Gun M1A1

Magazine. With the weapon pointing in a safe direction, the bolt is pulled to the rear until it is held back by the sear. The checkered portion of the magazine catch, located on the left side of the receiver, is rotated counterclockwise and the magazine is removed. Check the chamber and make certain that it is clear. Grasp the bolt handle, located on the right side of the receiver, and squeezing the trigger allow the bolt to go *slowly* forward. (*Caution:* The bolt should never be allowed to go forward on an empty chamber without being retarded.)

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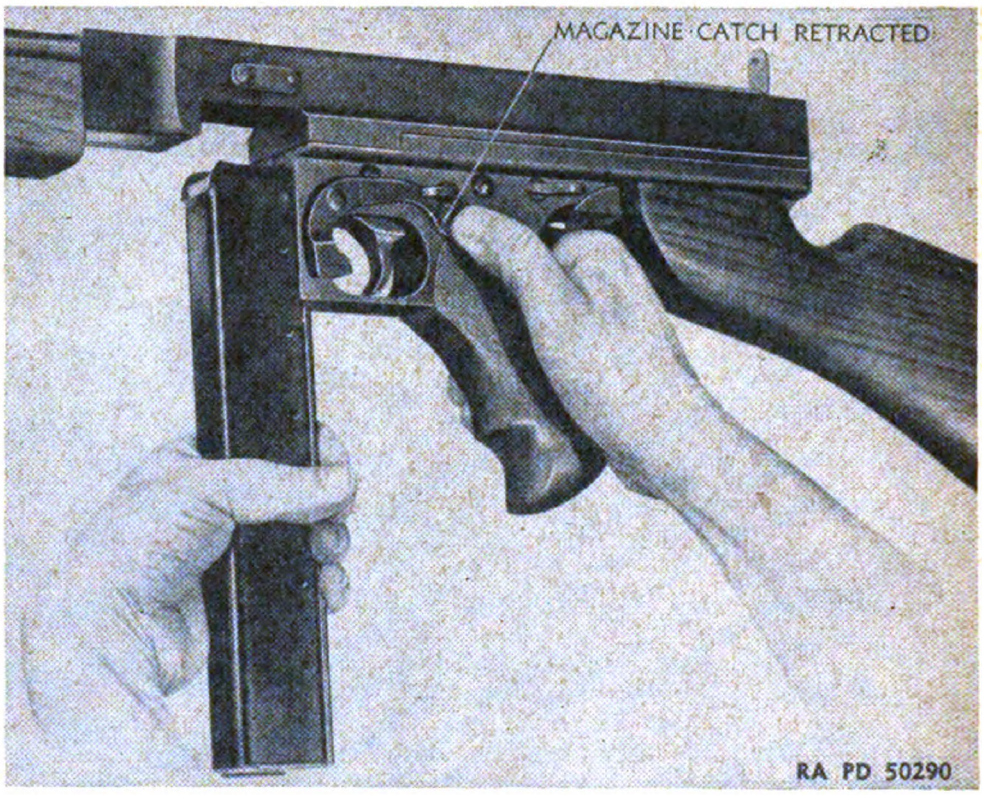
Sling. The next step is to disconnect the web sling hooks from the link and swivels, then to remove the sling.

Frame Group. Before any further stripping is attempted, extreme care should be observed to make certain that the rocker pivot (the first lever on the left side of the receiver) is pointing to the front so that it reads "full-auto") and that the safety (the rear lever) is also pointing forward (so that it reads "fire".)

Turn the weapon upside down; with the thumb of the left hand press the frame latch down. (*Note:* If a screwdriver, small stick, or pointed object is available, the disassembly of the frame group from the receiver group can be greatly facilitated since this frame latch can be pushed down much more easily.) As this frame latch is being depressed, slide the frame group rearward a short distance. Now, *squeezing the trigger,* remove the frame group by sliding it directly to the rear. (*Caution:* If the safety is not set at "fire" and the pivot at "full-auto," the bolt may be damaged.)



Removing the Magazine.
Figure 55. Field Stripping the Tommy Gun.

Bolt and Recoil Spring Group. The weapon is now positioned so that the open side of the receiver (*i.e.,* the bottom) is facing you, muzzle down, resting against your knee or against a table top. With the thumb of the left hand, force the buffer pilot slightly down and withdraw the buffer assembly.

This consists of two metal plates and a fiber center, riveted together. The next step is to remove the long recoil spring and its guide, the buffer pilot. (*Note:* Once you have removed the buffer assembly, the buffer pilot may be forced out under tension of the compressed recoil spring; so extreme care should be observed during the next few steps.) With the left thumb still retaining the buffer pilot in place, raise the bolt with your right hand by means of its handle a short distance. Now gradually let up on the buffer pilot with your left hand, remembering to retard its upward movement so as to prevent the pilot from slipping out of your grasp and possibly injuring you. The next thing is to remove the pilot and spring. At the first few attempts the removal of these three components

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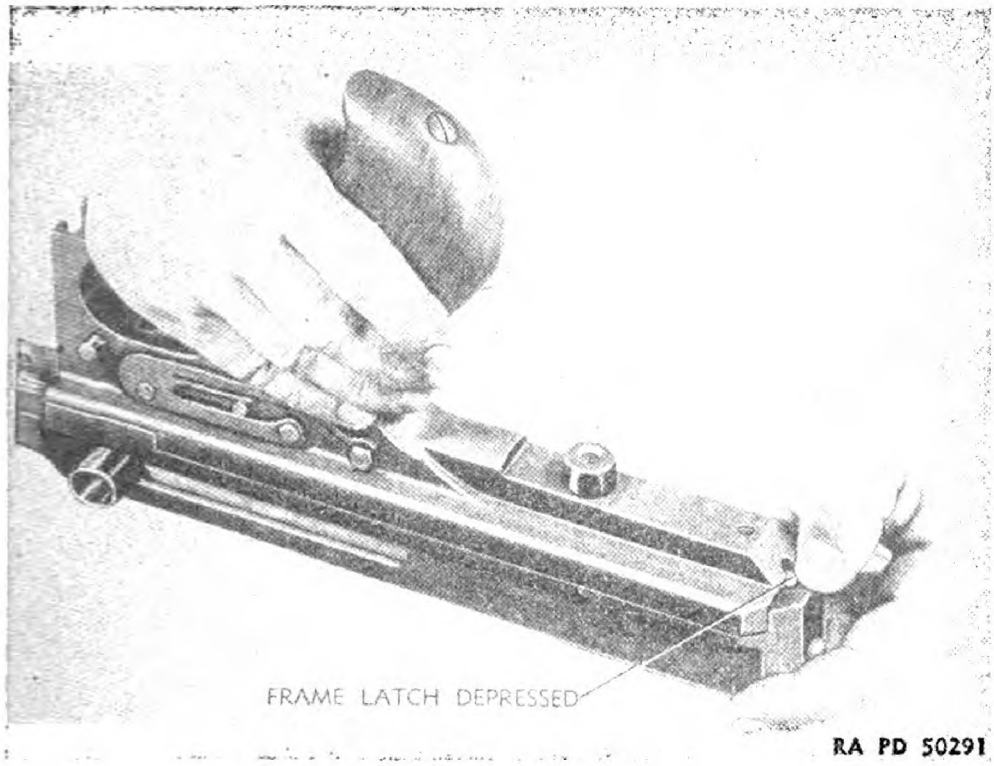
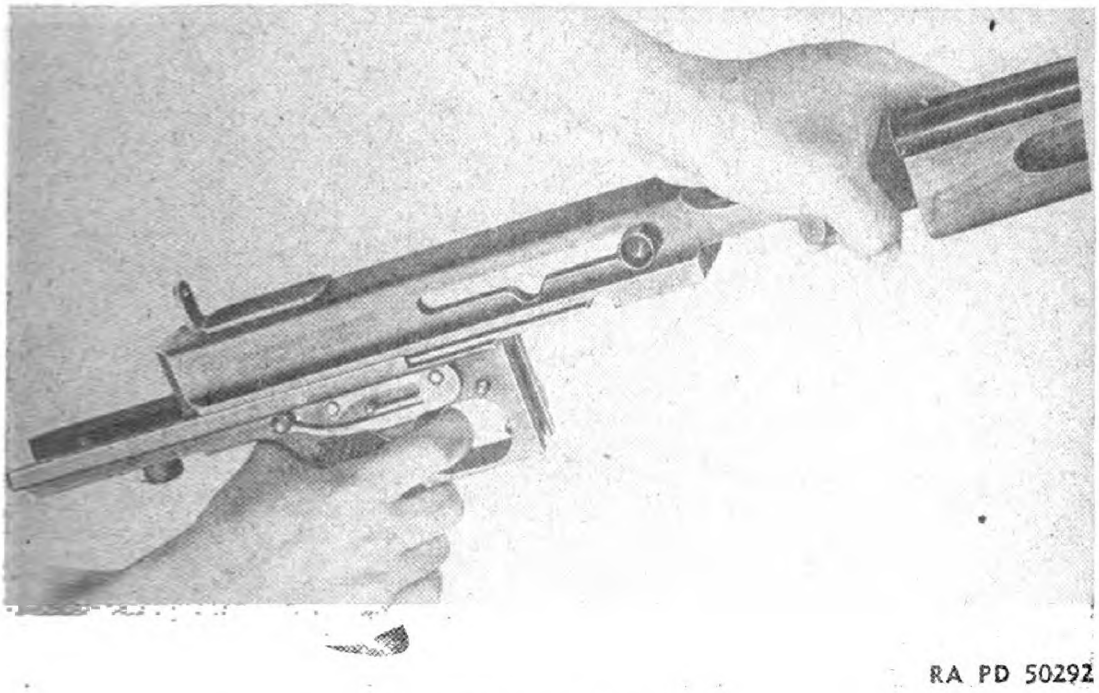


Frame Latch Depressed.



Removing the Frame Group.

Figure 55. Field Stripping the Tommy Gun. (Continued)

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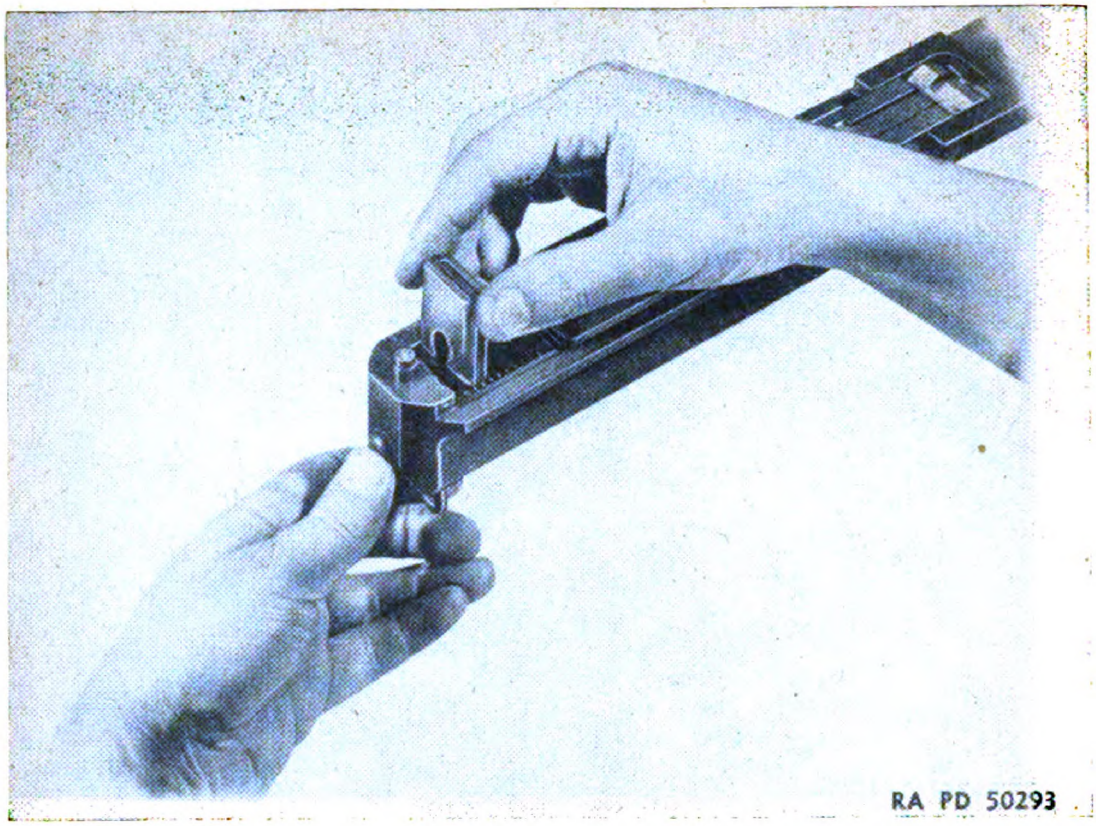
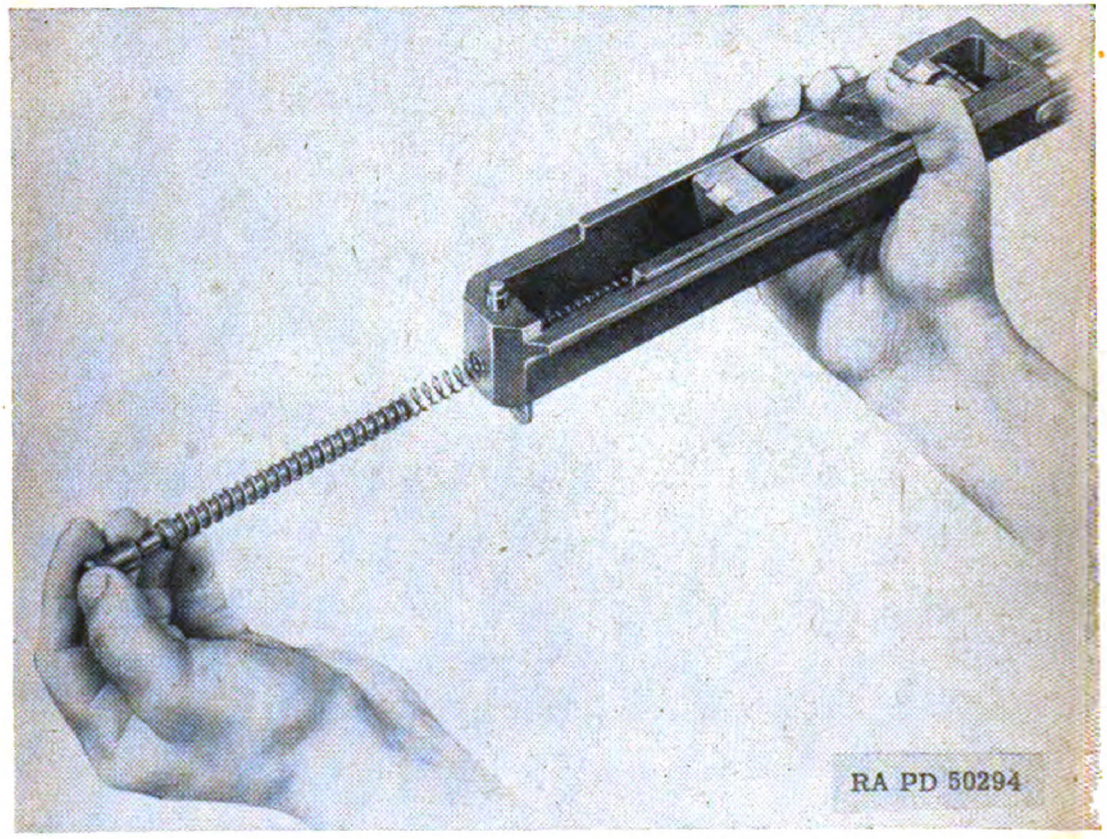


Removing the Buffer Assembly.



Removing the Recoil Spring and Buffer Pilot.
Figure 55. Field Stripping the Tommy Gun. (Continued)

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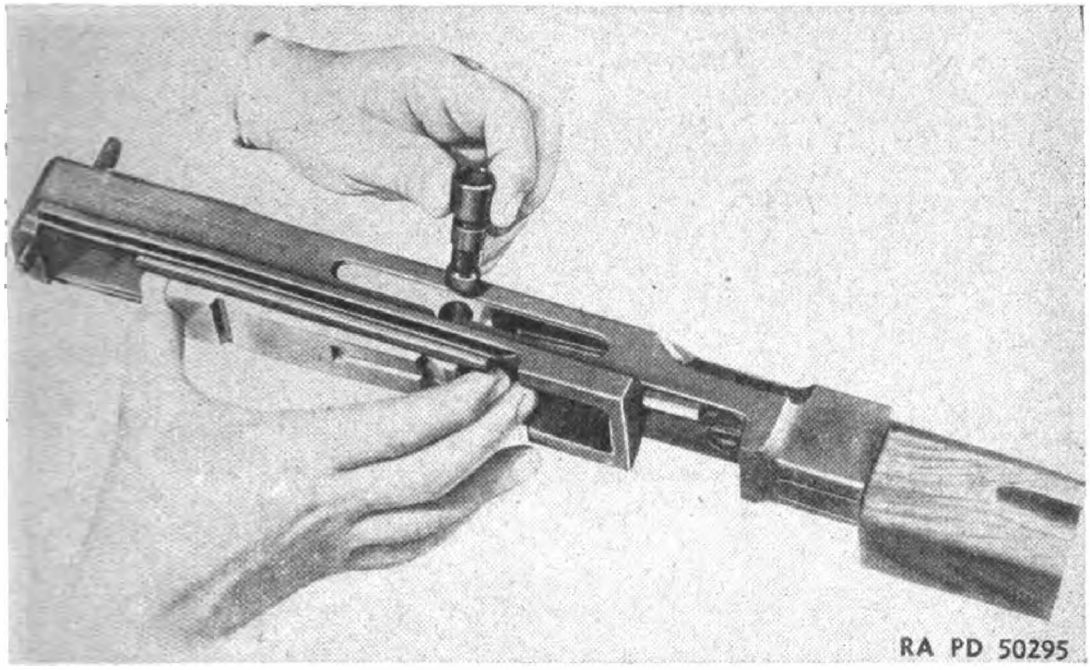
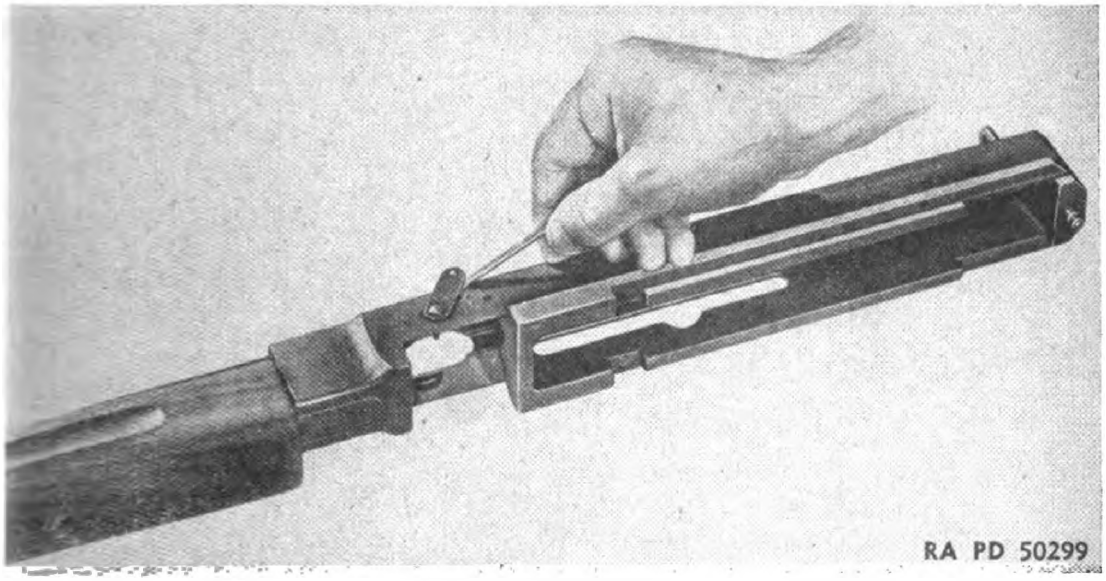
may seem quite difficult. However, once the technique is acquired, the stripping of these parts is simple.

Bolt and Bolt Handle. With the weapon held so that it is right side up, align the bolt handle with the semicircular cut on the right side of the receiver that is located in the elongated groove in which the bolt handle rides. *(Note:* Before



Removing the Bolt Handle.
Figure 55. Field Stripping the Tommy Gun. (Continued)



Removing the Ejector.
Figure 55A. Field Stripping the Tommy Gun. (Continued)

the bolt handle may be removed, the bolt must drop to its lowest position. This is to allow the collar on the bolt handle to clear the receiver.) Remove the bolt handle by pulling it from left to right.

Once this component has been removed, the bolt may be lifted out of the receiver, and the field stripping has been completed.

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To those who have had experience with the older M1928A1, it can be readily seen how the design and disassembly of the newer models has been greatly simplified. For ordinary cleaning it should not be necessary to further disassemble the weapon. The extractor should not be removed for ordinary cleaning or field stripping. To do so subjects it to unnecessary strain, and it is liable to break or become set.

Detail Stripping of Thompson Submachine Gun M1A1

If the weapon is to be further disasssembled, the following steps should be taken.

Removal of Extractor. Insert a screwdriver under the head of the extractor on the face of the bolt, and pull the extractor out and up, to withdraw it from its groove. When disassembling the extractor from, or assembling it to, the bolt, do not lift it higher than necessary for its lug to clear the anchorage hole, or setting or breakage may occur.

Removal of Ejector. The ejector may be removed by lifting the rear end of the leaf sufficiently to disengage its stud. The ejector is now merely unscrewed, counterclockwise, from the receiver. Do not attempt to unscrew the ejector with the bolt assembled and in the forward position in the receiver.

Disassembling the Frame Group. The only tool that is necessary is a screwdriver. With the frame held in the left hand, depress the short finger of the pivot plate assembly with the screwdriver and push out the rocker pivot with the thumb of the left hand. Lift out the rocker and withdraw the pivot. Next, depress the long finger of the pivot plate, and withdraw the safety. In this operation, you will find it necessary to steady your hand be means of your thumb against the frame. This will prevent excessive movement of the rear portion of the pivot plate.

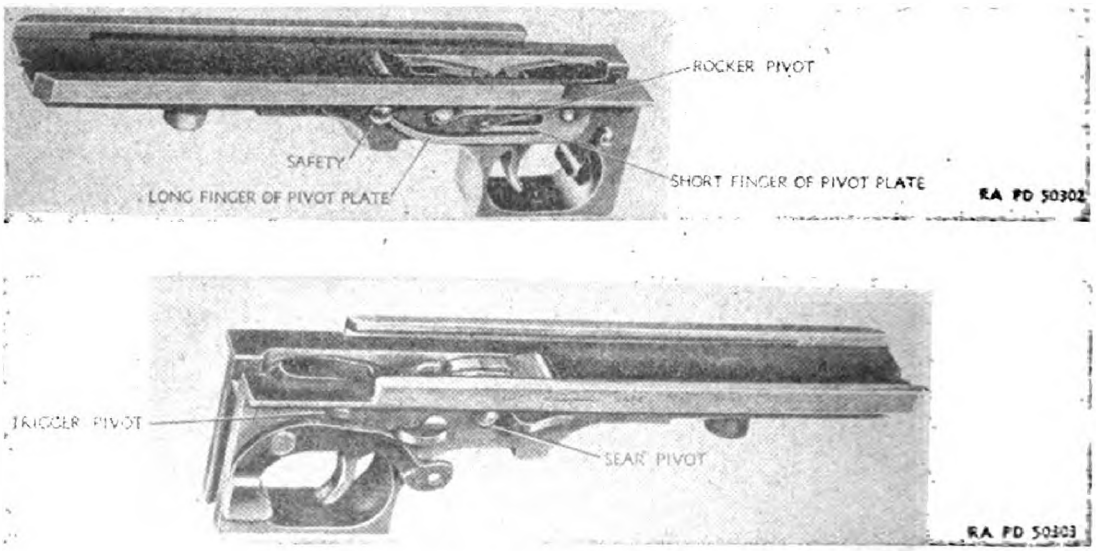

Figure 56. Frame Group. Right Side, Left Side Views.

Holding the frame, with the grip in the right hand, so that it is now upright, press simultaneously with both thumbs on sear and trigger pivots. Both of these pivots project sufficiently, so that a quick pressure thereon will cause the pivot plate to protrude on the right side of the receiver, far enough to permit withdrawal. While withdrawing the pivot plate with the left hand, press down on the trigger and sear with the thumb of the right hand to release pressure of the spring on the pivots. Do not cant the pivot plate during withdrawal. The remaining components, trip, trigger, disconnector, sear lever, and sear can be removed by withdrawing them. The disconnector may be removed from the trigger by simply withdrawing it. Note: The pivot plate assembly should *never* be removed from the frame, prior to the disassembling of the frame group from the barrel and receiver group.

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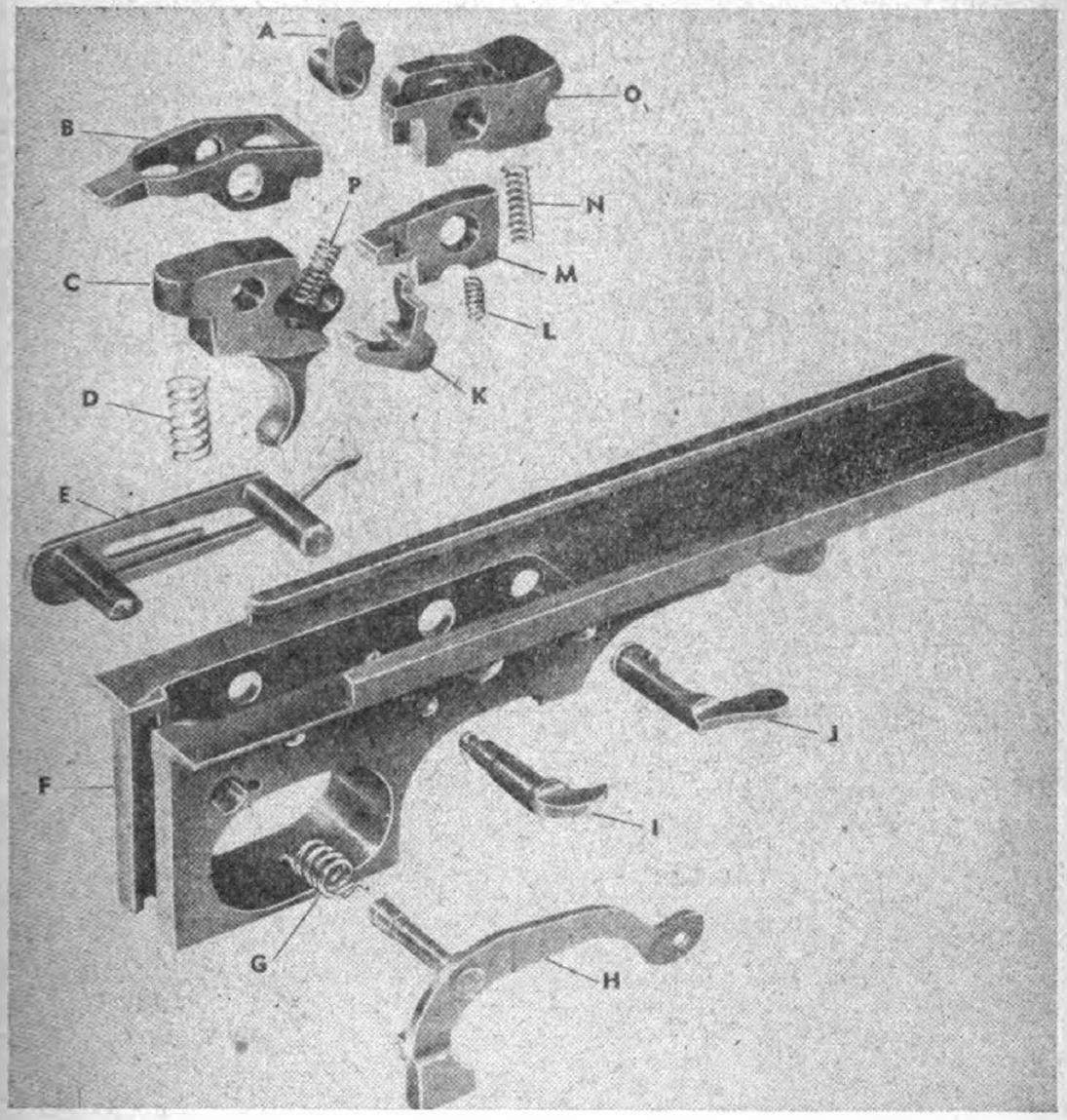
Removal of the Magazine Catch. To remove the magazine catch, rotate it counterclockwise to its full limit and lift it out. The removal of this component should be limited to the replacement of broken parts, since the removal subjects the magazine catch to unnecessary strain and is liable to damage it.



A—Rocker
B—Trip
C—Trigger
D—Trigger Spring
E—Pivot Plate Assembly
F—Frame
G—Magazine Catch Spring
H—Magazine Catch
I—Rocker Pivot
J—Safety
K—Disconnector
L—Sear Lever Spring
M—Sear Lever
N—Sear Spring
O—Sear
P—Disconnector Spring

Figure 57. Frame Group. Exploded View.

Removal of Fore Grip and Frame Latch. Unscrew the fore grip screw and remove the grip. The frame latch and spring are removed by withdrawing it from its recess in the receiver. Note that one end of the spiral frame latch spring is smaller in diameter than the other. Make certain, when replacing these parts, that the smaller end is assembled to the frame latch. The barrel and receiver group is now disassembled.

Removal and Disassembly of the Butt Stock Group and the Rear Grip. It is not necessary to go into any great detail as to the removal and disassembly of these parts from the weapons. All that is necessary is to remove their respec-

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tive screws. Extreme care should be observed, however, when disassembling and assembling these parts so as not to strip the threads or burr the screw-head slots on the screws.

Disassembling the Magazine. Holding either the 20 or 30-round box-type magazine securely in the left hand, slide out the floor plate, holding the fingers of the right hand over the bottom of the magazine tube to prevent the magazine spring from flying out. Carefully withdraw the spring and follower.

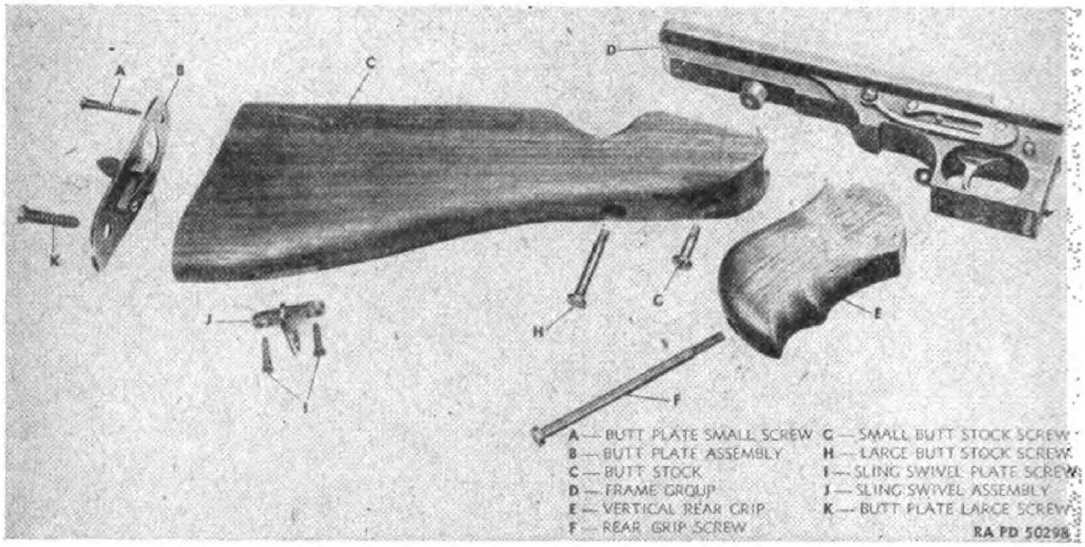

Figure 58. Butt Stock Group. Frame Group and Rear Grip.

Assembly and Replacement of Parts

In practically all small arms, assembly and replacement are in reverse order of disassembly and removal. However it is necessary that the following precautions be observed to insure the efficient operation of the weapon once it has been completely assembled.

Prior to assembly, all parts must be free of dirt, rust, and other foreign matter. Metal parts in contact must be covered with a light film of lubricating oil.

Frame Group. The magazine catch must first be assembled to the frame prior to the replacement of the trigger and sear mechanism. The disconnector must be assembled to the trigger. This is accomplished by depressing the disconnector spring and sliding the disconnector into place.

Place the trigger, trip, sear and sear lever in their respective positions in the frame, making certain that the forward end of the sear lever rests on the tip of the disconnector.

Insert the pivot plate assembly from right to left. To align the trigger and sear mechanism, so as to permit easy insertion of the pivot plate assembly, hold the frame in your left hand and press the trigger and sear downward with your thumbs. To avoid binding, apply gentle pressure with the ball of your right hand over the entire pivot plate.

Insert the safety from left to right as far as it will go. Using the screwdriver, depress the long finger of the pivot plate and push the safety home.

Place the rocker in position in the frame with its flat side against the sear lever. The point on top of the rocker should now be pointing to the rear. Insert the rocker pivot from left to right, as far as it will go. Depress the short finger of the pivot plate with the screw driver, and push the rocker all the way in.

The butt stock and rear grip is screwed directly to the frame group.

Bolt. Slide the extractor into place in the groove (right side of bolt). The head is to be lifted only high enough to clear its stud. Excessive pressure should be avoided.

Barrel and Receiver Group. Screw the ejector back into place, making certain that its stud (rear of leaf) is fully seated in recess provided for it in receiver.

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The small pin portion of the frame latch is securely attached to the small end of the spiral spring and the two are assembled, spring first, into the rear of the receiver.

The fore grip is screwed to the grip mount on the bottom of the barrel.

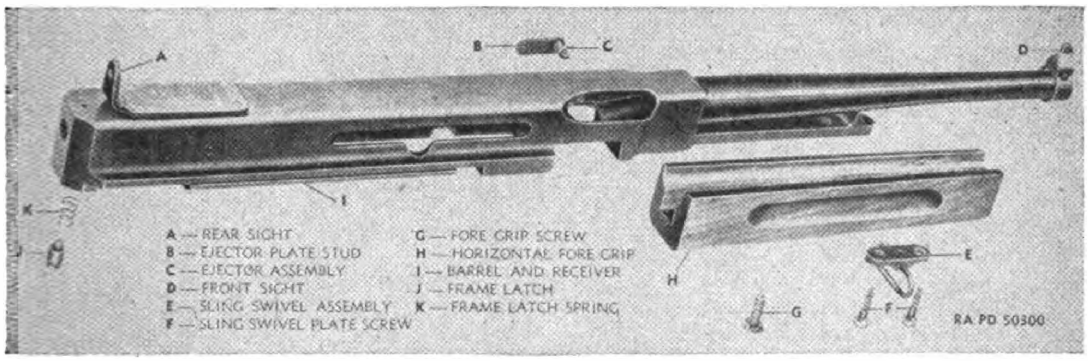

Figure 59. Barrel and Receiver Group.

Complete Reassembly

Bolt. Place the bolt into the receiver and slide it forward. Tilt the rear of the bolt downward until the semicircular cut on the right side of the receiver is aligned with the hole for the bolt handle on the bolt. Insert the bolt handle, making certain that the collar on the handle is fully seated inside of the semicircular cut in the receiver. Slide the bolt all the way forward.

Recoil Spring, Buffer Pilot, and Buffer. When the beginner attempts to reassemble the recoil spring, buffer pilot, and buffer into the weapon, in the reverse order of disassembly, he will invariably have the spring buckle or kink on him. Once again, any individual can after practice become quite adept at it. The main object is to force the buffer pilot down. This compresses the recoil spring without forcing the center to buckle between the rear of the bolt and the receiver and thereby become deformed. This can be accomplished very easily, as follows:

Stand the weapon on a table or your knee, muzzle down and bottom of the receiver facing you. Place the recoil spring and buffer pilot through the hole in the rear of the receiver and into the bolt. With the index finger of your right hand. force the bolt handle up approximately one inch. The other four fingers are placed around the receiver, steadying it.

Now for the tricky part: Place your left hand around that part of the recoil spring and buffer pilot that is protruding above the receiver. Force the top of the pilot down with the thumb of your left hand, remembering to guide the recoil spring and buffer pilot with the remainder of your left hand as you are forcing them into the receiver. When you have forced the buffer pilot down as far as it will go, ease the bolt forward slowly and then insert the buffer in the retaining slot in the buffer pilot. Gradually ease up on the pilot. The barrel and receiver group should now be fully assembled. If the spring becomes kinked at the rear of the bolt, you must start all over again. You will find that the best method is to raise the bolt and hold it in that position, while at the same time you are forcing the buffer pilot and recoil spring down.

Frame Group. Before the frame group is attached to the now fully assembled receiver, be sure that the safety is set at "fire" (pointing forward) and the rocker pivot at "full auto" (pointing forward). Slide frame onto the receiver, and at the same time squeeze the trigger. The frame latch will lock the frame in position. With the frame thus assembled to the receiver, squeeze the trigger and manually operate the bolt handle back and forth several times to test the mechanism.

Functioning of the 'Tommy Gun' M1A1

When G. I. Joe raises the Tommy Gun to his shoulder, squeezes the trigger, and hears the staccato bark of his weapon at the rate of almost 750 rounds per minute, he seldom realizes just what is taking place. For purposes of simplicity, we will divide the operation of the M1A1 tommy gun into six phases, namely:

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1. Loading
2. Firing
3. Extraction
4. Ejection
5. Feeding
6. Cocking

Most weapons of this type can be broken down into eight phases in a complete cycle of operation. However, since this weapon has a straight-blowback type of operation, and does not have a block, the two phases of locking and unlocking are eliminated.

Let us assume that we have a loaded magazine in the weapon. The safety reads "fire" and the rocker pivot is turned to "full-auto." The bolt is in the rear position. We bring the weapon up to our shoulder, get a quick bead on our target, squeeze the trigger, and this is what happens:

(If a tommy gun is available, remove the frame group from the barrel and receiver group. The functioning of the weapon and the operation of the rocker pivot, safety, and trip can then be seen very readily.)

Loading and Firing. As pressure is applied to the trigger, the trigger rotates about its pivot, causing the trigger spring to be compressed. At the same time that this is being done, the rear of the trigger moves upward, thus causing the disconnector to move upward. As the disconnector moves upward it forces the front of the sear lever up. Now, the left front part of the sear is resting on a shoulder of the sear lever. Therefore the front of the sear is also forced upward. Remember, all of this has taken place because of a mere squeeze of the trigger. Since the sear and sear lever rotate about the same axis (sear pivot), it is only natural that the rear of the sear and sear lever are depressed. As they both go down, their respective springs, located underneath the rear of both mechanisms, are compressed. As the rearmost portion of the sear (termed sear nose) is lowered, it becomes disengaged from the sear notch on the bottom of the bolt, and the bolt goes forward, actuated by a highly compressed recoil spring. As the bolt goes forward, its face comes in contact with the base of the top cartridge in the magazine, forcing the cartridge forward. The nose of the bullet comes in contact with the bullet ramp (in the front of the receiver) and is guided toward the chamber. It should be remembered that the magazine is so constructed that the lips of it hold the cartridge almost in a straight line until the cartridge is started into the chamber.

Since the firing pin is of the fixed type, the question may arise at this time as to why the primer of the cartridge is not struck as the bolt moves forward. By looking closely at the front of the bolt, one should be able to understand this easily. Notice that the extractor protrudes slightly beyond the front edge of the bolt. The extractor therefore will keep the firing pin (an integral part of the bolt) away from the primer of the cartridge until the extractor jumps over the rear base of the cartridge and into the extracting groove. When the cartridge case is fully seated in the chamber, the hook of the extractor snaps in the extracting groove. At the moment the firing pin strikes the primer, ignition takes place, and the bullet is on its way to the target. Remember that the piece has actually been fired before the bolt is all the way forward.

Extraction. As the cartridge is fired, the pressure of the powder gases acts against the now empty cartridge case. The expanding gases are thus transmitted through the case to the face of the bolt. The bolt moves rearward, compressing the recoil spring. Since the extractor is holding the cartridge case to the face of the bolt, the case is removed from the chamber.

Ejection. After the bolt has moved rearward approximately two inches, the ejector, which protrudes in a groove on the left side of the bolt, contacts the base of the empty cartridge case, and the case is pivoted upward and out to the right, through the ejection opening in the right side of the receiver.

Feeding. After ejection has taken place, the front of the bolt passes over the base of the top cartridge in the magazine and the cartridge is then forced up to a position in front of the bolt by the magazine follower under tension of the magazine spring.

Cocking. During its rearward movement, the bolt compresses the recoil spring and most of its energy imparted by the chamber pressure is expended, so that the bolt does not strike heavily against the buffer. The buffer absorbs the remaining shock. Once the bolt has struck the buffer, it then goes forward. Since we still have pressure applied to the trigger, the sear nose is in its fully de-

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pressed position. Therefore, it will not engage one of the sear notches on the bottom of the bolt. And now we know that as long as we keep pressure on the trigger the weapon will fire "full auto." Now let us assume that we removed our finger from the trigger. The trigger spring would cause the trigger to return to its original position. Thus the disconnector would be lowered. This, in turn, would remove the support from under the front of the sear lever, causing the front of it to move down and the rear up (actuated by the sear lever spring). We know that the rear of the sear (sear nose) will only stay down as long as the front of it is being held up. Since the shoulder on the sear lever no longer holds the front of the sear up, the sear nose is free to move upward, actuated by the sear spring, and enter one of the two sear notches on the bottom of the bolt, thus holding the bolt in the rear position.

As was mentioned previously, there are two sear notches on the under side of the bolt. If the bolt strikes the buffer, the rear sear notch will pass over the sear and allow the sear to enter the front notch. (NOTE: This occurs as the bolt moves forward in counterrecoil.) Let us assume now that there is insufficient recoil of the bolt to the rear. The bolt in this instance will not move as far to the rear as it did before, and to insure that the bolt will be held in its rearward position when pressure is removed from the trigger, a second sear notch is added to the bolt. Thus, the sear nose will enter the rear sear notch and positively hold the bolt to the rear when you remove your finger from the trigger. If the bolt moves to the rear far enough to eject the empty cartridge case and to feed the next cartridge from the top of the magazine, the bolt will normally be back far enough to have the sear nose enter the rear sear notch.

Now that we have fired several rounds through the weapon automatically, let us turn the rocker pivot to its rear position so that it reads "single." Notice that the rocker moves slightly upward, when the rocker pivot is turned to the rear "single" position. This is due to the rocker pivot being of eccentric design. The reverse is true when the rocker pivot is turned to the forward "full auto" position.

With the rocker pivot reading "single" we squeeze the trigger and the same action takes place with relation to the trigger, disconnector, sear lever and sear. Note, however, that the point of the rocker is now much higher than in automatic fire. Now, as the bolt goes forward, actuated by the compressed recoil spring, the point of the rocker rides in the "T" grooves on the under side of the bolt. When the point of the rocker strikes the rear end of the groove, the rocker is forced forward. The rounded front part of the rocker comes in contact with the disconnector and forces the disconnector out from underneath the front of the sear lever. The rear of the sear and sear lever are then forced up by their respective springs. As the bolt is forced rearward by recoil, and then starts forward again, it will be caught and held by the raised sear nose. As long as pressure is applied to the trigger, the weapon will fire only once, and we call that semi-automatic fire. To fire a second shot, we must first release the trigger and then squeeze it again.

How the Safety Works

When the safety is turned to the forward position, the flat milled surface is in such a position that the sear nose may be depressed, thus allowing the bolt to go forward when the trigger is squeezed.

When the safety is turned toward the rear position so that it reads "safe", the rounded part of the safety engages in a recess in the rear of the sear and prevents the sear nose from becoming depressed.

In the M1928A1 gun, the safety could be turned only when the bolt was in the rearward position. In the newer models, however, the safety may be turned while the bolt is in either the forward or rearward positions. It has been found that when the weapon is dropped on the butt from a height of 18 inches or more, and a loaded magazine is attached to the weapon, the inertia of the bolt is sufficient to move the bolt rearward far enough to pick up a round and fire it. Therefore the tommy gun is not considered safe when a loaded magazine is in place, and the bolt is forward unless the safety is turned to the rear (safe) position.

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How the Trip Works

The trip functions only when the box-type magazine is in use, and only then when the weapon is firing full automatic. The purpose is to cause the bolt to be held in the rear position after the last shot has been fired.

As the magazine is gradually being emptied, a fin on the back of the magazine follower rises upward. When the last cartridge has been removed from the magazine, the fin pushes the front of the trip up; this in turn causes the trip to rotate around the trigger pivot pin. The rear of the trip moves downward, camming the disconnector out from under the front of the sear lever. The sear nose then rises and keeps the bolt from going forward on an empty chamber.

Malfunctions

Proper care of the submachine gun before, during, and after firing will usually eliminate most stoppages. Most malfunctions and stoppages are caused by defective magazines, normal wear and tear of functional parts, unauthorized disassembly of groups and assemblies, lack of proper cleaning and lubrication, and lack of supervised inspection.

If the ejector is broken, or worn excessively, we would have a failure to eject. If the magazine is defective, such as the lips being bent in, or if the magazine is dented (usually due to careless handling), the magazine follower will not completely rise, and the result will be poor feeding. If dirt, grease, and other foreign matter are not removed from the magazine tube assembly, we would have difficulty in feeding. A failure to extract might be caused by an extremely dirty chamber, dirty ammunition, or a broken extractor.

All of the above mentioned malfunctions deal primarily with the phases in a cycle of operation. Other malfunctions may occur such as:

Failure of the weapon to fire semiautomatically. This can be traced to a broken or worn rocker or one which has been assembled incorrectly. If the point of the rocker is not facing to the rear, it will not catch in the "T" groove in the bottom of the bolt and will not therefore actuate the disconnector. Thus the weapon will not fire semiautomatically.

Failure of the loaded magazine to remain in place is usually caused by a broken or worn magazine catch spring.

Failure of the safety to turn from one position to the other may be due to burrs on the safety or rear of the sear.

As a rule of thumb, if any mechanism or component is worn, broken, missing, or assembled improperly, it cannot carry out its specific function, and a malfunction will result. As a result of this malfunction, a stoppage will occur in most cases.

Care and Cleaning

Proper functioning and accuracy of firing in any type of small arms depends to a large degree on proper cleaning and lubrication. In general, all points of preventive maintenance discussed at the close of this chapter can be applied to the tommy gun. In addition, the following points pertain primarily to this weapon.

The following parts should be lubricated with a drop of oil from the oiler, which is carried in the buttstock: Extractor groove on bolt, Magazine catch, Trigger pivot, Disconnector, Sear pivot, Rocker pivot, Dovetail grooves on sides of frame and receiver, Frame latch.

(*Note:* Oil should be applied lightly, because it has a tendency to collect dirt which may act as an abrasive on the operating parts.)

Inspection

In general, all functional and operating parts of any weapon should be checked prior to and after firing. The tommy gun is no exception.

This weapon as a unit should be visually checked. Test the functioning with dummy rounds. There should be no binding or sluggish movement. Check the metal parts for scratches, burrs, rust, or wear and the wooden parts for cracks and nicks.

Barrel and Receiver Group. Inspect the chamber and bore for pits. If the rifling appears to be worn excessively or if the barrel is unserviceably pitted, the

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barrel should be replaced. A bent, cracked, or bulged barrel will also be declared unserviceable. Check the ejector for looseness and wear.

Bolt and Recoil Spring. Examine the bolt surface for rust, roughness, or foreign matter. Inspect the sear notches, edges, corners, and grooves for burrs and wear. Check the recoil spring for kinks, fracture, and lost tension.

Frame Group. The rocker pivot should rotate freely. Point of the rocker should be facing to the rear. Rocker should move upward when the rocker pivot is turned to "full auto". Squeeze the trigger, and force the rocker forward with your finger. The sear nose should then be forced up. Check the safety for smooth operation.

Magazine Catch. Test the function of the magazine catch. It should return to position when pressed and then released. Insert magazine and test catch for retention.

Box Type Magazine. Check the magazine for fit and retention in receiver. Depress the magazine follower and note smoothness of operation and tension of spring. Inspect the magazine tube assembly for dents, cracks, deformed lips and foreign matter. Check the magazine follower for wear, burrs, and the magazine spring for set and fracture.

Technically speaking, we do not employ gages in the inspection of the weapon. We do use trigger weights, however. The minimum trigger pull is 10 lb. and the maximum is 14 lb. for both field and shop.

Accessories

Accessories include the tools required for disassembling, assembling, and cleaning the submachine gun, and the sling, cover, and similar articles.

There are a number of accessories, the names or general characteristics of which indicate their uses or application. Accessories of a special nature or those which have special uses are described below.

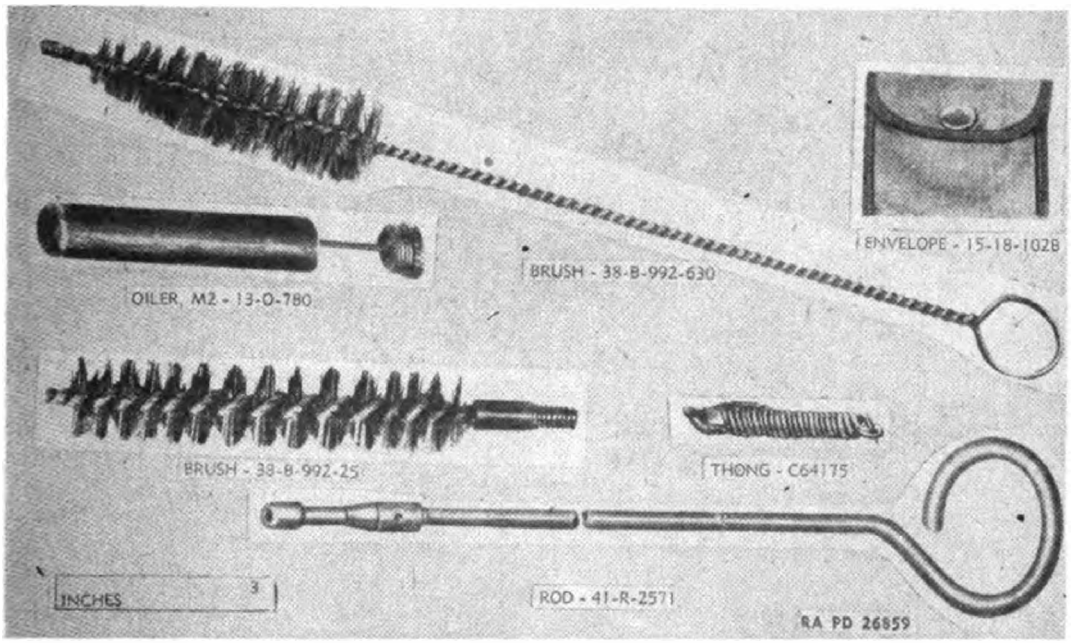

Figure 60. Accessories for Gun, Submachine Cal .45 Thompson M1928A1 M1 and M1A1.

Chamber Cleaning Brush M6. The brush consists of a steel wire core with bristles, the core being twisted in a spiral to hold the bristles in place.

Cleaning Brush, Cal .45 M5. This brush consist of a brass wire core with bristles and tip. The brass tip is threaded for attaching the brush to the cleaning rod.

Accessory and Spare Parts Case M1918. This leather box-shaped case is approximately 3¼ inches wide, 3½ inches high, and 5½ inches long. It is used to carry spare parts and accessories.

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Fabric Envelope. This is an olive-drab cotton envelope used for carrying small tools and accessories.

Oiler M2. This oiler is carried in the butt end of the stock. It is used for lubrication purposes.

Submachine Gun Cleaning Rod. This is a long rod having a circular loop at one end and a cleaning patch slot at the other end. Permanently affixed to the cleaning patch end of the rod is a head having a threaded hole to receive the cleaning brush.

Thong. The thong consists of a tip with cleaning patch slot and a weight tied to the ends of a 30-inch length of cord. It is used in cleaning the bore of a submachine gun if a cleaning rod is not available.

SUB-MACHINE GUN, CAL .45 M3

Now we come to a real 'war baby.' From several theaters of combat came a demand for a light, rugged, and compact automatic weapon, a lot like the British Sten or the German Schmeisser machine pistol. An excellent weapon which would solve the problem was the 'tommy gun.' However, by July 1940 it had become obvious that the production capacity available for this weapon was hopelessly short of meeting the swiftly growing demand. It was also obvious that to materially increase the production of the 'tommy gun' or even a cheaper and simplified model of it would run into time which could ill be spared. The problem boiled down to producing a submachine gun that was compact, rugged, cheap, easy to manufacture, and able to pack plenty of rapid fire punch. The result was the submachine gun cal .45 M3.

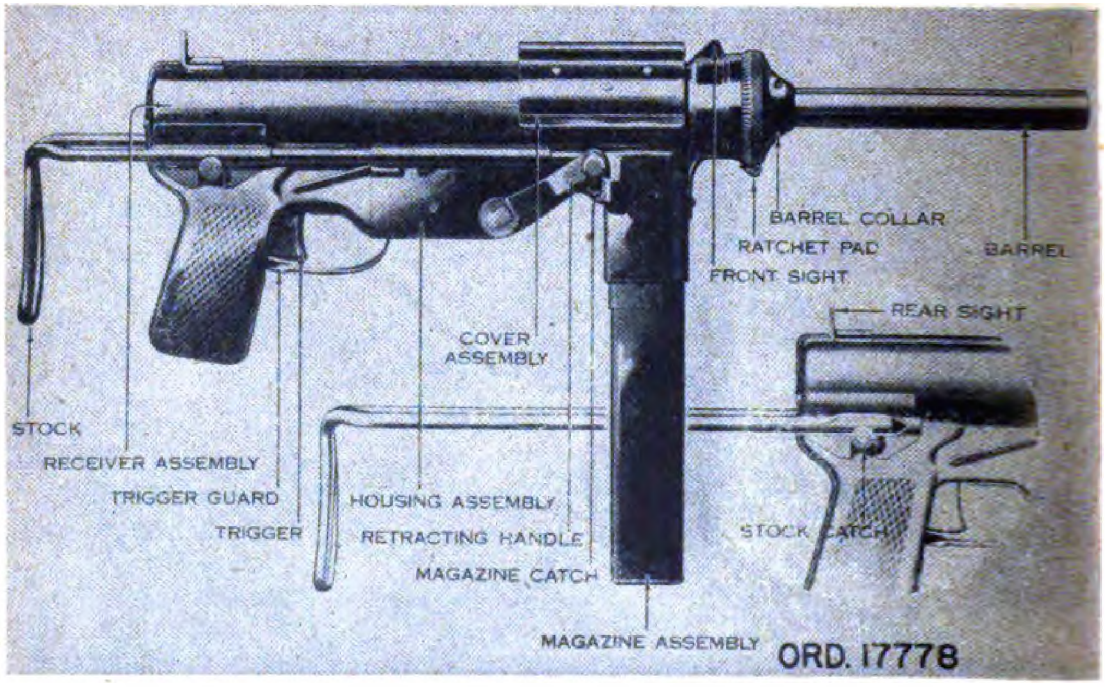

Figure 61. Basic Nomenclature. U. S. Submachine Gun Cal .45 M3.

With the precedent already established by similar American, British, and German weapons, the M3 spent little time on the drawing boards after its conception by Colonel Rene Studler of the Ordnance Department. Less than 10 months after the need was established, the M3 began to roll off the assembly line. It is now the standard submachine gun. It is 22½" closed; 30" open. It is fully automatic (450 rounds per minute); straight blowback operated. Capacity is 30 rounds. Its weight is considerably less than that of the 'tommy gun'—only 7.66 lbs. With complete accessories, such as the sling, magazine, and oiler, it weighs less than 8 lbs. 15 oz. Its effective range is 300 yards.

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American ingenuity and industry came through with one of the strangest looking instruments of destruction yet seen. Its grip and trigger remind us of the water pistols we played with as kids. It has a tubular stock reminiscent of a twisted croquet wicket. Its deceptively powerful recoil spring looks as if it were borrowed from some back screen door.

An excellent feature of the new sub-machine gun is the quick and easy disassembly. It can be almost entirely disassembled without the turning of a screw.

It fires the same hard hitting cartridge as the tommy gun. By quick substitution of a special barrel, bolt, magazine catch, magazine adapter, and magazine, it can shoot the 9mm cartridge of either the British Sten or the German Schmeisser machine pistol. Because of this factor, the using arm has the tremendous advantage of being able to fire captured ammunition in a weapon that they are familiar with.

The M3 is nicely balanced; consequently, the muzzle does not tend to rise when fired.

Field Stripping

Before this or any other weapon is disassembled the chamber should be checked to make certain that it is clear.

Magazine. Press the magazine catch from left to right and remove the magazine. Raise the cover located on the top forward part of the receiver. Pull the retracting handle to the rear slightly, thus withdrawing the bolt a short distance. Check the face of the bolt and chamber for any rounds.

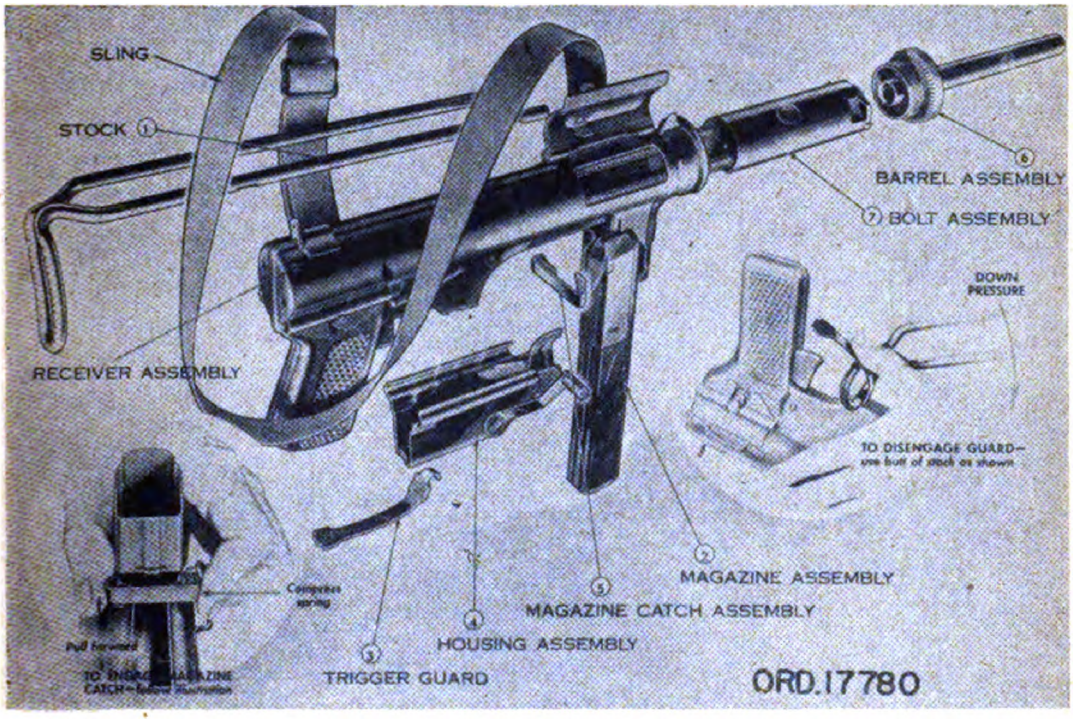

Figure 62. Field Stripping. U. S. Submachine Gun Cal .45 M3.

Stock. Depress the stock catch and withdraw the skeleton stock. Notice that both open ends of the stock are threaded; a cal .45 cleaning brush may be screwed onto it and used to clean the bore.

Trigger Guard. With the weapon held upside down, place the shoulder portion of the stock underneath the front part of the trigger guard and pry it out of the pistol grip. To prevent the rear portion of the trigger guard from jumping and possibly injuring someone, retard its upward movement with your left hand. Once the rear of the trigger guard has been disengaged from the recess in the grip, it may be rotated forward and unhooked from the housing assembly.

Housing Assembly. Pull the rear of the housing up approximately one inch

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and remove it by pulling straight to the rear. *Caution:* Do not use excessive force when exerting pressure upward. If the housing assembly is pulled too far up before its front end is released, the locating slot in the magazine opening will be deformed, causing a binding action on the magazine catch. The housing group must always be removed *before* the bolt and guide rod group is removed and must be assembled *after* the group is assembled to the receiver.*

Barrel Assembly. Spring the ratchet assembly away from the notches in the barrel collar and unscrew the barrel assembly counterclockwise from the front.

Bolt and Guide Rod Group. Tip the front of the weapon down and the bolt and guide rod group will slide out of the receiver.

Magazine Catch Assembly. Slide the left side of the magazine catch assembly toward the rear until the magazine catch spring slips off the receiver, then unhook the magazine catch from the right side of the receiver.

Trigger and Sear Group. Remove the trigger pin from the receiver. If any difficulty is encountered, use the trigger guard to pry it from the recesses. Remove the sear pin, using one end of the trigger pin as a punch if necessary. Turn the gun upside down and then right it; the trigger and sear group should drop out of the large opening in the bottom of the receiver.

Disassembly of Groups and Assemblies

Magazine. Slide the magazine base to the rear, being careful to prevent the magazine spring from flying out. Withdraw the magazine spring. The follower will fall out if the magazine is turned over.

Housing Assembly and Barrel Assembly. The housing assembly should not be disassembled except for replacement of parts and must be done under the supervision of ordnance personnel. The barrel assembly is not to be further disassembled.

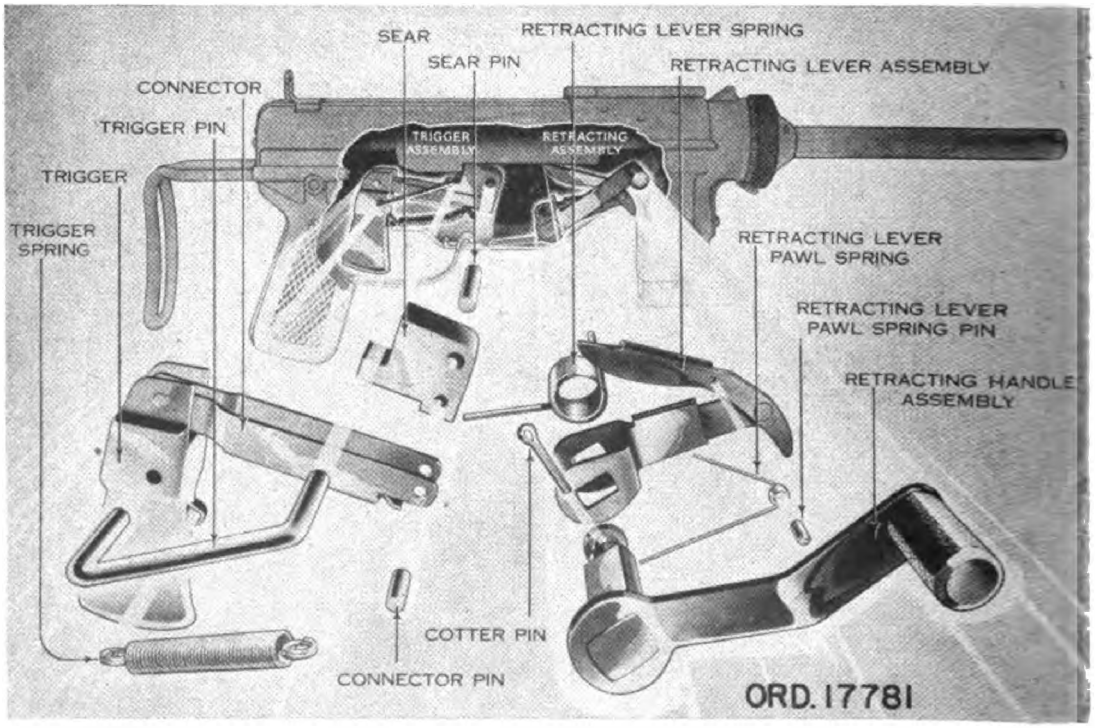

Figure 63. Trigger and Retracting Assemblies. U. S. Submachine Gun Cal .45 M3.

Bolt and Guide Rod Group. Placing the rear of the guide rod retaining plate against your knee (or a table if available), retract the bolt slightly against the pressure of the driving spring. Remove the guide rod retaining clip, the guide

* If this is not done, the ejector will be deformed and rendered useless, and the retracting lever pawl spring will be bent if the pawl is forced beyond its normal open position. A bent pawl spring will cause a binding action.

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rod locating plate, the bolt assembly, and the two driving springs from the guide rod assembly. The bolt assembly should not be disassembled except to replace defective parts. The guide rod assembly is not to be disassembled.

Trigger and Sear Group. The sear may be removed by merely punching out the connector pin. The trigger spring can now be unhooked from the trigger and sear connector.

Receiver Assembly. The stock catch may be removed by drifting out the stock catch sleeve retaining pin. By supporting the stock catch sleeve on a block, you can keep it from bending. After the pin has been driven out, the stock catch sleeve is released from the stock catch. The stock catch and spring may now be removed from the left side of the receiver. The cover assembly may be removed by driving the cover pin to the rear and out.

Assembly and Replacement of Parts

The following precautions and steps are necessary during assembly for the efficient and reliable functioning of the weapon.

Cover Assembly. After the cover assembly and pin have been assembled to the receiver, the cover hinge should be staked in the groove in the cover pin to hold it in place.

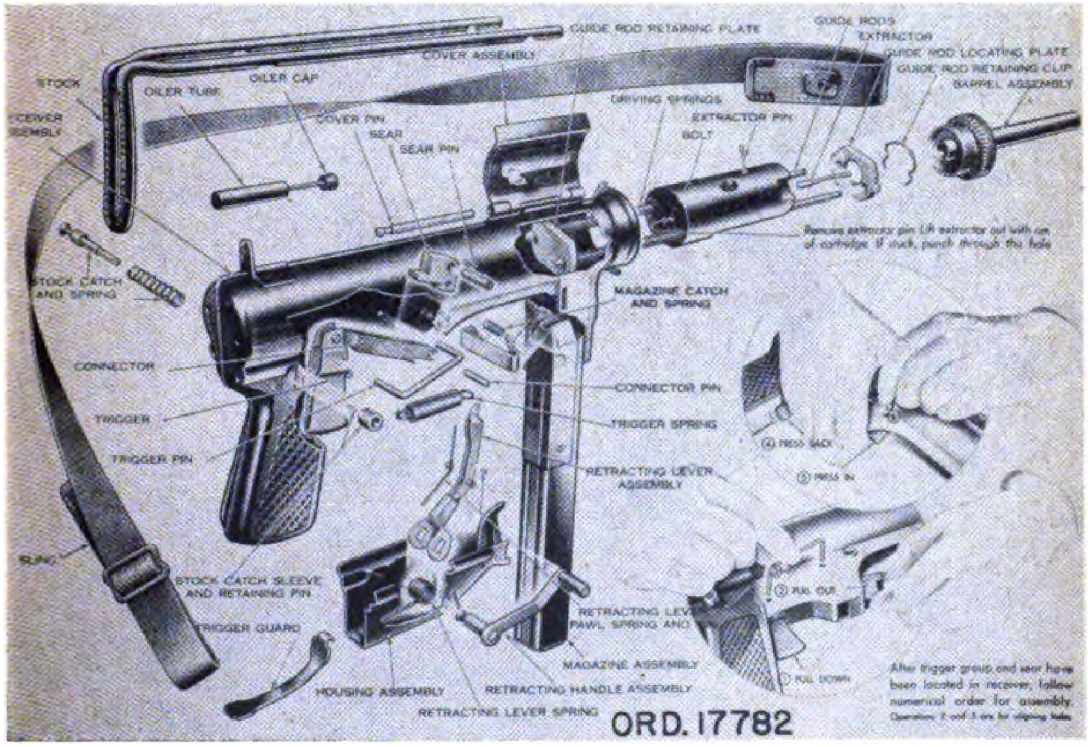

Figure 64. Detail Stripping. U. S. Submachine Gun Cal .45 M3.

Stock Catch and Spring. Once the stock catch and spring have been assembled, the stock catch sleeve retaining pin should be riveted on both ends to keep it in place.

Bolt and Guide Rod Group. Assemble the two driving springs to the guide rods and insert both guide rods into their recesses in the rear of the bolt. Pull the bolt back slightly and attach the guide rod locating plate and the guide rod retaining clip. The clip may be put on from the top or bottom of the locating plate. It should be remembered that prior to assembly or replacement all the parts must be free of dirt, rust, grease, and other foreign matter. Metal parts in contact must be lightly lubricated.

Trigger and Sear Group. After the sear has been assembled to the sear connector by the connector pin, and the two ends of the trigger spring hooked on

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to their respective projections on the trigger and sear connector, the group may be assembled to the receiver. The following steps are not difficult. With the receiver held upside down, drop the trigger and sear into the large opening in the bottom. Tip the receiver to the rear and then to the right to allow the trigger to fall into its recess in front of the pistol grip. Line up the trigger pin hole by pulling the sear forward and moving the trigger up and down. Replace the trigger pin. The sear can be lined up with its pin by squeezing the trigger to the rear and pressing the sear upward at the same time. As soon as the hole in the sear comes in line with the hole in the receiver, insert the sear pin.

Magazine Catch Assembly. Place the coil of the magazine catch over the magazine catch spring guide. Press the spring end against the left side of the receiver with the thumb of your right hand, at the same time guiding the hooked end with the forefinger of the same hand until this hooked end clears the right side of the receiver. The hooked end is then guided into the notch on the right side of the receiver and pressed upward into position.

Receiver Group. With the cover in the raised position, slide the bolt and guide rod group into the receiver. *(Note:* When properly assembled the bolt should be toward the front with the grooved section on the bottom.)

Barrel Assembly. The barrel assembly is screwed clockwise into the front of the receiver and tightened firmly into place. Close the cover on the top of the receiver.

Housing Assembly. Locate the projection of the front of the housing assembly in the notch in the magazine opening of the receiver, and then press the rear of the housing assembly down into place, being careful not to bend the ejector. *(Note:* Undue force should *never* be used in assembly or disassembly, as it might weaken or break a part and thus cause a malfunction.)

Trigger Guard. With the weapon held upside down, insert the hooked end (front part) of the trigger guard into the slot in the housing. Rotate the trigger guard to the rear and snap the rear of it into the slot in the pistol grip. To make this extremely easy, take the shoulder rest part of the stock and force the rear of the trigger guard down and into place.

Stock. Insert the two ends of the stock into the holes in the rear of the receiver and slide it forward. The stock catch must be pressed from left to right to allow the stock to go fully forward.

Magazine. Slide the follower into the magazine body. Carefully press the magazine spring up into the magazine body. Holding it in place, slide the magazine back into the grooves of the body to retain the powerful spring. The weapon and magazine have now been completely assembled.

Functioning of the Submachine Gun M3

In modern combat, functioning of a weapon, whether it be a pistol, rifle, submachine gun, or machine gun, cannot be over-emphasized. With the knowledge of functioning comes the basic principles of why and how malfunctions and stoppages occur.

It is of paramount importance that each individual know the steps to be taken in case the weapon should not function properly.

With this thought in mind, let us see exactly what happens when we insert a loaded magazine into the weapon. Extend the stock by pulling it sharply to the rear. Raise the cover and cock the weapon by rotating the retracting handle to the rear and then releasing it. The weapon is raised to the shoulder, the front sight is centered squarely in the rear sight, and the trigger is squeezed. *(Note:* If an M3 submachine gun is available remove the trigger, sear connector, and sear. The functioning of these parts can then be readily seen.)

Loading and Firing. Since the trigger is pivoted near the top, the top will move forward as the bottom is squeezed to the rear. The sear connector (which is assembled to the top of the trigger) is forced forward causing the bottom portion of the sear to move forward. The sear rotates about the sear pin and the rear end (sear nose) becomes depressed.

As the sear nose becomes disengaged from the sear notch on the underside of the bolt, the bolt moves forward because of the two highly compressed driving springs.

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As the bolt moves forward, the feed ribs on the bottom of the bolt pass between the lips of the magazine, stripping a round from the magazine and forcing it forward. The beveled edges of the opening in the center of the guide rod locating plate and the rear end of the barrel guide the nose of the cartridge into the chamber.

As the cartridge moves into the chamber, the rear end of the cartridge rises until it is opposite the recessed cartridge seat in the face of the bolt. The extractor then forces the cartridge into the chamber until fully seated. When the cartridge is fully seated, it overcomes the spring tension of the extractor, causing it to cam outward and into the extracting groove. At the same time, the fixed firing pin (an integral part of the bolt) strikes the primer, igniting the cartridge.

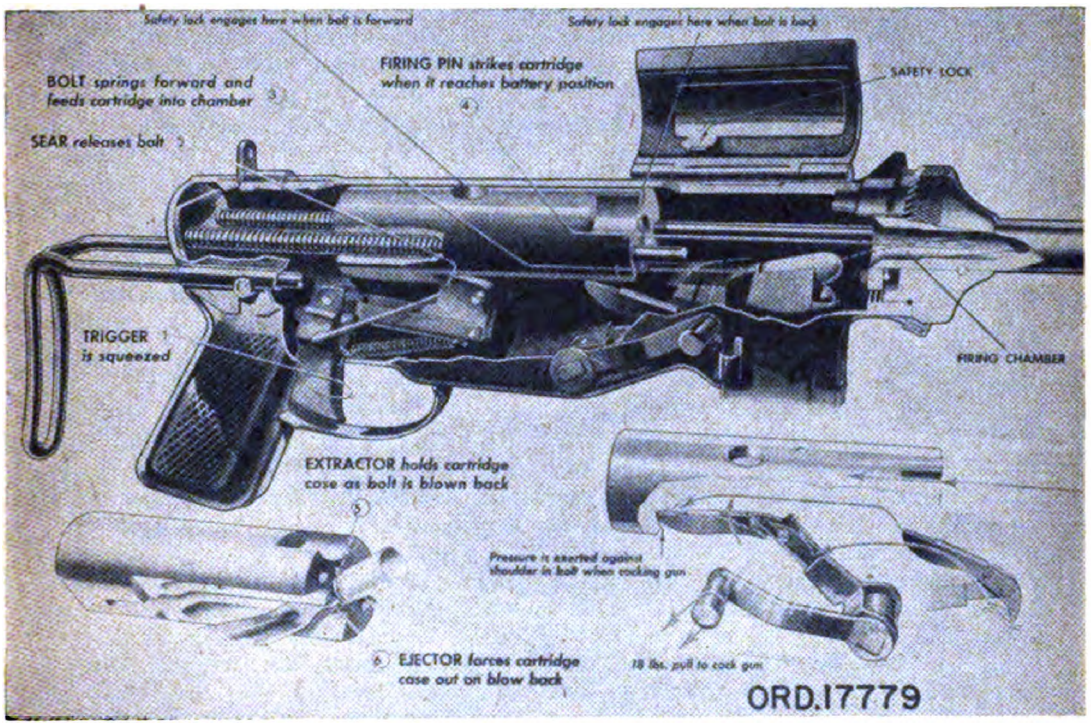

Figure 65. Basic Functioning. U. S. Submachine Gun Cal .45 M3.

Extraction and Ejection. The resistance of the forward movement and the tension of the two driving springs tend to delay the overcoming of the inertia of the moving parts until the bullet has left the muzzle and the chamber pressure has subsided to a safe degree. It must be remembered that, although the piece fires before the bolt is all the way forward, the cartridge is fully chambered.

As the bolt moves rearward due to the pressure which is exerted on the face of the bolt by the cartridge case, the extractor, which is engaged in the extracting groove of the cartridge, removes the now empty cartridge case from the chamber. The cartridge case continues to the rear, being held by the extractor until the ejector, a part of the housing assembly, strikes the rear base of the empty cartridge case and causes it to pivot around the extractor and out through the ejection opening. As long as the trigger is held to the rear, the weapon will fire automatically. Its cyclic rate of fire is approximately 450 rounds per minute which is much slower than that of the tommy gun. This slower rate of fire is an advantage rather than a handicap. Once an individual gets the feel of the M3 submachine gun, he can release his finger from the trigger fast enough to get semiautomatic fire. This does away with the necessity of having to turn a lever to control the type of fire.

Feeding. As the bolt moved rearward because of the blowback action of the gases after firing, the underside of the bolt cleared the lips of the magazine.

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The compressed magazine spring then pushes the follower up, which in turn pushes the next cartridge up into the path of the bolt.

Cocking. When pressure is released from the trigger, the trigger spring tends to return the trigger to its original position. At the same time, the sear connector is moved rearward, causing the sear to rotate on the sear pin. The front of the sear goes down, and the rear (sear nose) goes up to enter the notch on the bottom of the bolt, thereby causing the piece to be cocked. It should be remembered that this weapon fires with the bolt open, as do the other two models of the tommy gun.

How the Retracting Lever Works. The normal position of the retracting lever is forward and disengaged from the bolt. When the retracting lever is rotated rearward, the rear of the retracting lever pawl contacts the rear end of the elongated groove on the underside of the bolt and pushes it to the rear. After the bolt has been brought all the way to the rear, the retracting lever spring will return the retracting lever to its forward position once the pressure is removed from the lever.

How the Safety Works. The cover assembly has a two-fold purpose. In addition to preventing dirt, grease, or other foreign matter from entering the receiver through the ejection opening, it acts as a safety.

When the bolt is in the rear position and the cover assembly is lowered, the safety lock (a lug on the inside of the cover) pushes the bolt back slightly. This in turn cams the sear notch on the underside of the bolt rearward and away from the sear nose. Thus the lock on the cover is holding the bolt in its rearward position.

There is a circular recess on the top of the bolt just opposite the safety lock on the cover that permits the cover to be lowered while the bolt is forward, thus locking it in that position.

How to Load the Magazine. Normally, most magazines can be loaded merely by pressing the cartridges into place, but since we have a strong magazine spring and the magazine itself is different in design, we can facilitate the loading with the use of the hand loader (manual magazine filler). Use the hand loader in the following manner:

Slide the hand loader over the top of the magazine with the hook to the rear. With the thumb of your left hand force the hook portion down. Insert a cartridge into the magazine until its base contacts the loader. Raise the loader until it clears the cartridge and push the cartridge to the rear. Press the loader down on the first cartridge and insert a second one. Continue this procedure until thirty cartridges are loaded into the magazine. *(Note:* Normally there will not be enough room for a thirty-first cartridge. To check this and to insure proper clearance for the bolt, press the last cartridge down until it is about ⅛ inch below the lips of the magazine. If the last cartridge cannot be pressed down far enough, it should be removed, as it will be the thirty-first cartridge. The gun will function properly with the extra round in the magazine provided the weapon is cocked before inserting the magazine).

If a hand loader is not available, the magazine can be loaded in the following manner:

Holding the magazine in the left hand with the curved, open end up; insert the base of the cartridge in the opening on top of the magazine and press it down against the follower with the thumb. Force the cartridge below the lips of the magazine. Push the cartridge beneath the lips until the base of the cartridge contacts the rear of the magazine body. Continue this procedure until you have loaded thirty rounds. Check for a thirty-first cartridge as explained previously. *Caution:* Make certain when loading the magazine that the magazine is held so that the cartridges are pointed away from the operator. *(Note:* Magazines of the M3 submachine gun and the 'tommy gun' are not interchangeable.)

Malfunctions

Proper and intelligent care of any weapon before, during, and after firing will in most cases greatly reduce the number of malfunctions and stoppages. The M3 submachine gun does not need more than the usual amount of care afforded any small arm; however, malfunctions will occasionally occur. Those which

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cannot be remedied by the application of immediate action should be dealt with according to the following steps:

Failure to Fire, Bolt Fully Closed.

Cause. 1. Defective ammunition;
2. Defective firing pin;
3. Barrel assembly loose on gun.

Corrective Action. If the primer of the round is deeply indented, discard the round as this indicates that the round is defective. If the primer is not indented or only slightly indented, the barrel assembly may be loose on the weapon, or the firing pin may be worn or broken. Either tighten the barrel or replace the bolt.

Failure to Eject, Bolt Jams Against the Empty Cartridge Case.

Cause. 1. Bent, worn, or broken ejector;
2. Cover partly closed.

Corrective Action. If the ejector is bent so that it is not well centered in the notch in the bolt, straighten it. If it is worn or broken, replace the housing assembly. If the cover is partly closed, thus preventing the empty cartridge cases from being ejected through the opening, open it fully.

Failure to Feed.

Cause. 1. Defective magazine;
2. Magazine not fully home;
3. Dirty magazine.

Corrective Action. If the magazine is defective, such as the lips being bent causing an improper location of the top cartridge, it should be replaced. A distorted magazine spring will also cause trouble. If the magazine is not fully home either the receiver or the magazine is dented. If the receiver is dented, the weapon must be repaired. All defective magazines should be replaced and dirty ones should be cleaned and lubricated.

Failure to Cock Manually.

Cause. 1. Retracting lever pawl spring bent or broken;
2. Retracting lever assembly bent or broken.

Corrective Action. If the retracting lever pawl does not hinge upward freely by the pressure of the retracting lever pawl spring when the handle is operated, the retracting lever with bracket assembly will jam against the bolt, and the bolt will not be moved rearward to its cocked position. If the retracting lever pawl spring is bent, replace it. If the retracting lever binds on the retracting lever with bracket assembly, replace the retracting lever assembly.

Bolt Fails to be Engaged by Sear.

Cause. 1. Sear nose badly worn;
2. Notch on underside of bolt badly worn;
3. Trigger spring broken;
4. Trigger and sear extremely dirty.

Corrective Action. If the sear or bolt are bady worn, replace them. Replace the trigger spring if it is defective. If the trigger and sear group is extremely dirty causing a binding action, thoroughly clean and lubricate the group.

Firing Speed Erratic.

Cause. 1. Excessive oil in magazine or chamber, or on face of bolt;
2. Broken or bent driving springs;
3. Bent guide rods;
4. Dirty weapon;
5. Bolt binding on ejector or receiver;
6. Burrs on sear and bolt.

Corrective Action. Excess oil gets on the cartridge and ignites during firing. This results in erratic firing by increasing the rearward pressure on the bolt and causing carbon to deposit rapidly in the barrel and on the moving parts of the weapon. Excess oil should be removed. Replace the two driving springs if they bind on the guide rods, or if they are broken. If the binding of the bolt on the guide rods, the ejector, the sear, or the receiver is caused by a dirty gun, thoroughly clean and lubricate the weapon. If the guide rods are bent, replace the assembly. If the bolt binds on the ejector, straighten the ejector. If the bolt binds on the receiver, the receiver should be turned in to ordnance

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maintenance for repair. If the binding action is caused by burrs on the sear or bolt, remove the burrs with a fine stone. *(Note:* Due to the design of the weapon, firing upward is slower than normal and firing downward is more rapid than normal.)

Care and Cleaning

Almost as important as his ammunition is the soldier's confidence in his weapon. A weapon in modern combat must be able to shoot straight and function properly in any climate. Efficient and complete functioning and accuracy in firing depend on the proper and intelligent care, cleaning, and lubrication an individual gives his weapon. This cannot be over-emphasized and is of equal importance whether it be in garrison, in camp, on the range, or in the combat zone.

It is not necessary to go into detail as to the proper methods of cleaning and lubrication, as it is covered quite thoroughly at the end of this chapter. It is important, however, that certain points pertinent to this weapon be mentioned. Before firing, the following instructions should be followed:

Do not oil the bore and chamber before firing as dangerous pressures may develop.

The following parts should be lubricated lightly with a drop from the oiler rod: *(Note:* This submachine gun carries the same oiler that is carried in the stock of the carbine.) retracting level pawl pin, retracting lever pivot, guide rods, stock catch, trigger pin, sear pin, connector pin, connector rivet.

Inspection

The primary purposes of inspection are to determine the condition of the weapon, whether or not repairs or adjustments are required, and the correct action necessary to insure serviceability and proper functioning.

An inspection is often broken down into two phases: Visual and Gaging.

Technically we do not employ gages to check this weapon. We do use trigger weights, however, to check the trigger-pull. It must be between 5 and 7 pounds for both shop and field. A 5-pound pull should not cause the bolt to go forward, but a 7-pound pull should. If the bolt goes forward when the 5-pound trigger weights are used, the trigger pull is too light. If the bolt does not go forward when the 7-pound weights are used, the trigger pull is too heavy.

Visual Inspection of M3 Submachine Gun When Fully Assembled. With an empty magazine in place, cock the gun rapidly and squeeze the trigger to release the bolt. Repeat several times. During this operation check the following points:

Bolt must slide freely on the guide rods.

Retracting mechanism must function smoothly.

Trigger mechanism must function smoothly.

With the weapon cocked, close the cover. The safety lug on the underside of the cover should force the bolt back slightly to remove it from the sear nose, thereby causing the trigger to become effective.

When the bolt is retracted, the sear nose must snap sharply into engagement with the bolt.

With the bolt only partly retracted, the ejector should be examined through the ejection port to see if it is properly aligned with the slot in the bolt.

The stock must be securely latched in both its extended and collapsed positions. A sharp pull on the stock must release it from its collapsed position, but the stock must be locked positively in its extended position. The stock catch should release the stock.

The magazine catch must hold the magazine positively, but pressure on the magazine catch must release the magazine.

The magazine must fit loosely in the magazine opening so that it will fall out when the catch is pressed. The magazine should be clean, and its lips must not be deformed. The magazine follower must move freely inside the magazine body.

The front and rear sights must not be bent or damaged.

Visual Inspection of M3 Submachine Gun When Disassembled. The weapon should be field-stripped and the following parts inspected:

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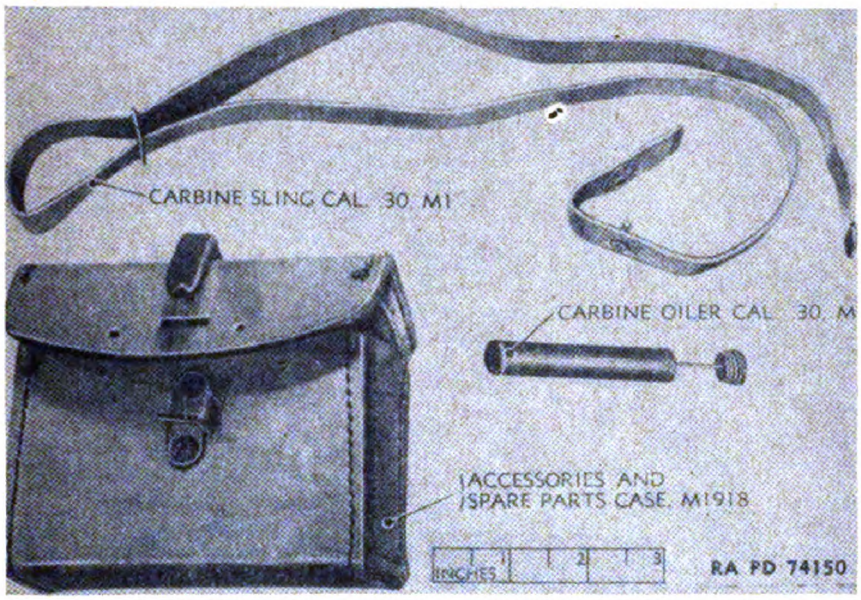
Housing Assembly. When the retracting handle is operated, the retracting lever pawl should hinge upward freely from the pressure of the retracting lever pawl spring. Make certain that the pawl has been lowered to its normal position prior to the replacement of the housing assembly. Check the ejector for wear, breaks, or deformation.

Barrel Assembly. Hold the barrel up to the light and check the chamber and bore for wear, pits, or bulges. A piece of white paper or a cleaning patch will



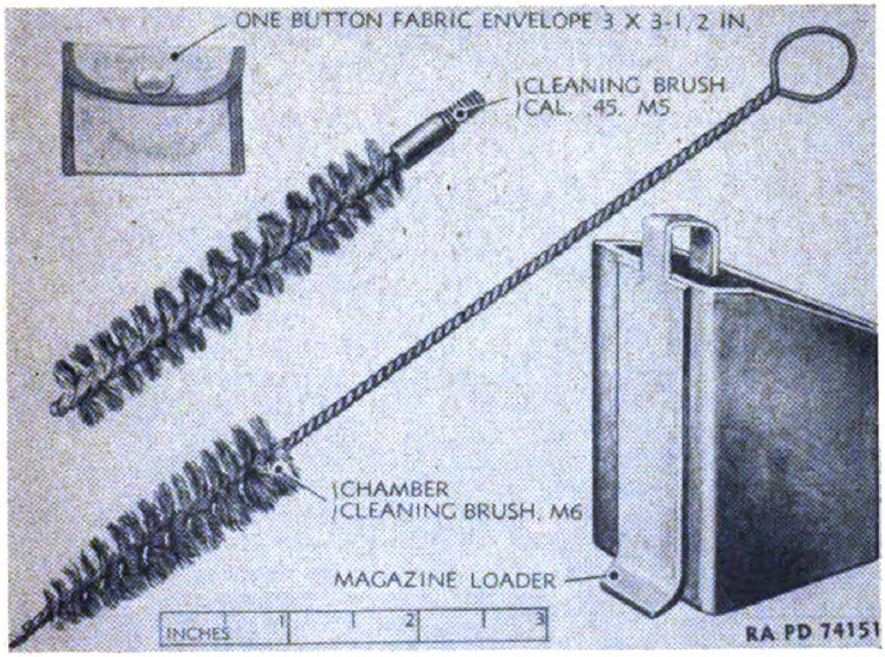


Figure 66. Accessories for Submachine Gun Cal .45 M3.

facilitate the inspection by reflecting light into the bore. Turn the barrel slowly so that the light follows the circumference of the bore.

Bolt and Guide Rod Group. The bolt should move back and forth smoothly without binding. The two driving springs must not be deformed or broken.

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The extractor should be checked for wear or breaks. The sear notch on the underside of the bolt must be free of burrs, wear, etc.

All surfaces, springs, and recesses should be clean, free of any rust preventive compound, and lightly lubricated.

Accessories

There are a number of accessories, the names of which indicate their uses. Others, embodying special features or having special uses, are described below.

Accessories and Spare Parts Case, M1918. This case is constructed of russet strap leather and is used for carrying spare parts.

Carbine Oiler, Cal .30 M1. This oiler is tubular in shape and has an over-all length of 2½ inches. When not in use it is attached to a clip on the left side of the housing assembly.

Carbine Sling, Cal. .30, M1. This is an olive-drab cotton webbing strap with buckle, fasteners, and tips, used to facilitate carrying the weapon.

THE BROWNING AUTOMATIC RIFLE

During the development of the machine gun, it became evident that a light machine or automatic rifle was necessary to fill the gap between the machine gun and the rifle. The machine gun had heavy fire power but was not very mobile. The rifle was mobile but lacked fire power.

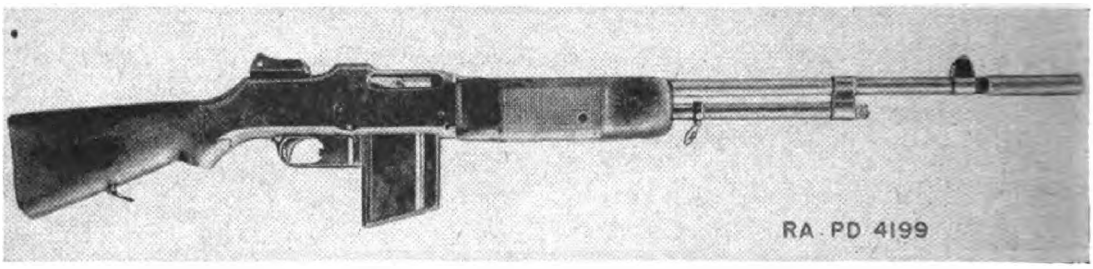

Figure 67. Browning Automatic Rifle Cal .30 M1918. Right Side View.

This brought about the development of an automatic or machine rifle; a weapon which weighed about twenty pounds, could fire fifteen or twenty round bursts but did not require a stationary mount. This type of weapon could be moved rapidly to where it would do the most good and its burst of automatic fire would have the desired effect. Also, by rapid movement the gunner could change his position frequently for greater protection.

At the time of World War I the United States Army did not have an automatic rifle that was designed in the United States. Our forces used several types designed by other countries, the most common being the Benet-Mercie automatic machine rifle and the Chauchat automatic machine rifle, both of French origin. Both were serviceable weapons but could not be supplied in sufficient quantity.

In May 1917, John M. Browning submitted two machine guns for competitive tests. One was the Browning heavy watercooled machine gun and the other was the Browning machine rifle. Both were adopted by the Army and the rifle became known as the Browning Automatic Rifle Cal .30 M1918. By the end of the war the Browning automatic rifle had proved its worth.

Later development of the weapon brought about a number of changes. It is now known as the Browning Automatic Rifle Cal .30 M1918A2.

Description and Differences Between the Various Models

Browning Automatic Rifle, Cal .30 M1918. The M1918 is a gas operated magazine-fed, air-cooled weapon. It delivers semiautomatic and automatic fire controlled by the operator. It has a smooth, slightly tapered barrel with a tubular flash hider screwed to the muzzle. The forearm is large and the stock is smooth with a butt plate similar to the M1917 rifle. The butt swivel is half way be-

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tween the grip and the toe of the stock. It weighs 16 pounds. The M1918 is now limited standard.

Browning Automatic Rifle, Cal .30 M1918A1. The M1918A1 has the same barrel and stock as the M1918, with the same location of the butt swivel. The butt plate is hinged at its heel, mounting an outer butt plate of full length. A bipod with spiked feet is attached to the gas cylinder tube just forward of the forearm. The gas cylinder has been changed, the new one having a pressure relief vent in the head and a larger diameter. The forearm is shorter and cut away from the barrel. The swivel link was removed from both the M1918 and M1918A1. the total weight is 18.5 pounds. It is limited standard.

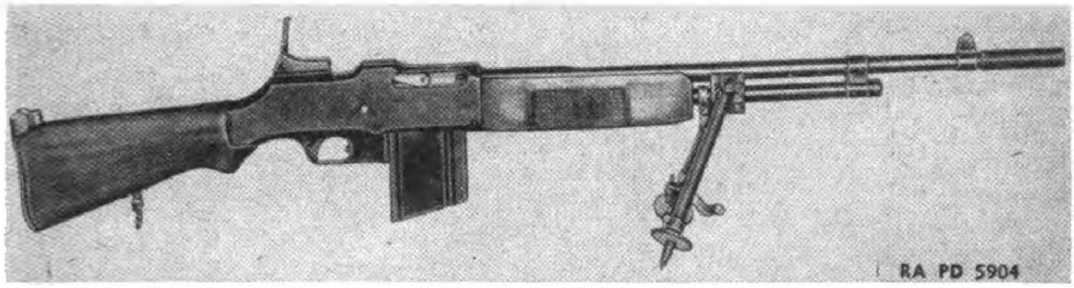

Figure 68. Browning Automatic Rifle Cal .30 M1918A1. Right Side View.

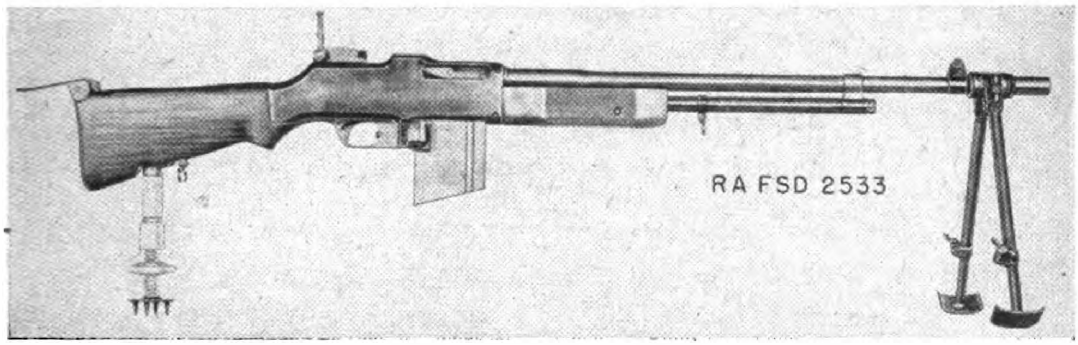

Figure 69. Browning Automatic Rifle Cal .30 M1918A2.

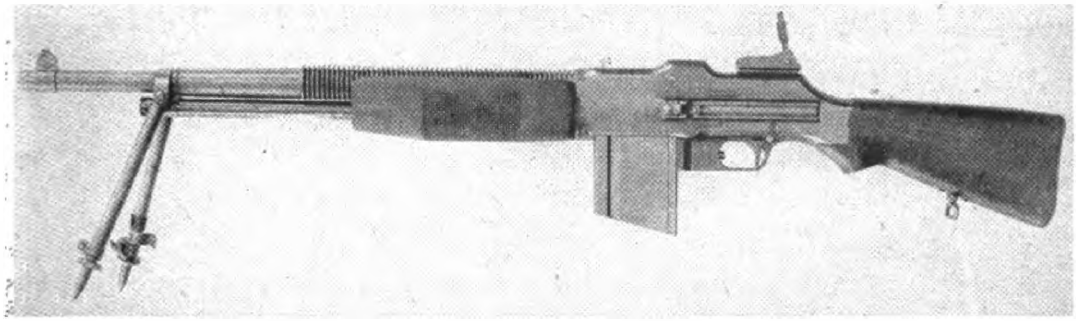

Figure 70. Browning Machine Rifle Cal .30 M1922.

Browning Automatic Rifle, Cal .30 M1918A2. The 1918A2 may use the same barrel as the M1918 and M1918A1. The forearm is cut away even more and a metal shield was added to protect the recoil spring from heat. A bipod with skid type shoes is assembled to the flash hider. The stock rest is mounted in a recess in the butt stock. The outer plate of the hinged butt plate mounting is the same as the M1918A1, except that it is shorter. The cyclic mechanism is housed in the buffer and butt stock assembly. The stock is cut away to fit the cheek. The rear sight is changed to include click mechanisms for both windage and elevation. Magazine guides have been added to the trigger guard. The flash hider has been

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changed to include a bearing for the bipod. The total weight is 19.4 pounds. This is the standard automatic rifle.

The M1922 has a finned barrel about 1½ inches in diameter at the receiver. The butt swivel is secured to the left cheek of the stock. There is a wide groove around the stock to the rear of the comb in which a stock rest may be fitted. This stock rest, and a bipod which may be clamped around the barrel just forward of the forearm, are listed in SNL A-18 as accessories. This type of rifle is now obsolete and no further reference will be made to it.

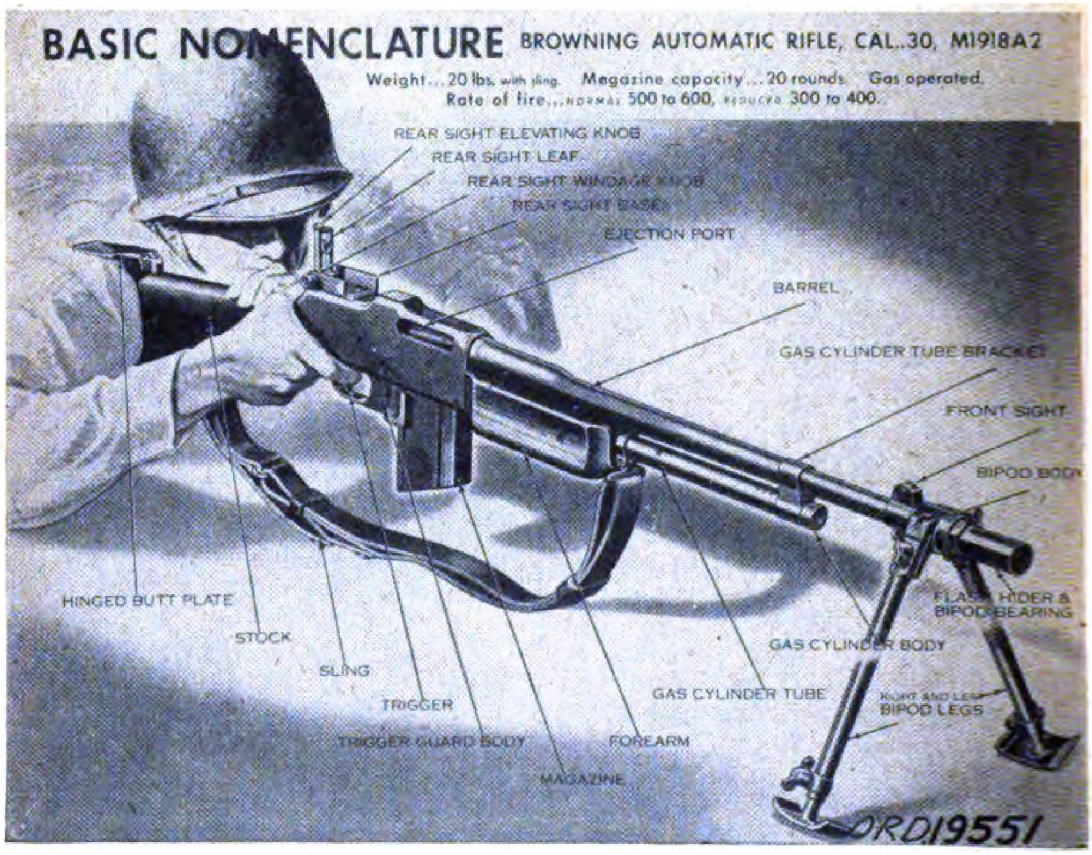

Figure 71. Basic Nomenclature Browning Automatic Rifle Cal .30 M1918A2.

Field Stripping

This is the authorized disassembly of the weapon by the soldier for proper care and maintenance:

Flash Hider. Unscrew flash hider and remove bipod assembly and friction washer. Remove stock rest by pulling it out of the bearing.

Gas Cylinder Tube and Forearm. Lay rifle on table, barrel down, pointing to left. Cock the rifle. This must be done in order that the gas cylinder tube may clear the gas piston and the female gas cylinder tube bracket. Turn gas cylinder tube retaining pin spring 180° in a clockwise direction and lift out gas cylinder tube retaining pin. Remove gas cylinder tube and forearm by sliding forward. Let the slide forward easily by pressing trigger with thumb of right hand and, at the same time, grasping slide with left hand so middle and index fingers are astride gas piston.

Trigger Guard Group and Recoil Spring. Turn trigger guard retaining pin spring 90° in a clockwise direction and lift out pin. Lift out trigger guard group. Remove recoil spring guide by pressing right index finger on knurled surface of head and turning until ends are clear of retaining shoulders. Remove recoil spring.

Operating Handle, Hammer Pin and Slide. Line up hammer pin holes on re-

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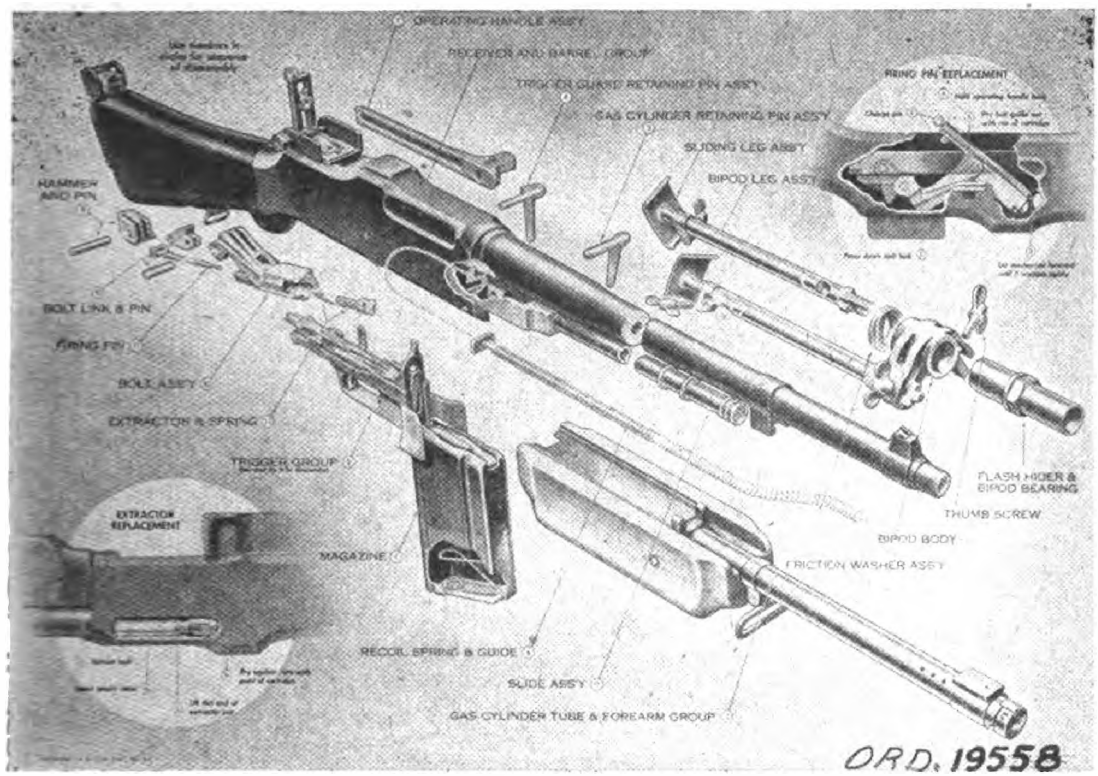

Figure 72. Field Stripping, Browning Automatic Rifle Cal .30 M1918A2.

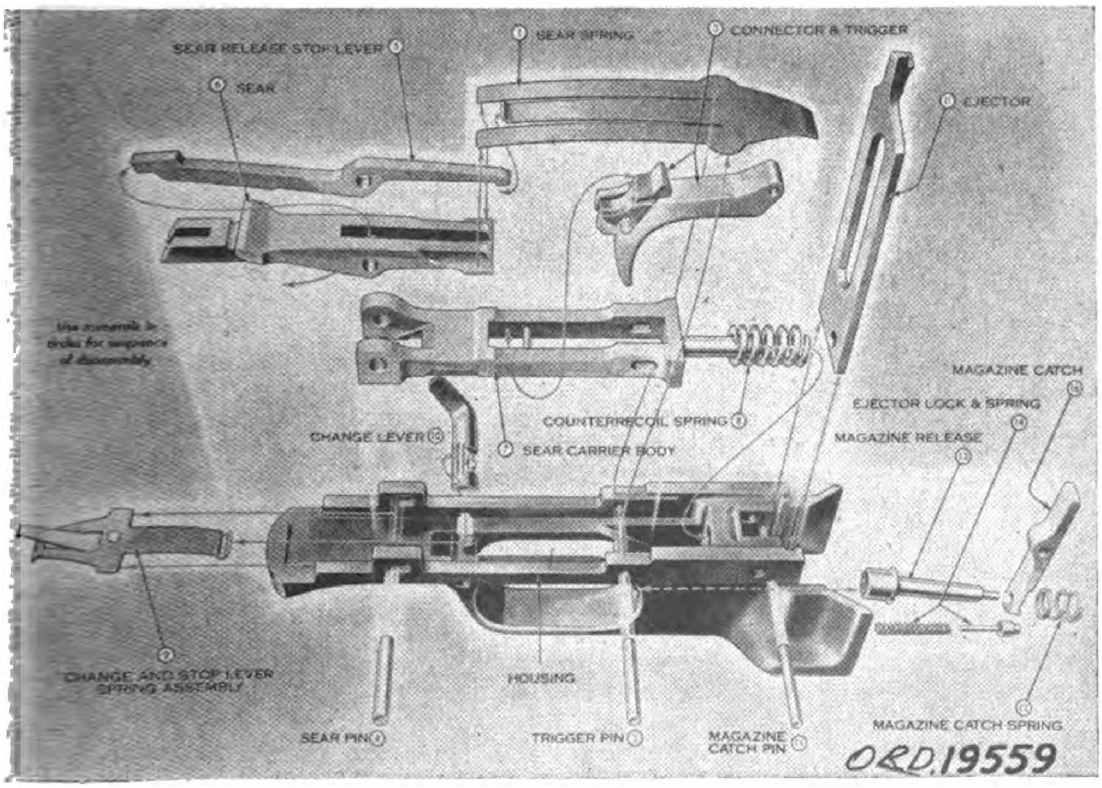

Figure 73. Trigger Group Assembly, Browning Automatic Rifle Cal .30 M1918A2.

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ceiver and operating handle by inserting point of recoil spring guide or dummy cartridge in hole in operating handle with right hand, pressing against hammer pin, and pushing operating handle backward with left hand. The recoil spring guide will push the hammer pin through its hole in the receiver as the hammer pin registers with the latter. Remove operating handle by pulling straight to rear. Remove hammer pin. Push slide to rear, push hammer forward out of its seat in slide, and lift hammer out of receiver. Remove slide by pulling it forward out of receiver, being careful that bolt link pin is pushed well down, allowing slide to clear. In removing slide, take care to avoid striking gas piston or rings against gas cylinder tube bracket.

Bolt, Bolt Link, Extractor and Extractor Spring. Force bolt guide out with left thumb or point of bullet. Lift out bolt, bolt link by pulling them slowly to rear end of receiver and up with right thumb and forefinger. Pull out firing pin from its 'way' in the bolt. Push out bolt link pin and remove bolt link. Remove extractor by pressing point of dummy cartridge against claw and exerting pressure outward and to the front. Remove extractor spring.

Trigger Mechanism. Depress ejector lock with point of dummy cartridge. Hold thumb in front of magazine catch spring to prevent it from flying out and then slide ejector out of its seat. Remove magazine catch spring. Remove magazine catch pin, lift out magazine catch and magazine release.

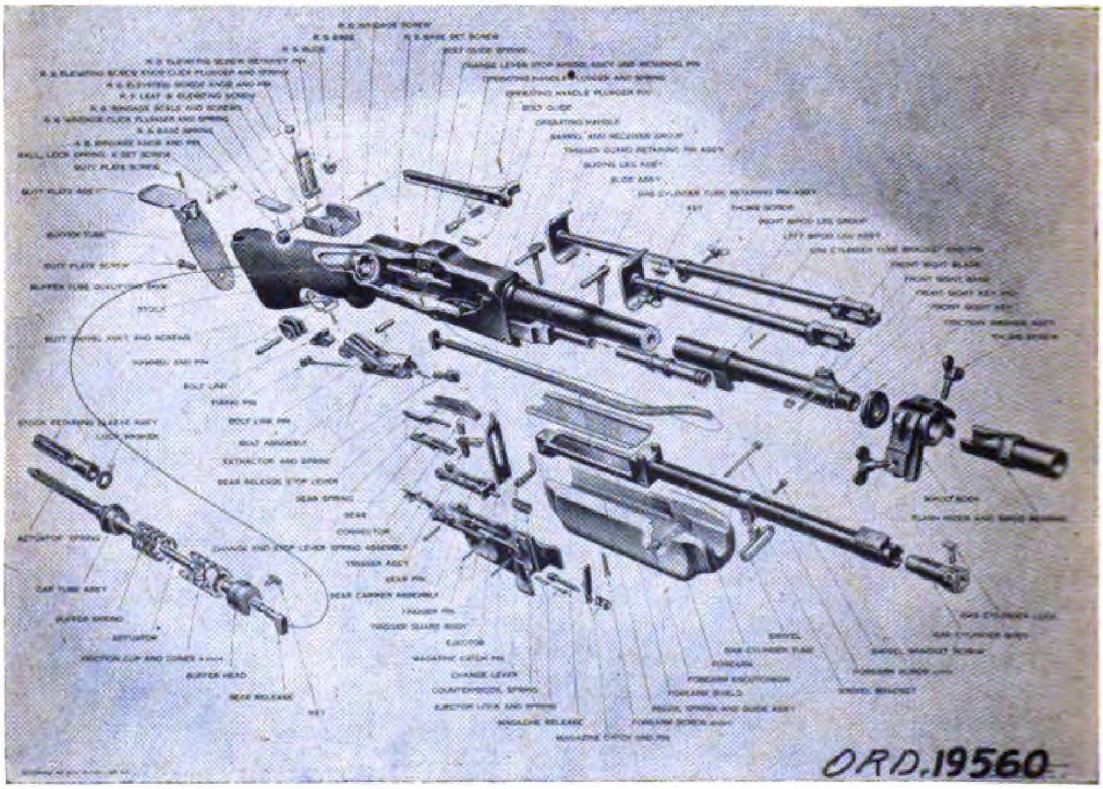

Figure 74. Detail Stripping, Browning Automatic Rifle Cal .30 M1918A2.

Insert trigger guard retaining pin spring as a tool under sear spring above connector stop. Pry up, pressing against sear spring with thumb, and pull it out to rear. Push out trigger pin. The trigger pin must always be removed before the sear pin in order that the force of the counterrecoil spring will always be on the sear pin. Remove trigger and connector through top of trigger guard.

Push out sear pin with the recoil spring guide as tool. Remove sear and sear release stop lever. Separate sear release stop lever from sear. Pry up on the rear of sear carrier and lift out sear carrier and countrrecoil spring.

Remove change lever spring by prying bent end out of its seat, with rounded

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end of sear spring as tool, and moving change lever from front to rear. When clear of change lever, push it out the rest of the way by pressing with the thumb against the base of sear release stop lever spring. Pull out change lever.

Further disassembly will be done under the supervision of an officer or Ordnance personnel.

Assembly

Trigger Mechanism. Replace change lever. Insert ears of change lever spring in slots in trigger guard, sear release stop lever spring up and to rear, push spring forward into place. Replace counterrecoil spring on counterrecoil spring guide (front of sear carrier). Insert counterrecoil spring guide into its seat. Brace forward end of trigger guard against a solid object and with thumbs of right and left hands pressing on rear of sear carrier, push sear carrier forward until rear end is held by ears of change lever spring. Hold sear so nose is facing up and to the rear. Insert short end of sear release stop upward through slot in forward part of sear, taking care that notched end is down. Align sear pin hole of sear release stop lever with sear pin hole in sear. Replace sear and sear release stop lever and force recoil spring guide through using recoil spring guide as lever to align holes in release stop lever, sear, sear carrier and trigger guard for sear pin. By a slight pressure on recoil spring guide push sear carrier forward against counterrecoil spring, thus permitting sear pin to be seated easily in sear pin hole. The sear pin must always be replaced before trigger pin in order that force of counterrecoil spring will always be on sear pin. Replace trigger and trigger pin.

Holding connector so its head is to rear of connector stop, and its toe is down and to the rear, depress rear end of sear and drop connector into its place in trigger. Engage sides of sear spring in recesses and press down and forward on sear spring with thumb of right hand until front end of spring rests in depression stop. Take care to see that outside leats of sear spring rest on their seat on sear and that middle prong rides freely in slot formed by walls of sear carrier. If middle prong rests on one wall, instead of riding freely between them, trigger mechanism will not function when barrel is inclined below horizontal.

Replace magazine release, magazine catch, and magazine catch pin. Replace magazine catch spring. Insert ejector into recess and move it down until it is flush with magazine catch spring. Insert ejector lock spring and lock into lock spring recess. Compress magazine catch spring in its seat and move ejector down until it is fully home and ejector lock is in position.

After trigger mechanism has been assembled, turn change lever to forward position, and pull trigger. If connector will not rise, it is not in place correctly. It should rise and snap out from under sear. If connector will rise but does not raise sear, sear spring is weak and should be replaced.

Assembly of Groups. Replace extractor spring in extractor. Replace extractor and spring in seat in bolt. Replace bolt link and bolt link pin with shoulder of link against flat surface of bolt lock. Lift bolt lock and replace firing pin in bolt.

Bolt Assembly and Slide. Place rifle barrel down and pointing to left, so rifle is resting on barrel and rear sight base wings. With bolt mechanism held in a perpendicular position, insert it in receiver, forcing end of bolt under ends of bolt supports, and press bolt mechanism down so it will lie flat in its place. Push bolt mechanism forward, swing bolt link down. Replace slide and push all the way back. With hammer resting between thumb and forefinger, lower and seat it properly in its seat in the slide.

Hammer Pin and Operating Handle. Push bolt lock fully into its locking recess and push slide forward. Gently insert hammer pin from right side in operating handle recess so that pin will enter hammer pin hole connecting bolt link and slide. Hammer pin is pushed through until it hits other side of receiver. Pull slide gently to the rear, and at the same time, press on end of hammer pin with forefinger of right hand. (Hammer pin is protruding ¼ inch from left side of receiver.) When hammer pin reaches hammer pin hole in receiver, it will follow through and protrude ¼ inch from right side of receiver. Take operating handle in the right hand between the thumb and forefinger and slide all the way

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forward in operating handle recess, being sure that the knob is forward. With the thumb of the left hand, push hammer pin into position as far as it will go and draw mechanism back.

Recoil Spring and Guide. Replace recoil spring and guide. With end of index finger on checkered end of recoil spring guide head, turn until it is properly seated. To facilitate this operation hold right thumb against forward end of receiver.

Trigger Guard. Replace trigger guard and trigger guard retaining pin.

Gas Cylinder Tube and Retaining Pin. Cock the rifle. Slide gas cylinder tube and forearm to rear on gas piston, fitting lug to bracketed dovetail (tapers to rear). Replace gas cylinder tube retaining pin.

Flash Hider, Bipod and Stock Rest. Replace flash hider friction washer on muzzle with spring forward, replace bipod assembly on flash hider, and screw flash hider onto muzzle. Replace stock rest assembly.

Functioning

All automatic weapons must have a mechanical means for performing the following functions: extraction, ejection, feeding, locking the breech while there is high pressure in the bore, and igniting the cartridge. Operations such as extraction and ejection are performed by cams, lugs, and springs, and the energy necessary to perform this work and to overcome friction in the rifle is derived from the explosion of the powder in the chamber.

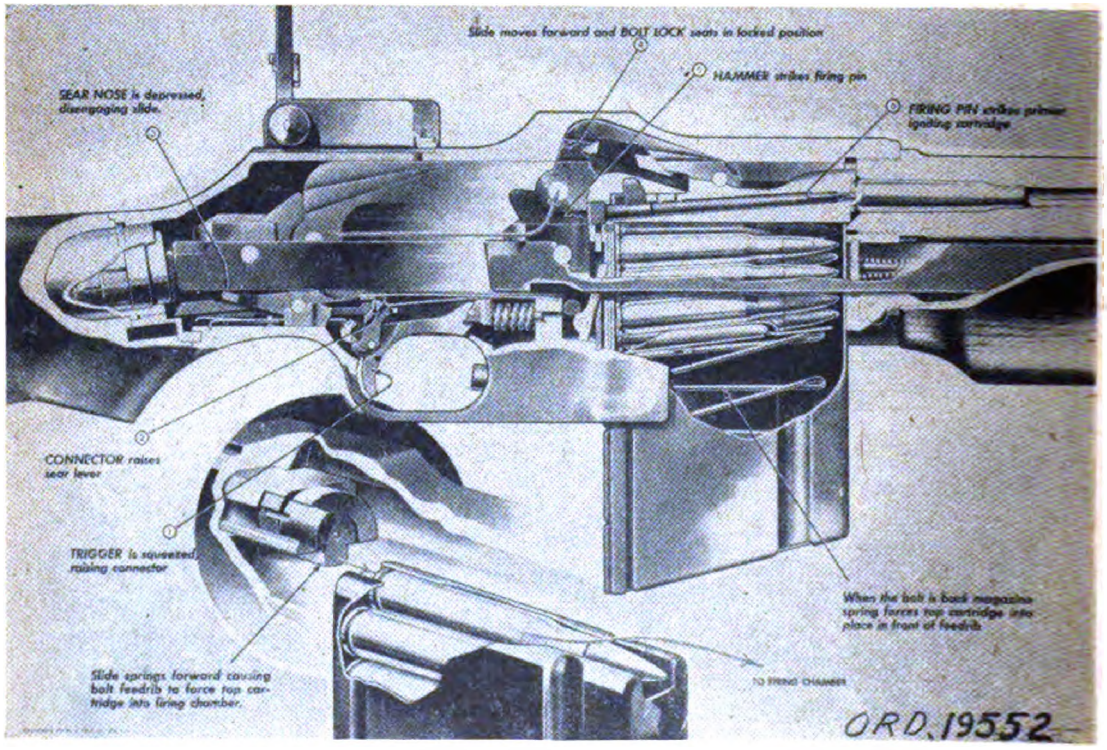

Figure 75. Basic Functioning, Browning Automatic Rifle Cal .30 M1918A2.

Cycle. One rearward and one forward movement of the mechanism is a cycle. The cycle begins with the ignition of one cartridge in the chamber and ends immediately prior to the ignition of the succeeding cartridge. The functioning of the automatic rifle is divided into two phases, based on the operaton of the mechanism during one cycle. These two phases are the rearward movement and the forward movement. The striking of the buffer by the slide marks the division of the two phases.

Description of the Cycle. *Rearward Movement.*

Action of the Gas. A cartridge having been ignited, the bullet under the pres-

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sure of the expanding powder gases travels through the barrel. When it reaches a point 6 inches from the muzzle, it passes a port in the bottom of the barrel. The barrel pressure, which at this instant is still very high, seeks this first natural vent. Aligned with the barrel port are other similar ports in the gas cylinder tube bracket, gas cylinder tube, and gas cylinder. The port in the gas cylinder body is the smallest and serves to throttle the barrel pressure. It leads radially into a well about ⅛ inch in diameter in the head of the gas cylinder body. The throttled barrel pressure is conducted through this well to the gas piston plug. This pressure acts on the piston for the short time which it takes for the bullet to travel the 6 inches from the barrel port to the muzzle. Its effect is that of a sudden severe blow on the piston plug. Under the impact of this blow, the gas piston is driven to the rear, carrying the slide with it. When the piston has traveled about 9/16 inch backward, the bearing rings on its head and the gas piston plug pass out of the cylinder. The gas expands around the piston head and into the gas cylinder tube and is exhausted through the six ports in the tube. It also passes out the pressure relief vent in the front of the gas cylinder body and the port back up into the barrel. The gas is prevented from traveling back through the gas cylinder tube by the two gas check bearing rings on the piston, about ⅝ inch apart and 1¼ inches from the piston head. These rings also serve as a bearing to hold the front end of the piston in the center of the gas cylinder tube after the piston head has passed out of the gas cylinder body.

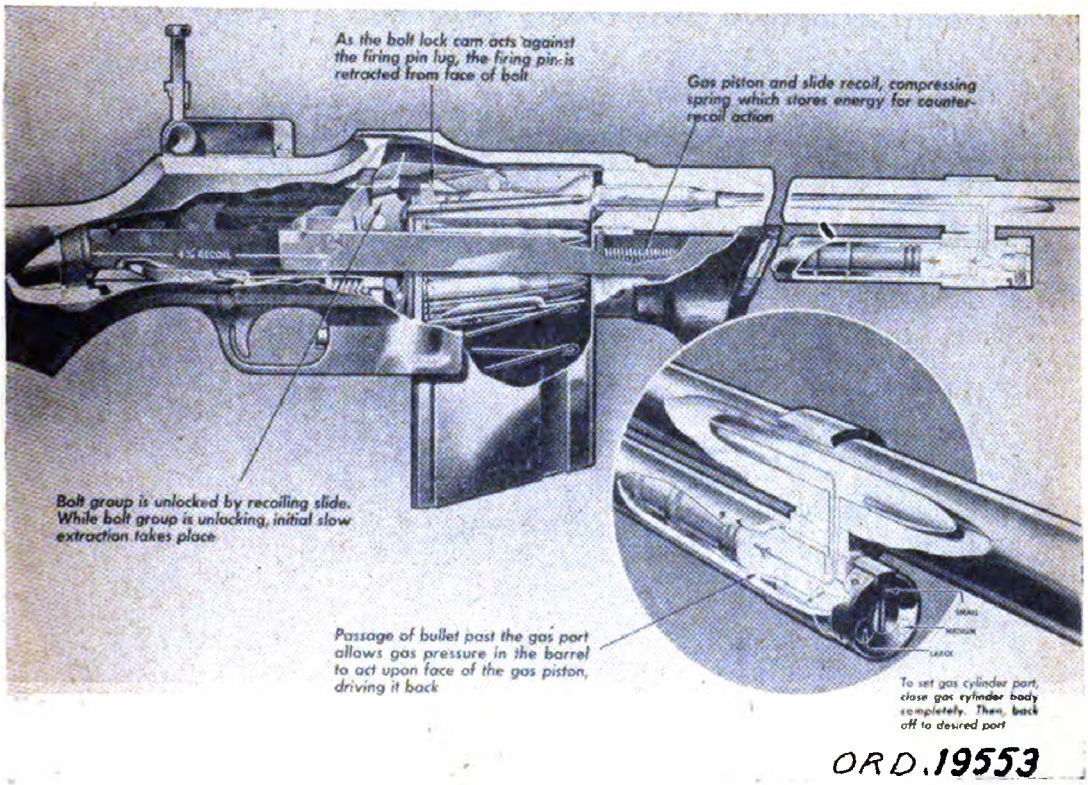

Figure 76. Gas Cylinder and Slide Functioning, Browning Automatic Rifle Cal .30 M1918A2.

The Slide. As the piston is forced back, it carries the slide with it. The first and the immediate result of the backward movement of the slide is to begin the compression of the recoil spring, thereby storing energy for the forward action. The hammer pin is slightly in advance of the bolt link pin, about 0.19 inch. The center rib of the hammer is very slightly in rear of the head of the firing pin. When the slide begins its motion to the rear, it imparts no motion whatever to the bolt and bolt lock. The slide moves back 0.19 inch and its only effect during this travel is to carry the hammer from the firing pin and the hammer pin to a point directly under the bolt link pin.

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At This Point the Unlocking Begins. The bolt link revolves forward about the hammer pin, drawing the bolt lock down to the rear. The motion of the lock and bolt, which is zero at the instant the hammer pin passes under the bolt link pin, accelerates from this point until the slide has traveled about 1.2 inches, at which point the bolt lock is drawn completely down out of the locking recess and away from the locking shoulder of the receiver. It is now supported in front on the bolt supports. The front upper surface of the bolt link has revolved forward and bears upon the locking surface of the bolt lock. These two factors prevent the bolt lock from revolving down below the line of backward travel of the bolt.

Withdrawal of Firing Pin. As the bolt lock revolves down from its locked position, a cam surface in a slot in the rear bottom side of the bolt lock comes in contact with a similar cam surface on the firing pin lug. This action cams the firing pin from the face of the bolt.

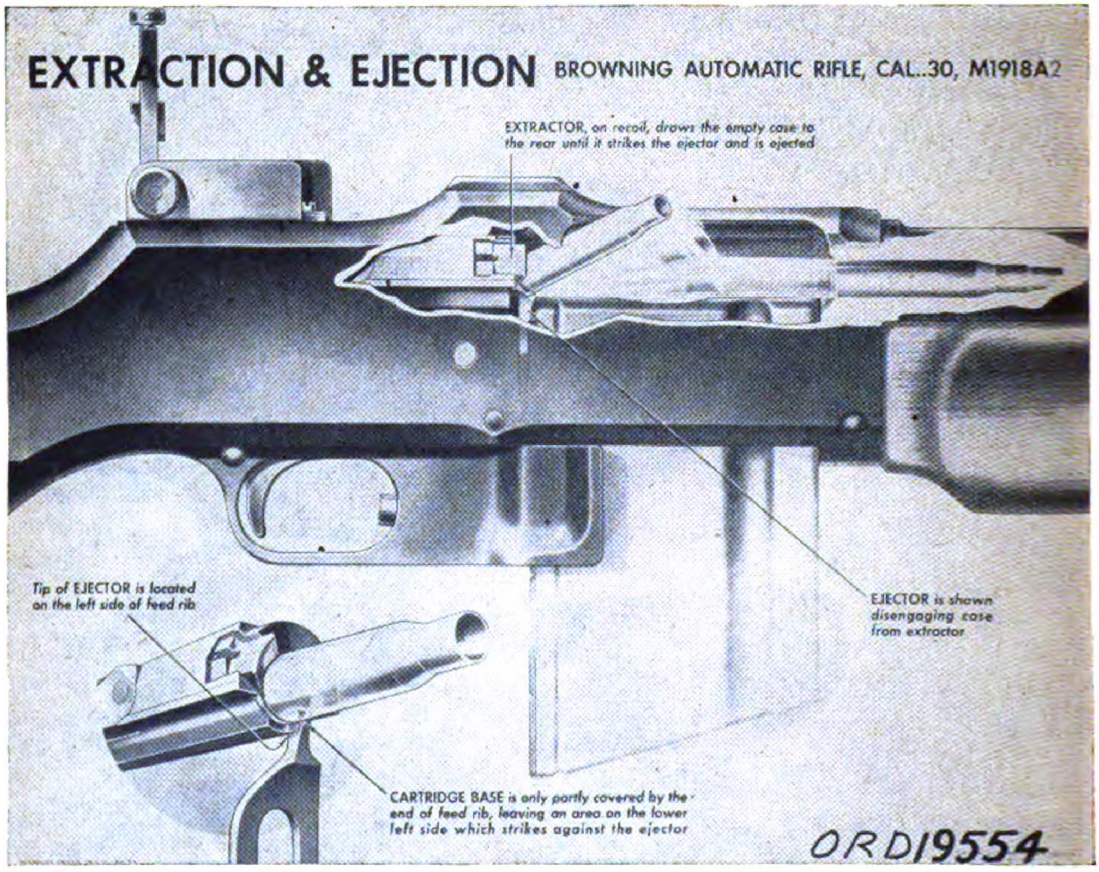

Figure 77. Extraction and Ejection, BAR M1918A2.

Extraction. The backward motion of the bolt begins when the bolt lock has been drawn down so that the circular cam surfaces on its under side are operating on the rear shoulders of the bolt supports. This produces a strong lever action which slowly loosens the cartridge case. The backward travel of the bolt has been slight; only about 5/32 inch when the firing pin is withdrawn. Its travel is about 11/32 inch when the bolt lock is completely drawn down. From this point the bolt is drawn to the rear by the bolt lock and bolt link, with the same speed as the slide. It carries with it the empty cartridge case which is held firmly in its seat on the face of the bolt by the extractor. The extractor is on the upper right side of the bolt next to the ejection opening in the receiver. A slot cut in the left side of the bolt lock near the back end passes over the bolt guide which supports the bolt lock and bolt when they are in the rear position.

Ejection. When the slide reaches a point about ¼ inch from the end of its

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travel, the base of the cartridge case strikes the ejector. This action causes the cartridge case to be pivoted with considerable force about the extractor and through the ejection opening in the receiver. The front end of the cartridge case passes out of the receiver first and is pivoted so that it strikes the outside of the receiver at a point about 1 inch to the rear of the ejection opening. It rebounds from the receiver toward the right front.

Termination of the Rearward Movement. The rearward motion terminates when the rear end of the slide strikes the buffer head and sear release. The slide, under the action of the recoil spring, moves forward 1/10 inch after striking the buffer head and sear release. If the sear nose is not depressed, it engages the sear notch on the slide and the piece is cocked for the next burst or shot.

Note: In the rearward movement, the motion of the bolt, bolt lock, and bolt link mechanism begins slowly at first and does not attain the speed of the slide until the latter has traveled about 1¼ inches backward. This is a very important characteristic of the rifle, since it is on this account that the mechanism is not subjected to an excess strain due to a sudden start at the instant the gas strikes the piston. This slow start also allows the bullet to clear the muzzle; thereby preventing a blowback of the expanding gases.

Forward Movement. *Action of Recoil Spring.* When the trigger is pressed the sear nose is depressed, disengaging the sear, and the slide moves forward under the action of the recoil spring. The position of the bolt link pin is slightly below a line joining the bolt lock pin and the hammer pin; therefore, as the slide starts forward, the joint at the bolt lock pin has a tendency to buckle downward. It is prevented from doing this by the tail of the feed rib on the bolt which extends backward under the bolt lock and by the upper front surface of the bolt link being in contact with the bolt lock. Since the joint cannot buckle, the entire mechanism moves forward with the slide. When it has traveled about ¼ inch, the front end of the feed rib strikes the base of the top cartridge, which the magazine spring and lips are holding up in its path.

Feeding. The cartridge is carried forward about ¼ inch when the nose of the bullet strikes the bullet ramp or guide on the breech of the barrel and is deflected upward toward the chamber. This action also guides the front end of the cartridge from under the magazine lips. The base of cartridge approaches the center of the magazine (where the lips are cut away and the opening enlarged) and is forced out of the magazine by the magazine spring. The base of the cartridge slides up the face of the bolt and under the extractor. Should the cartridge fail to slide under the extractor, the extractor will snap over its head as the bolt reaches the forward position. When the cartridge is released by the magazine, the nose of the bullet is so far in the chamber that it is guided by the chamber from this point on.

Locking. When the slide is about 2 inches from its forward position, the circular cam surface on the under side of the bolt lock begins to ride over the rear shoulders of the bolt supports on the sides of the receiver and the rear end of the bolt lock is cammed upward. The bolt link pin passes above the line joining the bolt lock pin and hammer pin. The joint at the bolt link pin now has a tendency to buckle upward, and the bolt lock being opposite the locking recess in the receiver, is free to pivot upward about the bolt lock pin. The bolt link revolves upward about the hammer pin, forcing the bolt lock up. A rounded surface on the bolt lock just above the locking face slips over the locking shoulder in the receiver, giving the lock a lever action which forces the bolt home to its final position. The two locking surfaces on the bolt lock and the receiver function as the hammer pin passes under the bolt link pin.

Igniting the Cartridge. The lug on the firing pin is at all times buried in the slot on the under side of the bolt lock except when the bolt is locked in the forward position. Therefore, the firing pin is locked away from the face of the bolt during all the rearward and forward motions of the bolt. When the hammer pin passes under the bolt link pin (which places the bolt lock into the locking recess in the top of the receiver), the firing pin has been released by the bolt lock. The slide and hammer move forward about 1/10 inch farther and the center rib of the hammer strikes the head of the firing pin a sharp blow, igniting the cartridge.

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Termination of Second Phase. The forward motion is not terminated by the hammer on the firing pin. The forward end of the slide strikes a shoulder at the rear end of the gas cylinder tube and terminates the forward motion. This can be seen by examining the head of the firing pin when the gas cylinder tube is assembled to the receiver with the bolt mechanism in the forward position. The firing pin is still about 1/16 inch from its extreme forward position.

Note: The locking shoulder of the receiver is inclined forward. Its surface is perpendicular to the line through the bolt lock which the shock of the explosion follows; therefore the force of this shock is exerted squarely against the normal surface. The speed of the bolt mechanism is slowed down gradually from the instant that the bolt lock starts to rise until the hammer pin passes under the bolt link pin, when the speed is zero.

Function of the Trigger Mechanism. With the change lever in the safe or rear position, the solid part is rotated over the shoulders of the trigger and the upward travel of the trigger is blocked. This prevents any rotation of the sear.

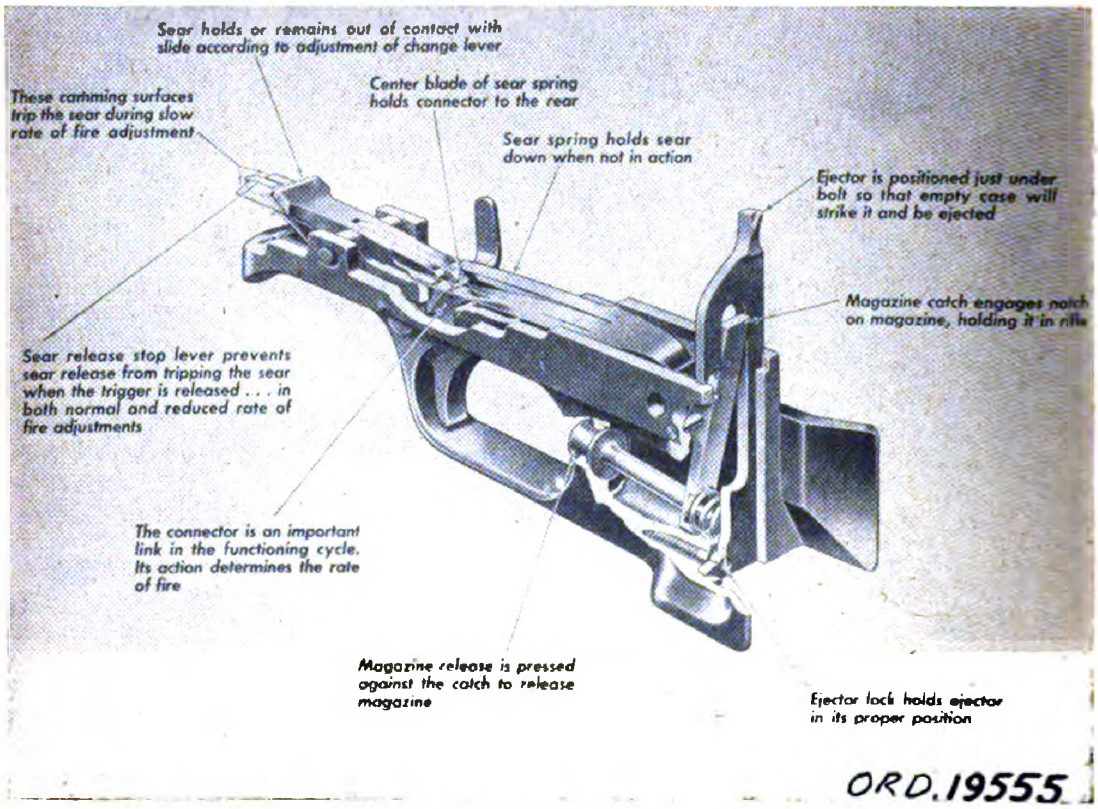

Figure 78. Trigger Group Functioning, BAR M1918A2.

With the change lever in the vertical or normal cyclic rate position, the shoulders of the trigger move into the slot in the change lever, but the upward travel is limited by the toe of the connector contacting the lug in the slot in the change lever. This contact causes the connector to be held firmly in the upright position. As the connector was raised by the trigger, it in turn raised the forward end of the sear and the sear release stop lever. The rear of the sear is drawn out of the notch in the slide and the sear release stop lever is held below the level of the sear release. The sear and the sear release stop lever are held in this position as long as the trigger remains depressed.

When the trigger is released, the rear of the sear and the sear release stop lever move up under the pressure of their respective springs. The sear engages the slide and the sear release stop lever blocks the sear release, preventing a runaway gun in the slow cyclic rate of fire.

With the change lever in the forward or slow cyclic rate position, the trigger

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and the connector are allowed to move all the way up into the slot in the change lever. The lug in the change lever does not block the toe of the connector. As the trigger is depressed, the connector moves straight up far enough to cause the sear to release the slide, then the cam on the rear of the connector contacts the cam surface of the sear carrier. This causes the connector to tip forward releasing the sear but holding the sear release stop lever up in front but down below the level of the sear release in the rear. Thus, the sear is free to engage the slide when it moves to the rear in recoil. The sear release is free to cam against the sear. (This is described in the section on the rate reducing mechanism).

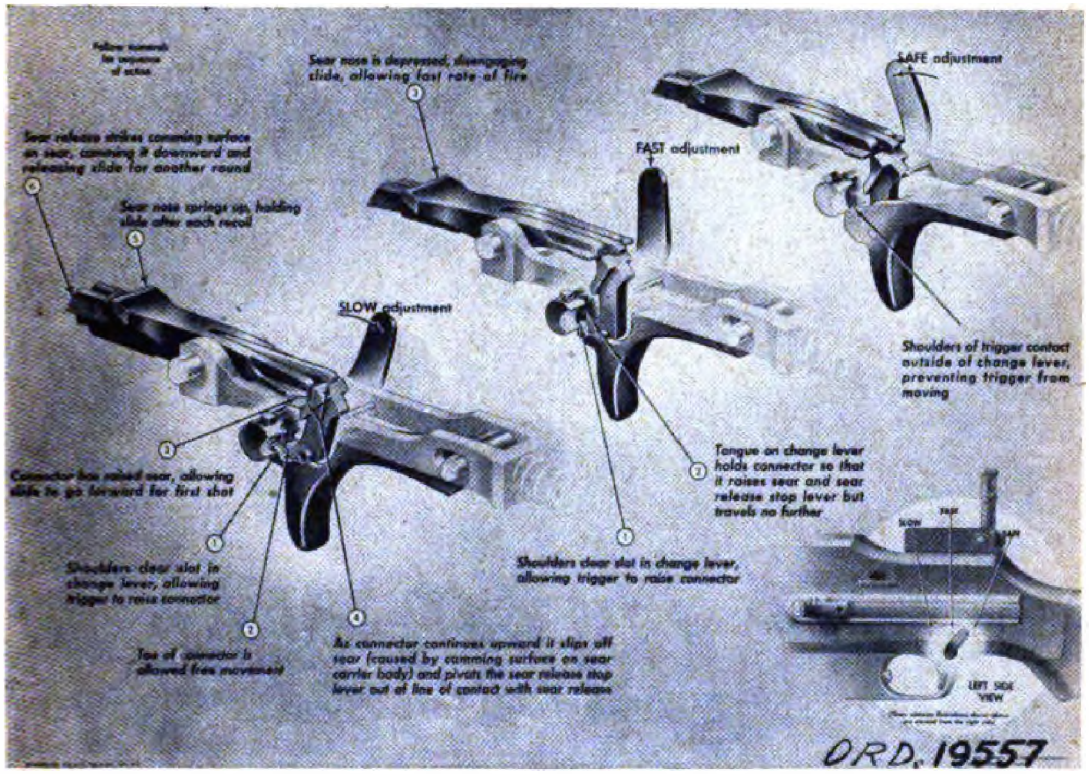

Figure 79. Rate of Fire Adjustment, BAR M1918A2.

As long as the trigger is depressed, the connector holds the sear release stop lever up in front. When the trigger is released, the rear end of the sear release stop lever moves up and blocks the action of the sear release, causing the gun to stop firing.

Function of the Combination Buffer and Rate Reducing Mechanism. As the automatic rifle is fired in the slow cyclic rate, the buffer is struck by the slide as it comes to the rear, forcing the buffer back against the buffer friction cups and causing them to expand over the buffer friction cones. This causes considerable friction as they move to the rear and compress the buffer spring. This action stops the rearward travel of the slide so gradually that there is practically no rebound. The buffer spring then returns the buffer head, friction cups, and friction cones to their original positions. After striking the buffer head and sear release, the slide moves forward until it is engaged by the sear. The shock of this engagement is taken up by the counterrecoil spring, which is located in front of the sear carrier. The delayed release of the sear is then accomplished as follows: The sear release, when struck by the slide, strikes the actuator in the buffer. Inside the actuator tube the actuator is driven to the rear against the actuator spring. It returns under the force of expansion of the actuator spring to drive the sear release forward against the camming surface on the rear of the sear, thus releasing the sear and permitting the rifle to continue its cycle.

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When the rifle is fired at the normal cyclic rate, the functioning of the combination buffer and rate reducing mechanism is the same as explained in the slow cyclic rate, except that the sear release is prevented from engaging the camming surface on the rear end of the sear by the sear since the sear and sear release stop lever are held down below its path as long as the trigger is depressed.

Inspection

The purpose of inspection is to determine the condition of materiel, whether repairs or adjustments are required, and the remedies necessary to put damaged materiel in serviceable condition. Before inspection is begun, the materiel should be thoroughly cleaned to remove any grease, dirt, or other foreign matter which might interfere with its proper functioning.

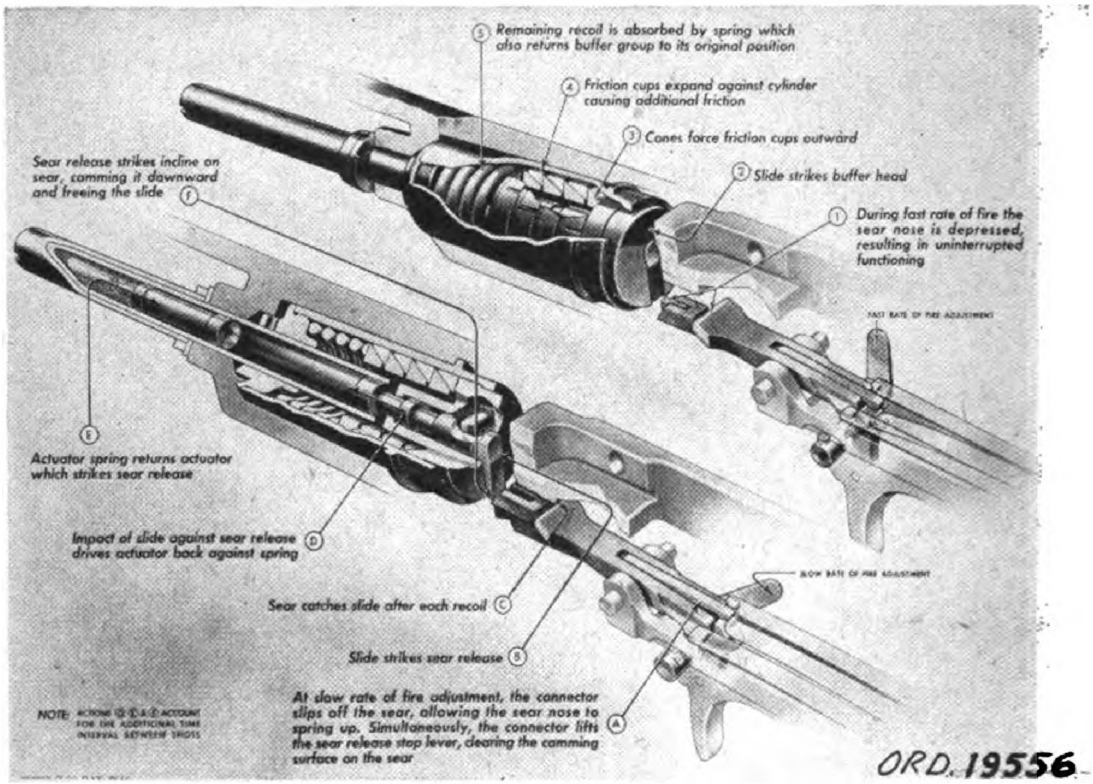

Figure 80. Buffer and Rate Reducing Mechanism, BAR M1918A2.

Visual Inspection. With the rifle assembled, inspect for the following points. completeness, lubrication, functioning, cleanliness, and condition of the weapon. With the rifle disassembled, check all parts for cracks, burrs, rust, wear, and functioning of groups or assemblies. The usual inspection should be thorough, as one bad part will cause the rifle to malfunction.

Upon reassembly, be sure all parts are properly assembled. Improper assembly is the cause of a large number of malfunctions.

Gage Inspection. *Headspace.* Disassemble the rifle and remove the firing pin and extractor from the bolt. Replace the bolt, bolt lock, link, hammer, and slide and insert the hammer pin; work slide back and forth to insure that the parts are correctly assembled. With slide fully forward, note the position of the hammer pin in the slot in the left side of the receiver. There is a clearance of from 1/32 to [illegible] inch between the hammer pin and the forward part of the slot. This position of the hammer pin is referred to hereafter as the locked position.

Retract the slide and insert the 1.940 gage in the chamber. Move the slide forward; the hammer pin should move into the locked position. Any slight binding should be disregarded. Remove the gage. The minimum headspace is correct if hammer pin was in locked position.

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If the rifle is in the shop, the 1.946 gage is used to check the maximum head space. Insert the 1.946 gage in the chamber and close the bolt. Note the position of the hammer pin. It should be ⅜ inch or more from the locked position. If it is less than ⅜ inch, the head space is excessive. Excessive head space may be corrected by replacement of the bolt, bolt lock or bolt links. If this will not remedy it, then the barrel must be removed and chamber depth checked (see below for this). If chamber depth is all right, then the fault lies in the receiver.

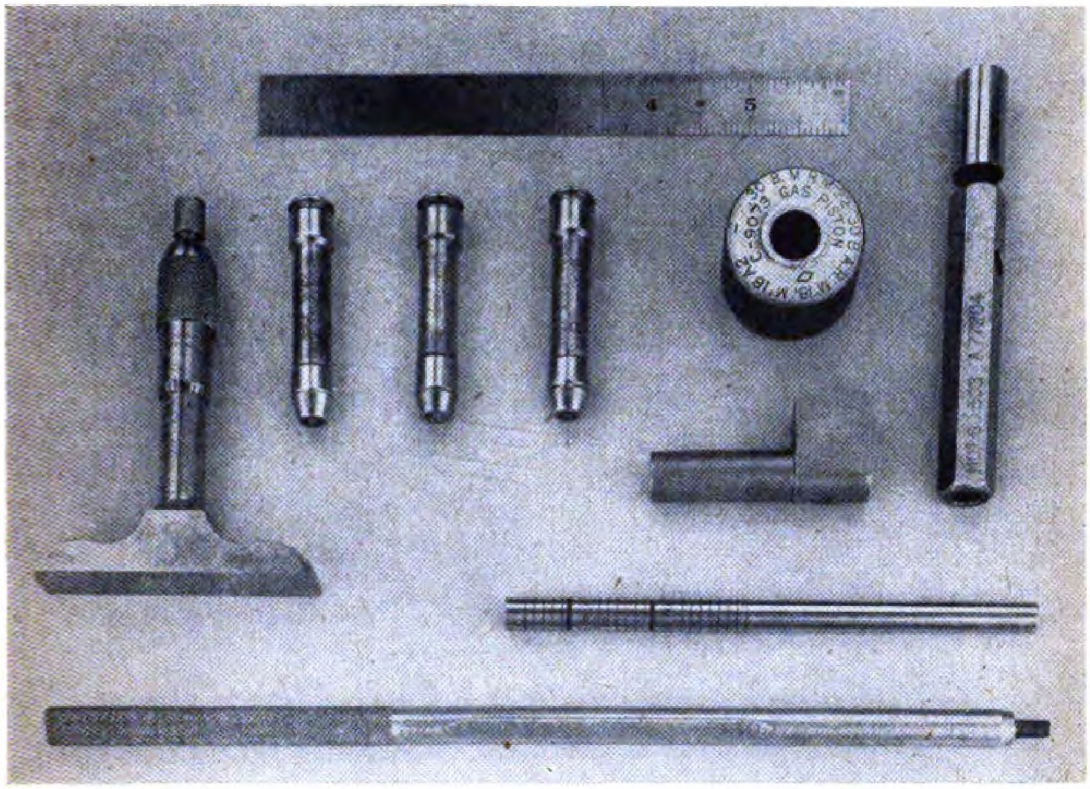

Figure 81. Gages for Inspection of Browning Automatic Rifle Cal .30 M1918A2.

If the rifle is in service, use the 1.950 gage. Follow the same procedure that was used with the 1.946 gage.

Chamber Depth. The barrel must be removed from the receiver. Place the 1.940 inch gage in the chamber. Place a depth micrometer on the gage and measure to the base of the barrel. This dimension should not be less than 0.75 inch. If it is less, the barrel should be scrapped. This measurement is taken to the flat surface on the back of the barrel.

Breech Bore Gage. Remove the handle from breech bore gage C 3940. Insert gage in chamber and read from flat surface on rear of barrel through the injection opening. The first set of graduations should be used. Reading should be under .310 inch. If reading is greater, the barrel must be scrapped.

The barrel is also usually inpected for condition. A bulged, bent, split, or excessively pitted barrel is rejected. A gun is excessively pitted when the outline of the bands is destroyed or a pit ⅜ inch or more long extends across a land or groove.

Gas Piston Gage. The gas piston should be clean when this test is made. When you attempt to insert the gas piston into the ring gage, it should not enter. The diameter of this 'no-go' gage is .494 inch.

Gas Cylinder Gage. The gas cylinder should be clean before this test is made. Attempt to insert the plug gage making sure to use the proper gage. It should not go into the cylinder proper. The diameter of the new type cylinder is .503 inch.

Firing Pin. The firing pin should protrude about 3/32 inch.

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Field Adjustments

Gas Cylinder. During assembly, the small port of the gas cylinder should be alined with the port in the barrel. If the operation is sluggish due to foreign matter or carbon in the port, turn the next larger port into position. Increase the size of port until proper functioning is obtained.

Buffer Group. The buffer plate should protrude about ⅛ inch. The buffer tube cap should be tight.

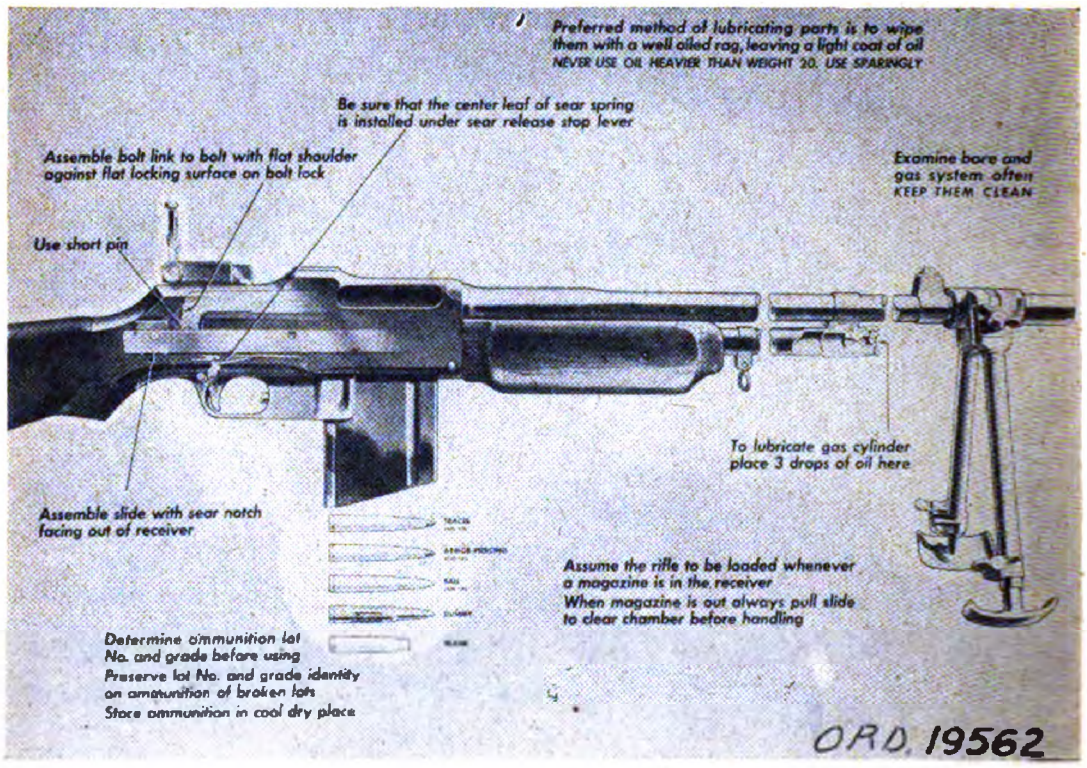

Figure 82. Precautions, BAR M1918A2.

Malfunctions

Malfunctions are caused by a large number of things. The most common causes are improper assembly, bad ammunition, dirty gas port, bad magazine, and foreign matter within the receiver.

Consult the table of stoppages in FM 23-15 or FM 23-20. There are four positions of stoppages. These positions are determined by the point at which the operating handle is stopped by the hammer pin. To find the position, move the handle to the rear until it strikes the hammer pin. These positions are set up so that one can more easily determine the malfunction.

The positions are: First position, operating handle all the way forward. Second position, anywhere from the first position to the top of the raised portion on the front of the slot. Third position, anywhere from the second position to the F on the receiver. Fourth position, anywhere between the F and all the way back.

The most common causes of first-position stoppages are failure to fire and insufficient gas. Second-position stoppages are caused by failure to lock, due to foreign matter within receiver or on face of bolt, long cartridges, dirty chamber, or insufficient head space. Third-position stoppages are caused by jams in feeding, ruptured cartridges, bulged and battered rounds, and foreign matter. Fourth-position stoppages are caused by failure to extract, failure of trigger mechanism, and double loadings. These are a few of the more common causes. Many others exist.

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Maintenance and Repair

The maintenance and repair of this rifle is primarily the replacement of worn or broken parts. During the visual inspection of the rifle the parts that are unserviceable should be noted. When parts of an assembly are bad and facilities for replacement are available, those parts should be replaced.

The preventive maintenance applicable to all small arms should be observed. This includes cleaning of the barrel, cleaning and lubrication of all moving parts, and proper care while handling the weapon. One point that should be checked frequently by authorized personnel is the buffer and rate reducing mechanism. The proper assembly of the weapon is essential to proper functioning.

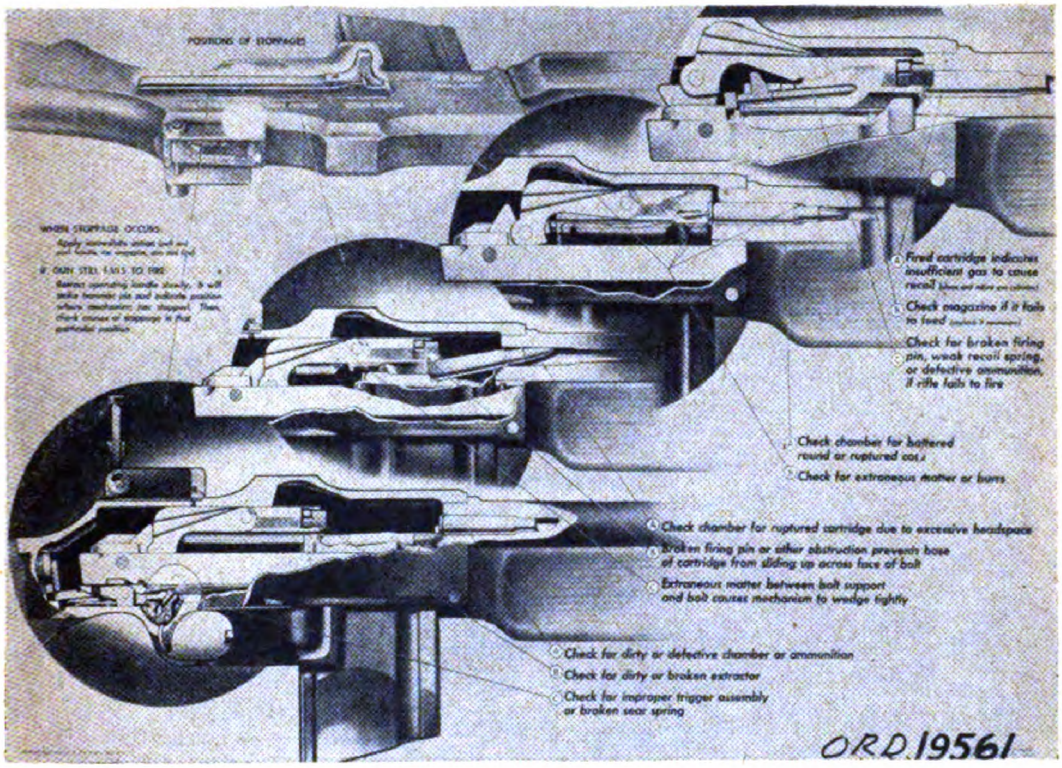

Figure 83. Stoppages, BAR M1918A2.

While cleaning, special care should be given to the gas cylinder, the gas piston, and the firing pin. These parts are sometimes neglected. The care of the stock and sling is the same as for the M1903 rifle.

AUTOMATIC PISTOL CAL .45 M1911 AND M1911A1

The forerunner of the cal .45 Pistol was the cal .32 Pistol brought out under Colt patents by the Fabrique Nationale in Belgium in 1898. This was designed by the well known John M. Browning of Browning machine gun fame. The first pistol put on the market in this country was the Colt Automatic Caliber .38 in 1900. Between 1900 and 1902 two more improvements were made to the .38. In 1905 the first Caliber .45 Colt automatic was brought out. It had at first a mechanism very similar to the early .38's, but under requests by the Army was worked over extensively during the next five years and appeared in 1911 as the Government Model .45 Automatic Pistol, Model of 1911. In this form, and at the same time, it was adopted as the official side arm of the United States services. The necessity for the caliber .45 weapon was felt during the Filipino Insurrection when the caliber .38 Colt revolver in use at that time failed to stop the natives when they atacked.

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Characteristics

The Automatic Pistol Cal .45 M1911 and M1911A1 are short, recoil operated, magazine fed, self loading hand weapons. In either weapon the recoil exerted by the gas generated from the fired cartridge is utilized to extract and eject the empty cartridge case, cock the hammer, and force the slide to the rearmost position, thereby compressing the recoil spring. Expansion of the recoil spring forces the slide forward. This loads a live cartridge into the chamber and the weapon is ready to fire again. Although called 'automatic,' it is, actually, only 'auto-loading' or 'semiautomatic,' as the pistol fires only once at each squeeze of the trigger. When the last cartridge has been fired the slide remains open. The magazine catch is then depressed and the magazine is forced out by the tension of the magazine spring. In the event that the magazine binds in the receiver, it is pulled out by the operator. The rate of fire is limited only by the dexterity or ability of the operator to change magazines and squeeze the trigger.

The cal .45 automatic pistol is not only the official military side arm, but is also fairly common as a civilian weapon. Great quantities have been sold commercially by the Colt Company. Variations of the weapon are the commercial Colt .38 Super and the Colt .22 Ace.

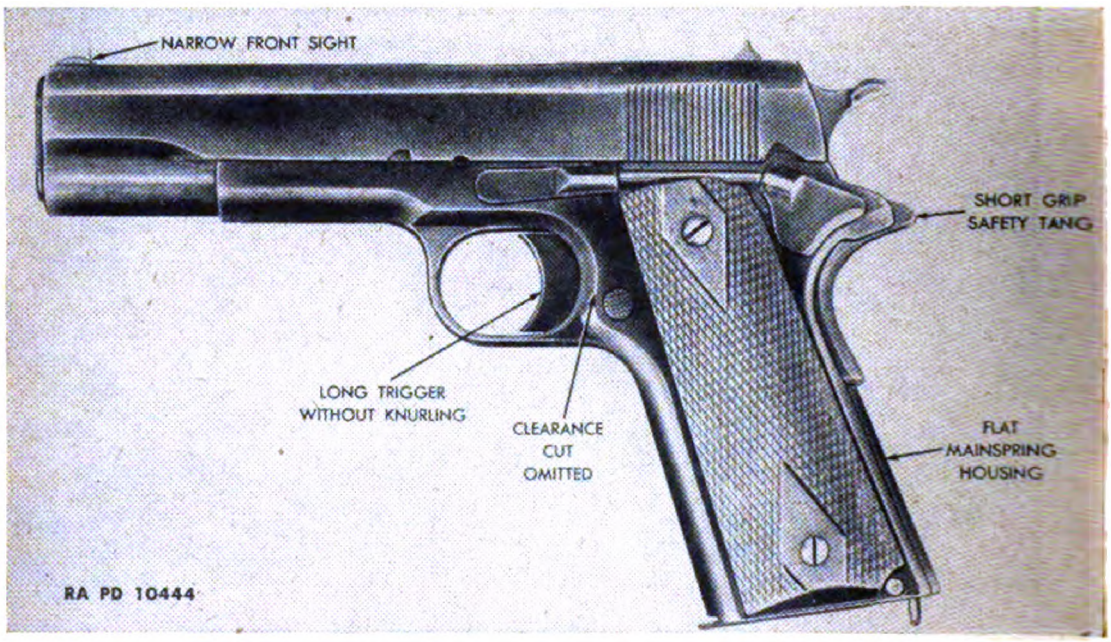

Figure 84. Pistol, Automatic, Cal .45 M1911. Left Side View Showing Differences Between it and M1911A1.

The M1911 is classified as limited standard and the M1911A1 as standard. The small differences of the two types do not materially affect the maintenance problem. In the Model 1911A1 there are five minor modifications made over the M1911; they are:

The tang of the grip safety is extended to provide better protection for the hand.

A clearance cut is made on the receiver for the trigger finger.

The face of the trigger is cut back and knurled.

The mainspring housing is raised in the form of a curve to fit the palm of the hand and is knurled.

The top of the front sight is wider.

The military services adopted the cal .45 as a side arm for defensive use only. Its 234 grain bullet, traveling in a 5.03 inch barrel at 800 to 825 feet per second, is very effective against personnel, and at ranges up to 50 yards no allowance for drop need be taken on a man-sized target.

The bore of the barrel has six lands and six grooves which rotate with a uniform right hand twist, making one complete turn in sixteen inches. The overall length

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of the weapon is slightly over 8½ inches and it weighs approximately 2½ pounds loaded.

The magazine holds seven rounds. It is possible to have an eighth cartridge in the chamber, but this is not advisable as it narrows the safety margin of the weapon.

Operation

An Infantry major firing at a son of Nippon on a tropical island or a soldier standing on the firing line of some pistol range thinks nothing about the pistol other than a means of sending a bullet traveling towards a target. He knows that all that is required to hit that target with the projectile is to hold the pistol properly pointed and to squeeze the trigger. As the gun fires it 'bucks' slightly in his hand, there is a sharp report and he has either hit or missed his target. He also knows that after firing the gun once he may release the trigger and squeeze it again and he has fired another shot.

Few realize what a tremendous amount of careful research, study, and observation went into the designing of the finely machined parts necessary to accomplish a complete cycle of operation every time this weapon is fired. On first thought it would appear phenomenal that a small weapon, fired comfortably from one hand, could be so planned and condensed to fire semi-automatically. Actually the operation of the pistol is quite simple and not hard to understand. Suppose we go through this cycle of operation briefly and see just what happens.

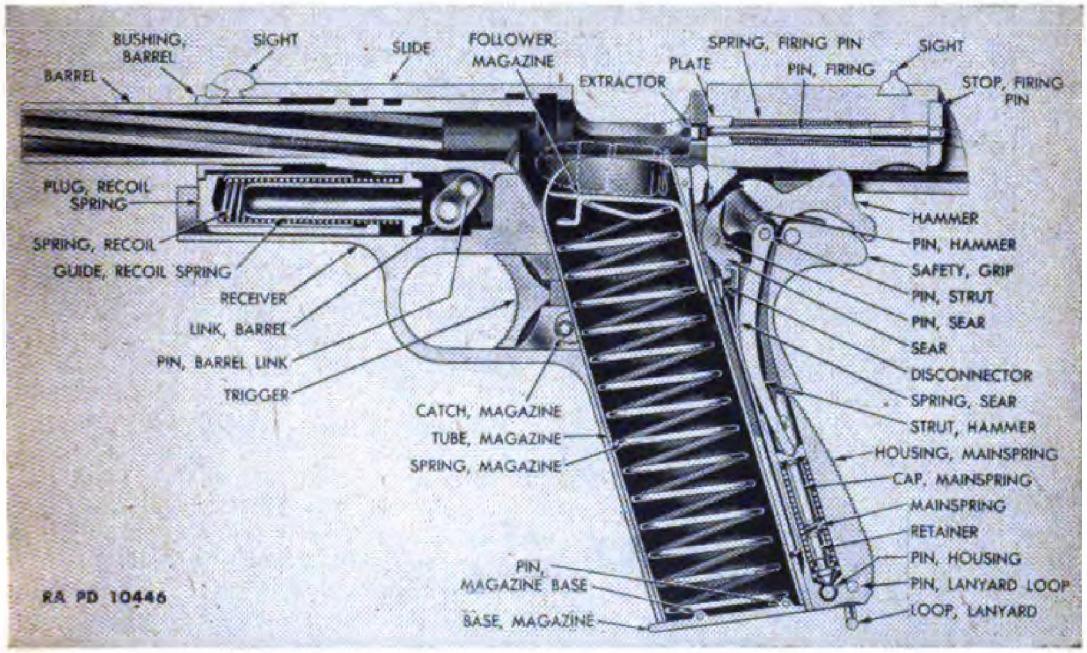

Figure 85. Pistol, Automatic Cal .45 M1911A1. Section View Showing Nomenclature.

The loaded magazine may be inserted into the receiver either when the slide is in the forward (locked) position or the rearward (unlocked) position. We will consider here that the slide is forward when the magazine is slipped into the bottom of the receiver and is secured in place by the magazine catch. The slide is drawn manually to the rear once. This movement compresses the recoil spring and cocks the piece. During this action, the solid part of the slide (the feed rib) clears the top round in the magazine. The first round is forced up in front of the feed rib by the action of the magazine spring. Upon releasing the slide it is forced forward by the expansion of the recoil spring and the feed rib on the slide strips the round out of the magazine and forces it forward and upward into the chamber.

As the cartridge is seated in the chamber, the motion of the slide is still forward. This action causes the barrel to move slightly forward and upward

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until the locking lugs of the barrel engage the locking recesses in the slide. The forward movement of the parts is arrested by the barrel lug meeting the pin of the slide stop. The weapon is now cocked and ready to be fired. Let's see what happens when the trigger is pulled. This is a semiautomatic weapon, so only one shot will result with each pull of the trigger.

As the trigger is pulled we release the hammer from its engagement with the sear. The hammer falls forward and hits the firing pin which in turn strikes the primer, igniting the propelling charge of the round. Pressure from the expanding gases simultaneously acts on the base of the bullet, driving it forward through the barrel and against the cartridge case, tending to push the latter back against the slide. Since the slide is by far the heavier of the two moving parts, it is slower to move. This gives the bullet a chance to utilize all the gas pressure to speed it on its way. The push of the cartridge to the rear forces the barrel and slide backward slightly until the barrel drops out of the locking recesses in the slide and the slide is free to travel to the rear unencumbered by the barrel. Residual pressure will cause the slide to continue rearward against the tension of the recoil spring. In the rearward action, the spent cartridge case is withdrawn from the chamber, its base strikes the ejector and it is flipped through the ejection opening in the slide. The hammer is cammed back to the full cock position where it is caught by the sear. Counterrecoil, or the action of the slide moving forward again, is as previously described for loading.

Safeties

Five safety features make the Colt the safest hand gun ever made. These five safeties will now be explained. The manual safety (safety lock) rotates upward to completely lock the slide and block the sear. It is perfectly safe to carry the piece loaded and ready for action with the hammer locked back in the full cock position.

A grip safety is provided which prevents the weapon from being fired except when the hand is grasping the weapon in a manner which permits pressing in of the grip safety, as in the 'aiming' position. This safety is independent of the manual safety and should one fail, the other would function.

The half cock notch provides a form of safety. If, while manually cocking the weapon, the hammer should slip from under the thumb, the half cock notch would catch and prevent an accidental discharge. It is not good practice to carry the weapon with a live round in the chamber and the hammer at half cock. A sharp blow caused by dropping the gun on the hammer may fire the weapon.

Probably the best method of carrying the weapon, particularly for your own peace of mind, is with the hammer fully forward even if there is a live round in the chamber. This is possible because of the inertia type firing pin; it is considerably shorter than the housing in which it rests. A blow from the hammer, falling from its full cocked position, is necessary to drive the firing pin forward to contact the primer of the cartridge hard enough to fire the weapon. After contact, it immediately is forced back into its recess by the action of the firing pin spring which was being compressed during the forward movement of the firing pin.

Acting also as a safety is the 'disconnector' which prevents the weapon from being fired in any position except the fully locked position; unless it can move up into a recess in the bottom of the feed rib, it will prevent any connection whatsoever between the sear and trigger. It controls the sear and trigger to the extent that it only permits one shot to be fired at each pull of the trigger.

Preventive Maintenance

The man who uses the pistol, whether he be an officer of field grade or an enlisted man, is faced with a highly important responsibility; that of care and maintenance of the weapon. It is common practice for the man with the gun to really respect his weapon as long as it performs efficiently and properly, but should a malfunction occur, this respect often turns to disdain. He doesn't stop to think that he himself controls the efficiency of his piece to a great degree; that the weapon depends upon its user for the proper cleaning, lubrication, preserving and handling. It is highly essential that every person who uses a pistol be

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thoroughly familiar with the care and preventive maintenance of the weapon. This care must become routine so that under extreme conditions, where such things are of apparently minor importance in the mind of the user, the pistol will automatically receive proper first echelon maintenance.

In order to do a good job of caring for his weapon, the operator must understand why he is doing each portion of the required procedure. Preventive maintenance for the M1911A1 Pistol is as follows:

After issue, the new pistol must be thoroughly cleaned before using to remove all traces of the rust preventive compound applied at the place of manufacture. To remove this compound, the authorized material is Solvent, dry cleaning. The parts should be placed in a container filled with this solution and cleaned with a brush or cloth dipped in the solvent. In particular, don't overlook recesses and wells in cleaning the piece.

After all trace of the rust preventive compound is removed, dry the parts carefully and apply a light coat of oil to prevent rusting. This coat of oil may be very light but must *always* be present.

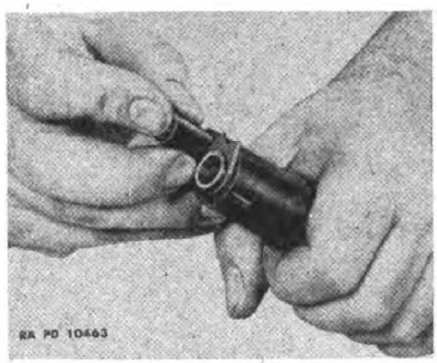

Figure 86. Removal of Recoil Plug, Pistol Automatic Cal .45.

For cleaning after firing, the proper procedure and materials will be covered at the end of the chapter under preventive maintenance. However, special points peculiar to the pistol must be stressed. For instance, before a new gun is cleaned in the solvent, is must be disassembled to insure a thorough job on every part. Even for ordinary cleaning, field stripping is necessary to make it possible to reach all parts and clean them properly.

Disassembly

To field strip the gun, remove the magazine and then check the chamber to be sure it is empty. With the slide forward, press the recoil spring plug (the knurled button beneath the barrel on the front of the gun) inward and turn the barrel bushing clockwise until the recoil spring plug protrudes from its seat. This releases the tension of the recoil spring. Keep your finger and thumb over the recoil spring plug so that it will not fly out as it is under considerable tension. Draw the slide to the rear until the small or middle notch on the left side of the slide is directly above the projection on the thumb piece of the slide stop. By pressing gently on the pin end of the slide stop, which protrudes slightly from the right side of the receiver above the trigger guard, you may remove the slide stop from the left side of the gun. This will release the barrel link and will enable the barrel and slide assemblies to be pulled forward together from the receiver. If the recoil spring plug is fastened to the recoil spring, twist it counterclockwise slightly and remove it. Be sure the barrel link is forward first and then pull out the spring and spring guide from the forward end of the slide.

This constitutes field stripping, and for ordinary cleaning purposes, is sufficient. If it should ever be necessary to take the weapon down further, due to extreme cleaning precautions or for the replacement or repair of parts, more care must be exercised to prevent damage to parts and more experience is needed to accomplish disassembly and assembly properly.

In further disassembly, start with the slide group. Press in on the rear of the

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firing pin with a small punch until it frees the firing pin stop. The stop may then be drawn out of its seat in the slide. This makes it possible to remove the firing pin and the firing pin spring. The finger and thumb should be kept over the firing pin to hold it in when the slide stop is removed. The extractor is now pried out to the rear with a punch or screwdriver. This completely disassembles all parts that are removed in installations other than base shops and arsenals.

The safety lock is readily withdrawn from the receiver by cocking the hammer, placing the lock midway between its upper and lower positions, and pushing on the pin from the right. Lower and remove the hammer by taking out the hammer pin from the left side of the receiver. Never allow the hammer to be snapped forward after the slide and receiver have been separated; it may crack or break if not retarded with the thumb as it goes forward.

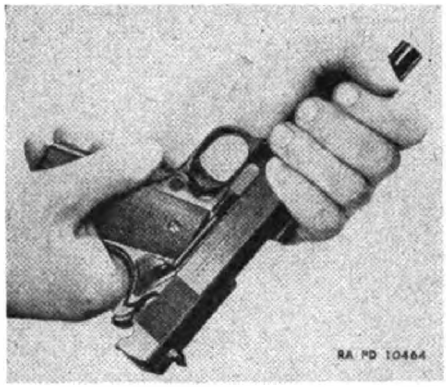

Figure 87. Lining Up Slide Stop of Pistol M1911A1.

Push or drive the mainspring housing pin from the right side of the receiver by placing a punch on the recessed end of the pin. Withdraw the mainspring housing down and out of the receiver. Lift out the sear spring and, by pushing the sear pin out from the right to the left side of the receiver, the sear and disconnector are released.

The mainspring housing assembly is not ordinarily disassembled, but should it become necessary, proceed as follows: Mount the housing in a vise with protected jaws, compress the mainspring by placing a punch on the mainspring cap and push the mainspring cap pin out with a small drift.

To remove the trigger, first take out the magazine catch. Press the magazine catch inward with finger on the knurled button, and with a very small screwdriver on the right side of the receiver, turn the magazine catch lock a quarter turn counterclockwise. The magazine catch with its contents and the trigger can now be removed.

The slide stop plunger, the safety lock plunger, and plunger spring are removed only when absolutely necessary because they deform very easily. To take these out of the plunger tube (which is the small tube on the upper left side of the receiver), push out from front to rear.

Ordinarily the magazine is not disassembled but occasionally sand, grit, or other foreign matter will collect in it and this will necessitate its being taken apart and thoroughly cleaned. To disassemble, proceed as follows: Push the magazine follower down a short way into the magazine to compress the magazine spring. Keep the magazine spring compressed by inserting the end of a drift through the small holes in the side of the magazine. Hold your hand over the top of the magazine to prevent the spring from jumping out and slide the magazine follower out the top front of the magazine.

The weapon is now disassembled completely except for a few parts that were not designed to be removed unless the parts became unserviceable. These parts must be sent into a 5th echelon repair shop. The stocks on either side of the receiver should not be removed because of ensuing wear and injury to the threads of the stock screws and stock screw bushings.

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Reassembly

Assembly is nearly the reverse of disassembly with the exception of a few specific points that must be observed to prevent injury to the assembler or the parts and to emphasize the fact that sheer strength and consequent awkwardness is not the procedure to use when working on small arms.

To reassemble the magazine, use a blunt tool to compress the magazine spring far enough into the magazine to permit inserting the end of a drift through one of the small holes in the magazine. Insert the magazine follower and withdraw the drift.

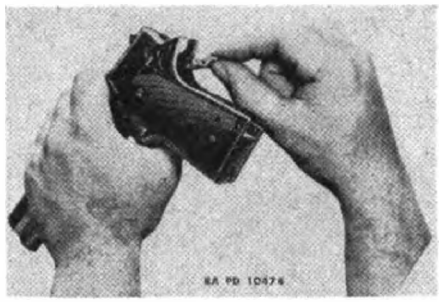

Figure 88. Reassembling Sear and Disconnector on Pistol M1911A1.

Assemble the slide stop plunger, the safety lock plunger, and the plunger spring forward into the plunger tube.

Push the trigger forward into position through the receiver. Insert the magazine catch and turn the magazine catch one-quarter turn to the right with a small screwdriver.

Replace the componets of the mainspring housing in the reverse order of disassembly.

To reassemble the disconnector and sear, place the cylindrical part of the disconnector in its hole in the receiver with the flat face or lower part of the disconnector resting against the yoke of the trigger. Place the sear, lugs downward, so that it straddles the disconnector. By squeezing the trigger slightly, the three parts will snap into alignment. Insert the sear pin from the left side so that it passes through both the disconnector and the sear.

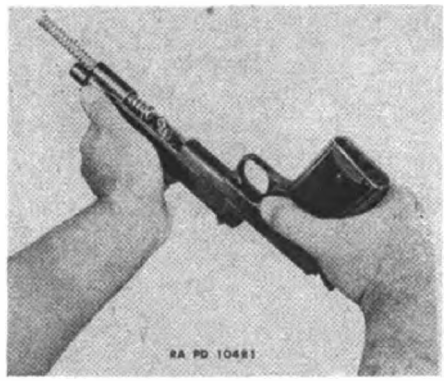

Figure 89. Replacing Slide and Barrel on Receiver, Pistol M1911A1.

Replace the hammer in the uncocked position, let it go forward and put the sear spring in under the hammer strut. Locate the lower end of the sear spring in the cut in the receiver with the long leaf resting on the sear. Push the mainspring housing up into the receiver until it is nearly home and put the grip safety into position. Be sure the hammer strut fits in its recess in the mainspring cap and replace the mainspring housing pin (it may have to be forced as it must compress the mainspring slightly). By cocking the hammer and pushing the safety

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lock plunger into the plunger tube, the safety lock may be seated into is proper position.

The reassembly of the slide and barrel group is just the reverse of disassembly. After the parts have been replaced in the slide, turn the receiver group upside down and move it forward on the slide.

When assembly is completed, check for proper positioning of all parts by cocking the piece and releasing the hammer by pulling the trigger.

Inspection

It is possible for any person who carries or uses a pistol to inspect it completely except for trigger pull tests. This is due to the fact that the trigger weights are the only necessary accessories needed to inspect the pistol.

The trigger pull on the pistol should be between 5 and 6½ pounds in the field and from 5½ to 6½ pounds in the shop.

In the visual inspection, the pistol is examined as a unit to note its general appearance, the action of the slide, and smoothness of operation. The alignment of sights is also verified. Examination is made for split stocks or missing stock screws, and a thorough check made for completeness and condition of all parts.

The five safety devices or features of the pistol can all be easily tested with the exception of the inertia type firing pin. It is necessary to actually fire the gun to determine whether the firing pin is of proper length. For the other four tests, be absolutely certain that the weapon is unloaded, and proceed as follows:

To test the safety lock, cock the hammer and press the safety lock upward to the safe position. Grasp the stock so that the grip safety is depressed and squeeze the trigger several times. If the hammer falls, the safety lock is not safe and must be repaired.

To test the grip safety, cock the hammer, and without depressing the grip safety, point the pistol downward and squeeze the trigger several times. If the hammer falls, or if the grip safety is depressed by its own weight, the grip safety or the sear spring is defective and must be repaired or replaced.

Draw the hammer back until the sear engages the half cock notch. Squeeze the trigger. If the hammer falls, the sear or hammer must be replaced or repaired. Draw the hammer back nearly to full cock and then let it slip. It should fall only to half cock, otherwise it should be repaired or replaced.

To check the disconnector, cock the piece and move the slide ¼ inch to the rear. Holding it in that position, squeeze the trigger. Let the slide go forward, maintaining the pressure on the trigger. If the hammer falls, the disconnector is worn and must be replaced. Hold the pistol in the right hand with the forefinger squeezing the trigger and grasp the slide between the thumb and forefinger of the left hand and pull it to the rear. Release the slide quickly and at the same time move the pistol downward sharply. The hammer should not fall; if it does, the disconnector is defective. Release the trigger and squeeze it again. This should cause the hammer to fall; if it does not, the sear spring is weak or the disconnector is faulty.

The remainder of visual inspection will be covered in the chapter on preventive maintenance which includes bore classification and barrel condition. In order to check the barrel properly during pistol inspection, the piece should be field stripped and the barrel removed.

SMITH AND WESSON AND COLT REVOLVERS CAL .45 M1917

Development

The Cal .45 Model 1917 is the result of more than one hundred years of design and development. A young seaman, Samuel Colt, is supposed to have noticed that the spokes of the wheel of his ship always returned in a perfect line with a clutch that locked the wheel in any position with any spoke that was in line with it. Colt whittled out a 5-shot wooden model of the new hand gun, which he patented in 1836. After several years of experimental manufacture, he produced a reliable weapon of the cap-and-ball variety. Each chamber was individually loaded from the front by inserting first the powder, then by ramming home the ball on top of it. At the rear of the chamber a small percussion cap was inserted over a hollow nipple leading into the chamber. When the flat

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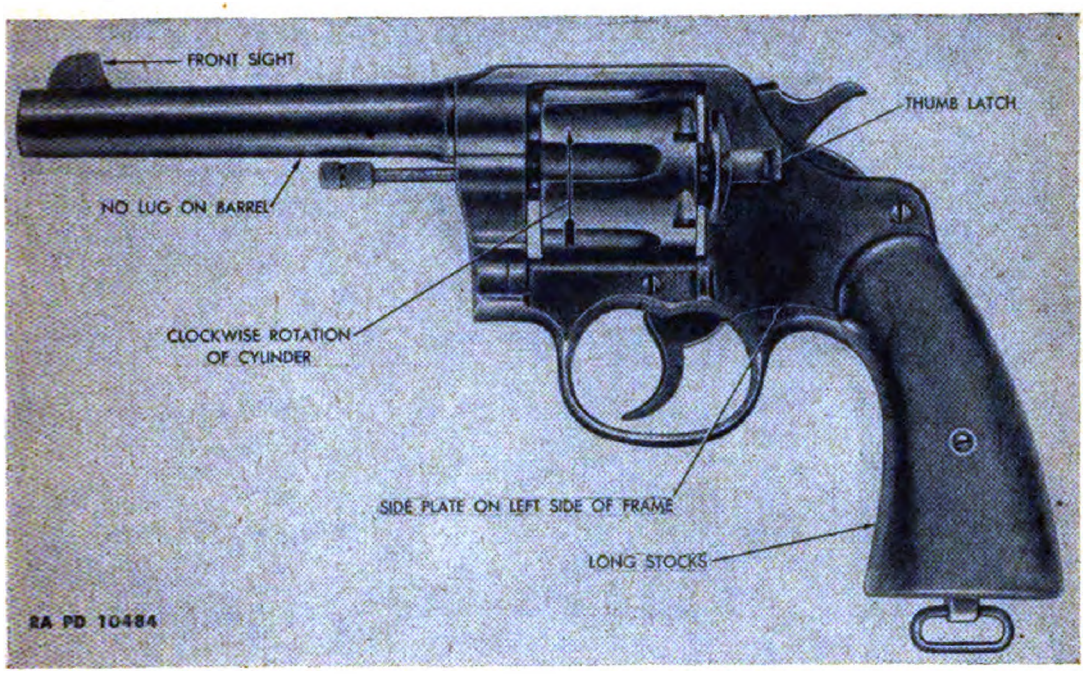
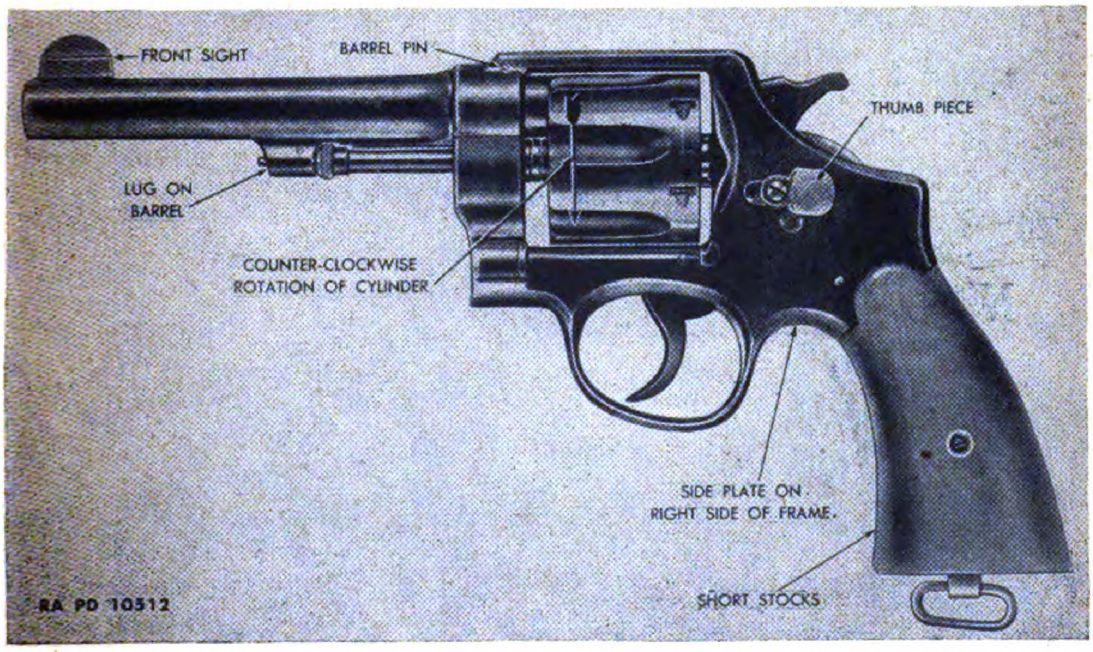


Colt.



Smith and Wesson.

Figure 90a. Revolvers, Cal .45 M1917. Left Side View.

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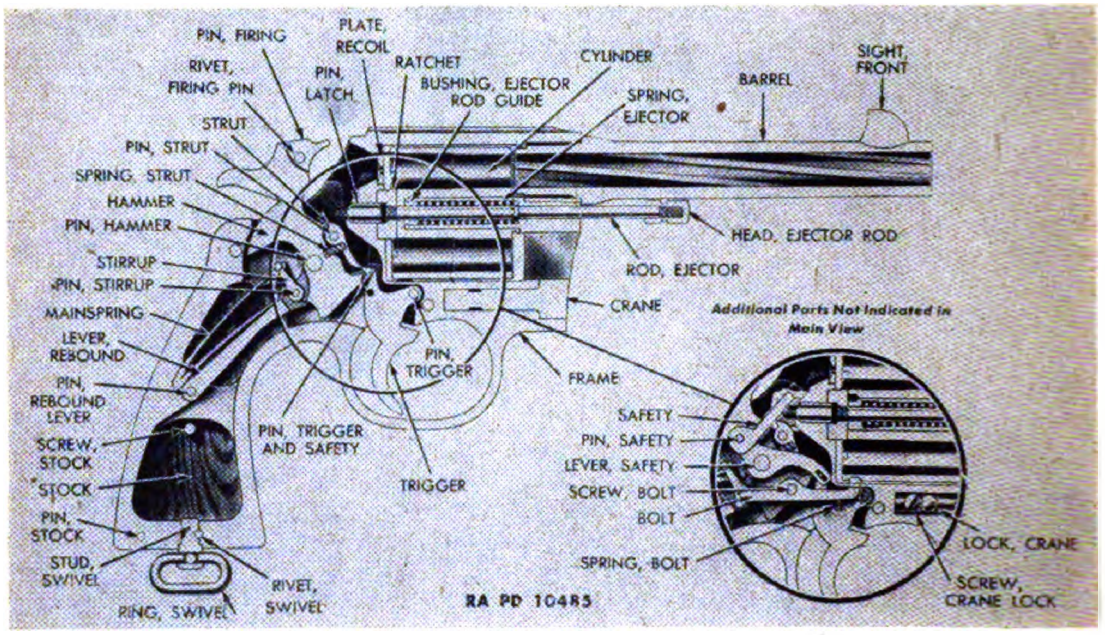

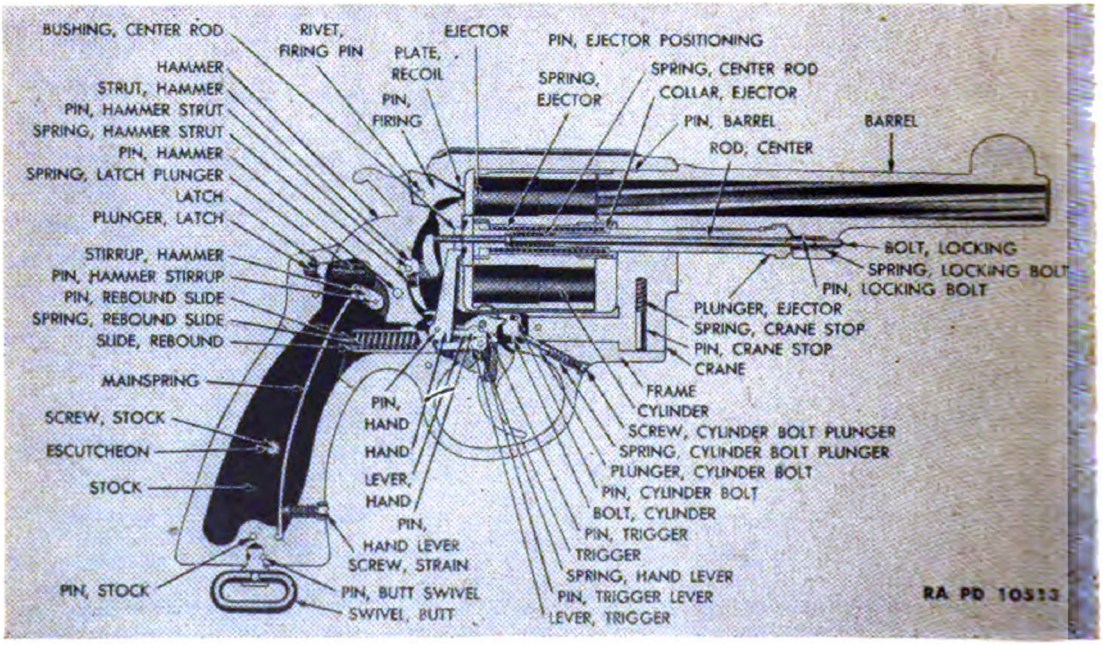

Figure 90b. Revolver Cross-Sections Showing Nomenclature.

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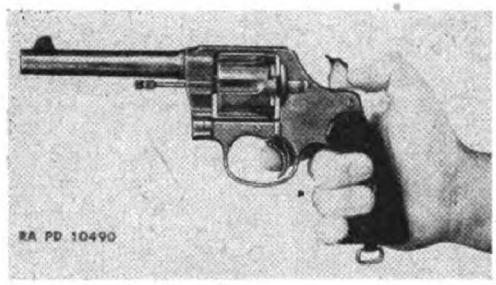
hammer struck the cap the nipple served as an anvil to explode it. The flash, entering through the hollow nipple, ignited the powder inside the chamber.

Various models, using this cap-and-ball principle, were used in such campaigns as the Seminole War, the Mexican War, etc. They were popularly known as the Paterson, Walker, Dragoon, Texas Arm, and so on, until the development of the center-fire metallic cartridge for hand guns. By 1872 alterations of cap-and-ball revolvers were being carried out to fit them for the new cartridges.



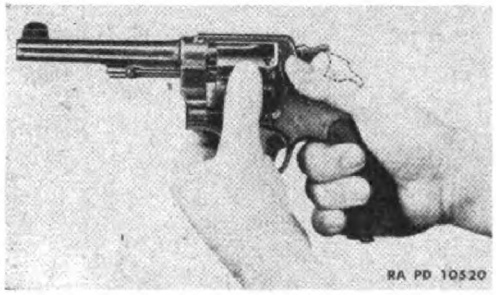


Figure 91. Safety Features of Revolvers.

In 1873, Colt delivered an initial order of eight thousand newly designed weapons known as the single-action Army model Cal .45. In 1877 the double action or self-cocking model came into service, later to be known as the Philippine Model because of extensive use there against fanatical Moro head-hunters. These were manufactured until 1910, when attention was turned to the Cal .45 semi-automatic pistol. The present cal .45 revolver, Model 1917, superseded the Philippine Model.

With the advent of modern submachine guns, carbines, and other light rapid fire weapons, the cal .45 revolver is no longer used extensively in theaters of operation. Although still carried by some officers as a personal side arm, it is now classified as substitute standard. It is used chiefly for interior guard duty in military camps, arsenals, and commercial organizations under protection of

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the Armed Forces. Large numbers of them also have been issued in lieu of the cal .45 semiautomatic pistol.

Description. There are two types of the cal .45 revolver, Model 1917: the Colt and the Smith & Wesson (S & W) types. They are single and double-action, six-shot hand weapons. Weight of the Colt is 2½ pounds, of the S & W, 2¼ pounds. Diameter of the bore is .445 inch, number of grooves and lands is 6. Standard ammunition is ball, cal .45 M1911. Loading is done by two clips of three cartridges each, both being ejected by means of a rod directly beneath the 5½-inch barrel. Both models are fitted with the swing-out type of cylinder. Finish is blue with hard wooden stock.

Safety Features. To insure against accidental discharge, premature firing, firing while the cylinder is out of line, etc., a number of mechanical safeties have been incorporated in the operation of both weapons. They are listed as follows:

Colt. As the cylinder begins to revolve through cocking action, the bolt comes up through the frame and engages in the locking recess milled opposite each of the six chambers, thus locking the cylinder firmly in place with the loaded chamber aligned with the barrel.

The hand that revolves the cylinder remains against the ratchet notch until the trigger starts forward again, insuring that each chamber will be held in perfect alignment with the barrel.

After the hammer falls forward, the rebound lever retracts the firing pin about ⅛ inch through the recoil plate to prevent its resting against the primer of a live round. This prevents accidental discharge from sudden jars such as dropping to the floor.

Through action of the safety, the latch pin cannot be withdrawn from the cylinder while the gun is cocked. Thus the cylinder can not be swung out while the weapon is cocked for firing. Only after the hammer has fallen forward can the latch pin be released and the cylinder leave the frame.

Smith & Wesson. As the cylinder begins to revolve, the cylinder bolt (as in the Colt) comes up through an opening in the frame, and engages in the locking recess milled opposite each of the six chambers, thus locking the cylinder firmly in place with the loaded chamber aligned with the barrel.

The hand that revolves the cylinder also serves as an additional safety by remaining against the ratchet notch in the ejector until the trigger starts forward again, aiding in perfect alignment between chamber and barrel.

After the hammer falls and the trigger is released by the finger, the trigger again moves forward under pressure of the rebound slide. This approximately ⅛-inch forward movement of the trigger withdraws the firing pin into the recoil plate to prevent the pin from resting against the primer of a live round. By such action, accidental discharge is prevented should the weapon be inadvertently snapped or dropped to the floor.

Through action of the latch the hammer can not be cocked while the cylinder is partly open. The latch plunger spring holds the latch forward, forcing a lug beneath the rear edge of the hammer. Only after the cylinder is swung into the frame does the center rod spring force the latch backward from beneath the lug at the rear of the hammer.

Differences Between the Colt and the Smith & Wesson Types

Although these two revolvers are basically the same in construction and operational principles, there are a number of differences that should be noted.

COLT	SMITH & WESSON
Rifling is left hand twist.	Rifling is right hand twist.
Cylinder rotates to right, or clockwise.	Cylinder rotates to left, counter-clockwise.
Side plate for disassembly is on left.	Side plate for disassembly is on right.
Uses a V-type main spring.	Uses a leaf type main spring.
Has a rebound lever for trigger tension.	Has rebound slide for trigger tension.

Functioning. As the hammer is being withdrawn to the rear with the thumb, the bolt that locks the cylinder in place is moved downward from its locking recess in the cylinder. This unlocks the cylinder and allows it to revolve. The same trigger action that draws the bolt downward into the frame also starts

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the hand upward to engage in the ratchet notch (Colt) or ejector notch (S & W), forcing the cylinder to begin revolving toward the next chamber. As the hammer proceeds to the rear, compressing the main spring, the cylinder bolt is released by the trigger (S & W only) and again allowed to come up against the under side of the cylinder. When the hand has pushed the ratchet one-sixth of a turn to the next chamber, bringing it in line with the barrel, the cylinder bolt slips into the locking recess under the new chamber and again locks the cylinder securely in place. This action leaves the weapon fully cocked, the tip of the trigger now being engaged in the full-cock notch in the hammer. Pressure on the trigger disengages it and allows the hammer, under tension of the main spring, to fall forward.

Operation: Single and Double-Action

Single-action. The hammer is first pulled all the way to the rear with the thumb until the upper edge of the trigger engages in the full-cock notch in the front end of the lower part of the hammer. When pressure is applied to the trigger, the upper edge engaged in the full-cock notch disengages itself. Under tension of the main spring the hammer falls forward. During this operation the trigger must be held back until the hammer falls all the way down. If the trigger is prematurely released, mechanical safeties in both weapons will prevent the hammer pin from striking the cartridge. On the Colt the safety will be re-engaged. On the S & W the projection on the rebound slide will accomplish the same action.

Double-action. Pressure of the finger upon the trigger causes the upper edge of the trigger to engage the hammer strut. On the Colt the hammer is thereby raised until in nearly full-cocked position; then the strut escapes from the trigger and allows the hammer to fall. On the S & W the same action occurs, except that when the trigger begins to escape the strut, another portion of the trigger engages under the hammer and carries it on higher until this part also escapes and allows the hammer to fall.

Loading and Unloading. Grasp the weapon in the right hand and push forward on the thumb piece with the right thumb; on the Colt, pull to the rear. This action releases the locking mechanism of both weapons and allows the cylinder to swing out on the crane. Lay the weapon in the palm of the left hand, but make sure the barrel is pointed away from the body or down range. With the second and third fingers of the left hand force the cylinder out from the frame.

Caution: Never flip out the cylinder by a snap of the wrist, as such action will damage the crane by throwing it out of alignment.

With the cylinder out and the weapon in the left palm, insert two clips of three cartridges each into the chambers, first making certain that the clips are not bent. Bent clips will prevent the cylinder from closing. With the left thumb swing the cylinder shut, and then turn it until the bolt underneath clicks into place in the locking recess of the chamber. The revolver is now ready to fire.

To unload the weapon push forward on the thumb piece and swing out the cylinder; on the Colt, pull to the rear. Place in the palm of the left hand, as in loading, with the second and third fingers extending through the opening in the frame to hold the cylinder firm. With the right hand, reach under the left hand and grasp the ejector rod. A sharp jerk on the ejector rod will push out the two clips containing the six cartridges. Swing the cylinder back into the frame with the thumb and two fingers of the left hand.

Inspection. Make a visual inspection for burrs, bent front sight, missing side plate screws, and bluing condition. Check the stocks for cracks and loose screws. Examine the frame for cracks where the barrel is screwed into the frame. Look for rust inside the opening in front of the cocked hammer, particularly during damp weather. Since the internal parts have not been treated with a rust preventive compound, this condition will appear regularly almost overnight. Check the barrel for looseness in the frame.

Hold the weapon upside down so that the cylinder bolt comes level with the eye. With the weapon in this position, pull back the hammer *very slowly* until the bolt engages its recess in the cylinder to insure perfect locking action.

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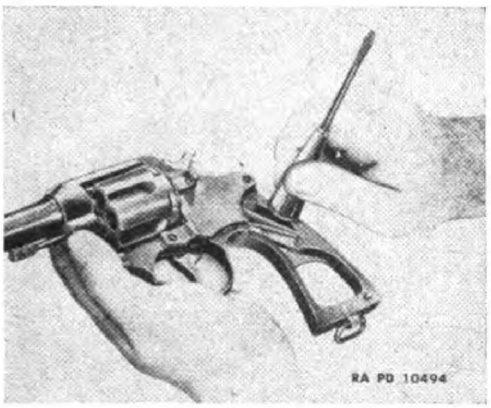
If the cylinder fails to lock at the end of this slow cocking, the hand is too short or the ratchet is worn.

With the hammer fully forward try to rotate the cylinder. If there is more than 1/64-inch movement, the cylinder bolt is worn and a new one must be fitted.

Hold the hammer back with the thumb, press the trigger and allow the hammer to move forward ¼-inch and release the trigger; then release the hammer and let it fall forward. If the firing pin projects through the hole in the recoil plate, the hammer or rebound slide is faulty. (On the Colt the safety or rebound lever would be faulty.)

Try the double-action two or three times. If it is too light, the main spring is faulty. If it is too strong or the action is not smooth, one of three things is to be checked:



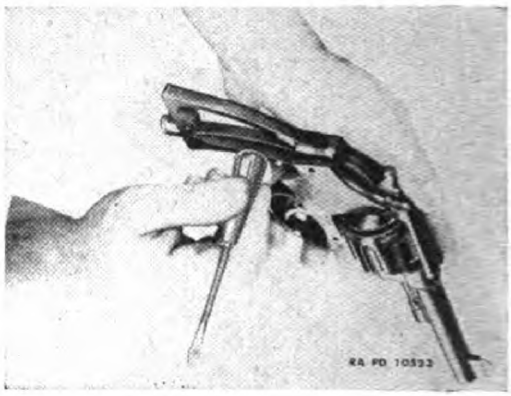


Figure 92. Removing Side Plate from Revolver M1917.

The hammer or trigger pin is loose or worn, causing a slight bind; burrs on the hammer or trigger.

The main spring strain screw (S&W) may be loose.

The side plate may be binding.

Check the trigger pull, which should be from 5 to 6½ pounds. Any suitable weights with a stiff wire hook attached can be used. Grasp the weapon by the barrel, holding the muzzle up, and insert the hook through the trigger guard against the cocked trigger. Lift very gently. If the trigger will not withstand a 5 pound pull, the trigger tip or cock notch in the hammer is worn. If the trigger withstands more than 6½ pounds of weight, the trigger tip should be stoned to allow easier release.

Preventive Maintenance. When a weapon is carried frequently but not fired, rub it externally with a lightly oiled rag and then wipe with a dry rag. Use an oily patch to swab out the bore and follow this with a dry patch. It should be noted, however, that acid from bare hands, particularly during hot weather, is very damaging to the exterior of a revolver. Therefore the weapon should be rubbed briskly with a lightly oiled rag after handling.

To clean the revolver after firing, swing out the cylinder and hold the weapon with the muzzle up. Insert into the muzzle a rod holding a cleaning patch that has been soaked in hot water and GI soap. Pump this forward and back for about one minute, dipping the patch frequently to keep it wet. While the bore is still wet a brass wire brush should be run all the way through the bore and back several times to remove any metal fouling. Make certain that the brush is run all the way through the cylinder opening in the frame before reversing the stroke. If this is not done, the wires of the brush will be reversed while inside the bore with consequent damage to the brush. Use this same method to clean the six chambers.

Wipe the weapon with a dry rag to remove all traces of water and soap. Wipe the cleaning rod. Run a dry patch through the bore and all chambers, followed by a lightly oiled patch.

Caution: Do not use an oily patch to clean a revolver bore and chambers

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immediately after firing. This will not be sufficient to remove salts and will only gum up the weapon. This method should be used only when conditions will not permit the immediate proper cleaning of the bore and chambers.

Further, due to damaging corrosion caused by gas escaping between the barrel and cylinder, the following parts require special attention after firing:

The frame just above the cylinder at the rear of the barrel.

The nose of the hammer.

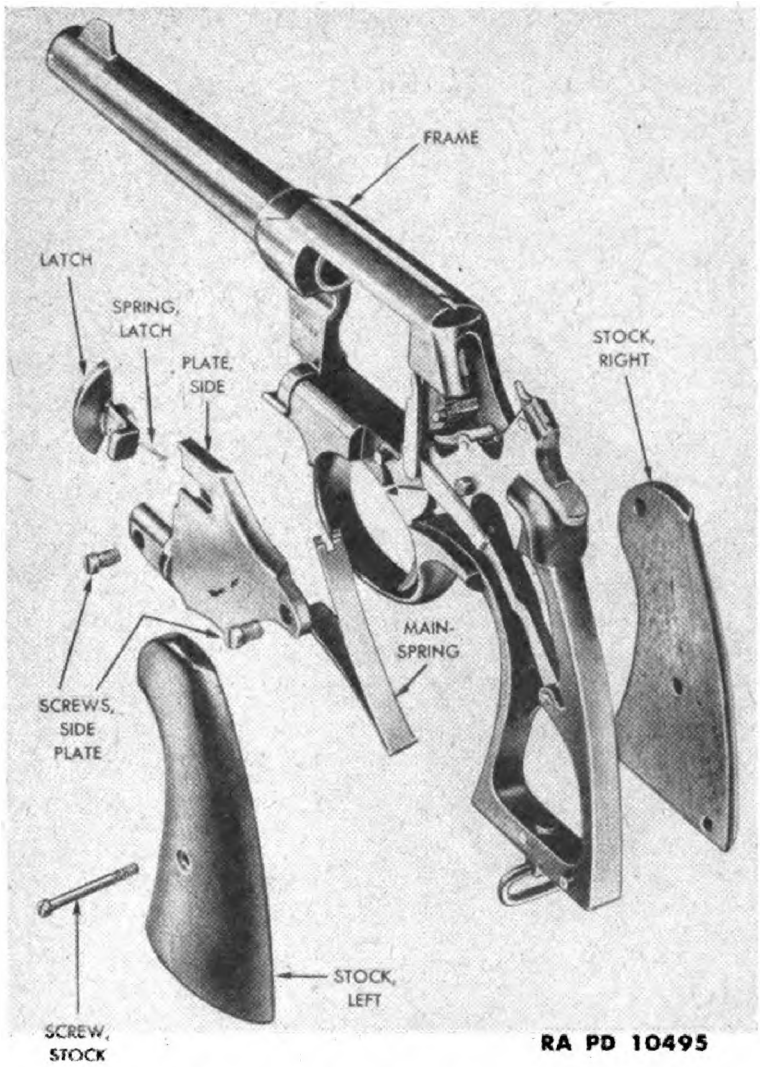

Figure 93. Field Stripping, Revolver Cal .45 M1917 Colt.

The hammer groove in the frame and firing pin in the recoil plate.

Repair. Of all the weapons in use by various branches of the Armed Forces the cal .45 revolver is probably the most difficult to repair properly. This is due to the fact that so many of the parts must be hand fitted. Some of these parts (particularly on the S&W) have been case hardened and are difficult to file, especially the hammer, trigger, hand, and strut.

A sharp-edge 'Arkansas' stone must be used on such operations as deepening the full-cock notch in the hammer. The edge on this stone can be maintained by placing a piece of emery cloth flat on the bench and sharpening the stone on it. For other operations ordinary square or triangular shaped oil stones and small Swiss files can be used.

It should be borne in mind that all internal parts of the revolver must be in perfect alignment and stoned in proper proportions to insure perfect operation.

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If, for example, the hammer strut is too long and causes a bind on the trigger tip during double-action cocking, the tendency is to file down the trigger tip. This will cause the shortened tip to drop below the full-cock notch lug on the hammer during *single-action* cocking and therefore cause a bind in a different place.

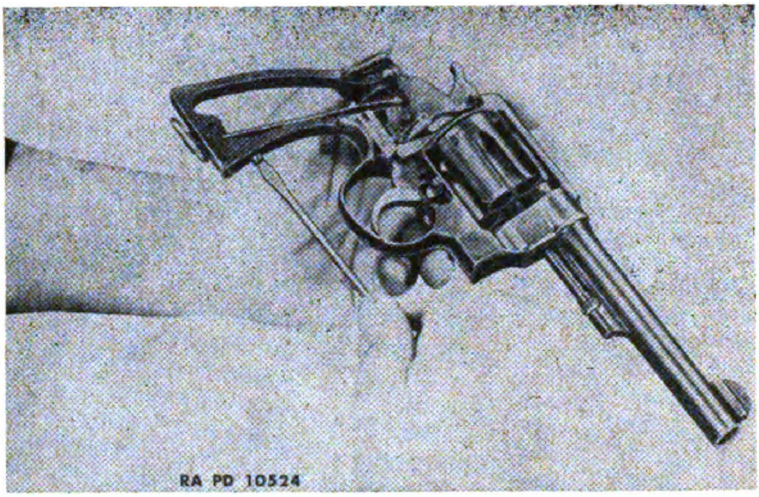

Figure 94. Removing the Mainspring Strain Screw from S&W Revolver M1917.

The hand fitting of the various internal parts of the revolver should be done as follows:

Remove the crane locking screw and take out the cylinder. Remove the stock screw and tap loose the stocks. Take out the side plate screws but *do not* pry loose the side plate. Each side plate is individually fitted to each weapon and must not be burred—nor can it be used in another revolver.

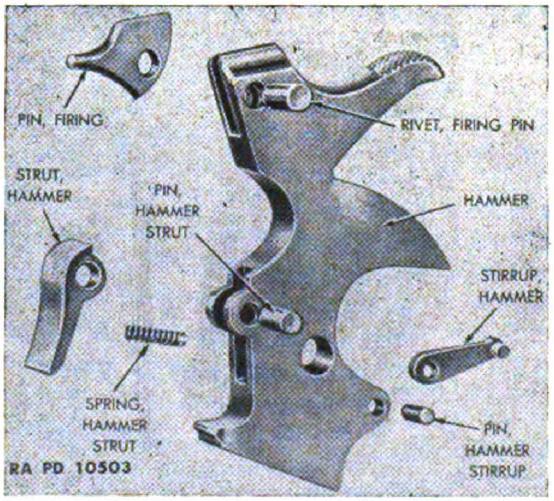

Figure 95. Hammer Assembly of Colt Revolver M1917. Exploded View.

Hold the weapon in the left palm with the side plate up. With the handle of a screw driver tap around the edges of the side plate until it breaks free of the frame.

Remove the main spring. On the S&W this is accomplished by first unscrewing the main spring strain screw beneath the grip.

Remove the rebound slide (or rebound lever on the Colt).

Disengage the hand from its groove in the frame and lift out the trigger and hammer assemblies.

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Remove the cylinder bolt.

Check the interior of the weapon for burrs around the hammer slot and cylinder bolt slot in the frame. Check all pins, such as hammer pin, trigger pin, cylinder bolt pin, etc. Some pins usually will be found to be loose, making a common cause of binding action among the various working parts. Loose pins should be screwed in tight again and staked fast in the frame with a center punch. Make sure that all center punch burrs are stoned away.

Replace the cylinder bolt and trigger. Work the trigger back and forth with thumb and finger to see that there is no drag on either part. Slip the new hammer into place. Work it back and forth for free action on the hammer pin, and see that it does not bind in its working slot. Fit the new or old stirrup at the rear, stoning away all burrs around the ends of the pin. Fit on the new strut and note its length.

In most cases the new strut will not fit, since it was made oversize. It must be filed down according to the thickness and length of the trigger tip, so that when the trigger is placed into position there will be no bind between the tip and the strut.

With the strut and stirrup in place, work the trigger back and forth to see that there is perfect action between the hammer, trigger, and cylinder bolt.

If a new cylinder bolt is to be installed, it, too, is oversize. The head must be filed and stoned away until it will move freely in and out of the locking recess in the cylinder. Once this bolt head is shaped to proper size, slip in the trigger and test its action by working the trigger back and forth. Action must be free.

With the hammer, trigger, and cylinder bolt working freely and smoothly, replace the rebound slide (S & W), and try the action again by working the trigger. Hold all parts in place with the thumb and try the cocking action.

After inserting the main spring, try the action once more.

Replace the side plate, but do not put in the hand (on S & W). See that the weapon's internal parts function perfectly, trying both single and double-action. Any binding action now will come from the side plate. Check for burrs should the parts not function freely.

When these parts work perfectly remove the side plate and slip in the hand. Replace the side plate. Put in the cylinder, thus completing the assembly of the weapon.

Now try to move the cylinder by grasping with the thumb and fingers. A new cylinder bolt head, properly fitted, should allow less than 1/64 inch of play.

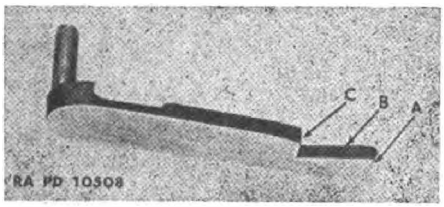

Figure 96. Hand of Colt Revolver M1917, Surfaces Requiring Fitting.

Next try single action cocking. If the new cylinder bolt head does not lock in the recess milled beneath each chamber, the hand is too short or the ratchet-notches (Colt) at the rear of the cylinder are worn. If the hand is too long, it will push the cylinder past alignment with the barrel and must be shortened by stoning.

In the case of a shortened hand, it sometimes can be lengthened by peening with a hammer, especially when new parts are not immediately available. Otherwise try a longer hand.

To fit this hand onto the Colt, it is necessary to observe the surfaces marked A, B, and C. If B does not clear the ratchet, the necessary clearance can be obtained by filing or stoning it to fit. When the cylinder is stopped by the cylinder bolt, the surface C should be resting firmly underneath the flange of the ratchet.

Should proper action not be obtained by fitting the new hand, a new ratchet or new trigger will be installed.

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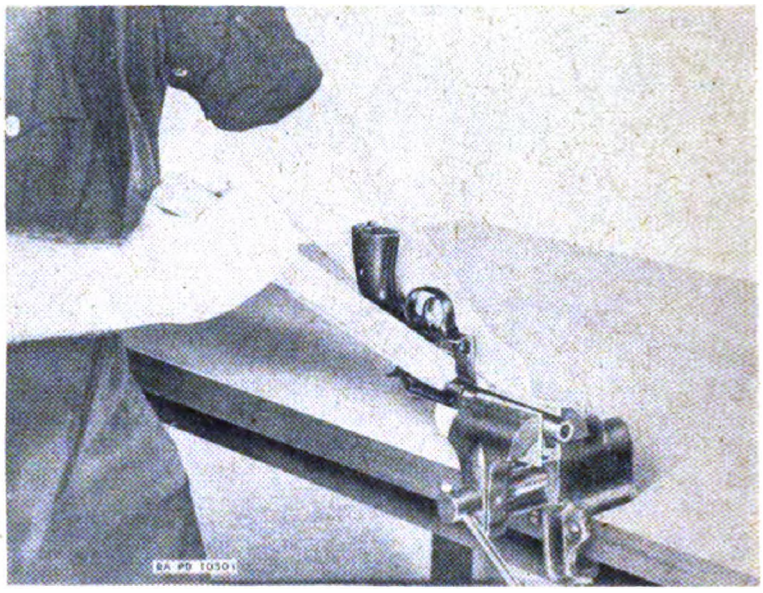
Use a cylinder alignment gage to insure a perfect fit by holding the muzzle up and letting the gage slide down the bore into the aligned chamber. Lift the gage until it clears the chamber, and cock the weapon by single-action until each succeeding chamber comes into line. Try with double-action cocking, letting the hammer fall forward.



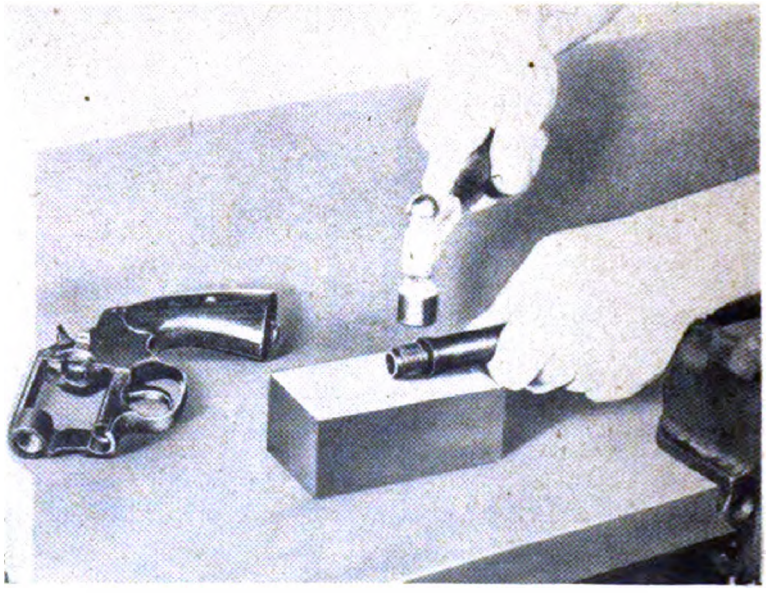


Figure 97. Repair of Barrel, Revolver M1917, Colt.
1. Removing Barrel. 2. Peening Shoulder.

Sometimes a weapon whose chambers will align perfectly with a barrel during single-action cocking will not align during double-action cocking. When this condition occurs on the S & W, file off the inside corner of the hand where it rests against the notch. This will allow it to clear during double-action cocking. This condition is not likely to occur on the Colt.

With the weapon in good working order, it is now necessary to check the clearance between the end of the barrel and the chamber. This should be from .002 inch to .008 inch. Use a feeler gage.

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If there is less than .002-inch clearance between the rear end of the barrel and the front of the cylinder, use a file to remove the necessary metal from the rear end of the barrel until proper clearance is obtained. Do this using great care.

Reduction of Excessive Clearance.

Colt: Since the cylinder is allowed no forward movement to close excessive space between its forward end and the rear end of the barrel, it is necessary to remove the barrel. Make a small alignment mark for the replacement of barrel in the frame. Place the barrel in a vise with lead jaws. Use a hardwood stick approximately 1⅜ inches square and 20 inches long as a lever in the cylinder opening in the frame. *Do not* use a metal bar. Unscrew the barrel.

Use a file or lathe to remove approximately .050 inch from the shoulder. This is one turn of the thread and will align the barrel again. Should the barrel not align, the shoulder can be peened or more metal removed with a file to bring the alignment marks together in a tight fit.

With the barrel again back in the frame and perfectly aligned, file off the necessary metal from the rear end to allow the cylinder from .002 inch to .008 inch clearance.

Smith & Wesson. Excessive clearance between the cylinder and barrel can be adjusted in the same manner as on the Colt, except that in cutting off enough metal from the shoulder to be the approximate equivalent of one turn of the thread, only .029 inch will be removed. This is because Smith & Wesson threads are finer.

However, if the excessive clearance is only .002 inch or .003 inch over, this sometimes can be remedied by removing the center rod bushing at the rear of the cylinder and by replacing it with a new one. This forces the cylinder forward from .001 inch to .003 inch, against the rear end of the barrel.

Fitting New Barrels. The fitting of a new barrel is done exactly as above, by removing the pin through the frame and unscrewing the threads. If the new barrel will not come into line, file off the shoulder until there is sufficient clearance. If it goes past the alignment mark, place the barrel on an anvil and peen the shoulder lightly. Replace the pin and secure proper clearance between the cylinder and rear end of the barrel as explained above.

MACHINE GUNS

Centuries ago, after the rifle had finally come into general use, soldiers began to dream of a rifle-like weapon that would produce a high volume of fire. As early as the 16th century men were experimenting with this idea. They tried placing barrels side by side, with one man firing them with a match. Crude, it's true, but this marked the beginning of the machine gun. Later, weapons were developed and operated by levers and cranks.

During the latter part of the 19th century, the first truly automatic machine gun, the Maxim, was invented. This paved the way for many such weapons and in 1917 John M. Browning developed a machine gun which bears his name. This weapon was accepted by the United States at that time as one of its standard weapons. Since this first acceptance by the US, the Browning machine guns have been standard weapons.

Following is on outline of the developments leading up to the present day standard ground machine guns. Although aircraft armament is discussed in a separate chapter, all types of Browning automatic machine guns are discussed here because of their close similarity in construction, functioning, stripping, maintenance, and care. A detailed description as to general data, functioning, disassembly and assembly, and references will follow this general information on the development of Browning machine guns.

The first Browning machine gun was a cal .30, recoil-operated, belt-fed, water-cooled weapon. The belt was fed from the left only. The water-cooling system is not of the forced circulation type, but depends on the fact that hot water will rise to the top part of the jacket that surrounds the barrel. The barrel lies in the bottom portion of the jacket surrounded by the cooler water. This gun, designated the Browning machine gun, cal .30 M1917 is the basic gun for all later weapons of this type developed by Browning. It was mounted on the Tripod Mount M1917

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and referred to as the 'heavy' machine gun. Reference to it as a 'heavy' gun is due to two reasons: it could deliver a heavy volume of fire, and the gun and mount were so heavy that the weapon was generally set up in a fairly permanent position. This gun was later modified to the Browning Machine Gun M1917A1 and the mount to the Mount Tripod M1917A1, both of which are standard at present.

In 1919, the Browning Machine Gun, cal .30 M1919 was adopted as a standard tank weapon. This gun was basically the same as the M1917, except that it was air-cooled and mounted as a fixed weapon in a tank. Later this same weapon was modified and made adaptable to a light ground tripod mount. So set up, it was first used by the cavalry as a light ground machine gun. Because it was air-cooled, the gun delivered a light amount of fire as compared to the 'heavy' machine gun. This, and the fact that it was mounted on a light mount, resulted in its being referred to as the 'light' machine gun. With modifications, this weapon was changed into the Browning Machine Gun M1919A4, which is standard at the present time. The standard mount for this gun is the Tripod Mount, cal .30 M2.

(The Browning Machine Gun, cal .30 M1919A5 which is a special tank weapon, and the M1919A6, having a bipod and stock and used much like an automatic rifle, are also standard at the present time.)

The above are all the present standard cal .30 machine guns. The development of standard cal .50 machine guns is a similar story since these weapons also utilize the Browning action.

Just prior to the end of the first World War, there was a demand for a larger caliber machine gun. Work was started on such a weapon by Browning; however, the war ended before the weapon was developed and actually put into use. Work continued on the gun however, and in 1921 the Browning machine gun, cal .50 M1921 was adopted as standard. Here again the weapon was recoil-operated, belt-fed from the left, and water-cooled by the same type system as the cal .30. The water-cooling system was changed later to a forced circulating system employing a pump in a water chest and connecting hoses from the chest to the water jacket. This M1921 machine gun was used on the AA (Antiaircraft) Tripod Mount, cal .50 M1. Further changes incorporated in this cal .50 resulted in the present standard cal .50 weapons. There are two standard cal .50 ground guns, the Browning Machine Gun, cal .50 M2, HB (Heavy Barrel), and the M2, WC (Water-cooled).

The M2, WC is practically the same as the M1921. However, further developments have resulted in a more efficient weapon. It was primarily intended for use against aircraft but of course can be used against ground targets also. The water jacket has been lengthened somewhat but still employs a forced circulating system.

The M2, HB is an air-cooled weapon mounted on the Ground Tripod Mount M3. This weapon was first put to use against light mechanized units but at the present time is being used more and more as an antiaircraft weapon. It is mounted on several types of antiaircraft mounts.

Another important change from the M1921 is that the M2 (HB, WC), as well as the aircraft machine gun, can feed either from the right or left by properly repositioning various parts of the feeding mechanism. The receivers of all M2 cal .50 machine guns are identical; therefore the one basic cal .50 machine gun may be assembled into the water-cooled, heavy barrel, fixed or flexible types, according to mount used, or into the aircraft type AN-M2.

The M2, WC was first set up to fire from the AA Tripod Mount, cal .50 M2. This mount had a fairly complicated remote control sighting system which was later discarded, and the mount is now known as the M2A1. At the present time, however, the AA Tripod Mount M3 is standard, although the M2A1 is also being put to much use.

During the latter part of World War I and until shortly before the outbreak of this war, all nations, our own included, mounted a machine gun of approximately .30 caliber in their aircraft. The Browning machine gun, cal .30 M2, AC was the standard machine gun for use by the U. S. Army Air Forces. This weapon is an adaptation of the Browning machine guns, M1917A1 and M1919A4. It is a short recoil-operated, metallic-link, belt-fed, air-cooled gun. Firing

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regulation cal .30 rifle cartridge a maximum range of 3,500 yards, with a muzzle velocity of 2,700 feet per second at a rate of 600 rounds per minute, it was considered adequate for the missions assigned to it during peacetime. With the increase in size of enemy planes, and their added fire power, armor plating, and increased speed, it became necessary to step up the striking power of our weapons. At the present, this gun is used only at gunnery training stations and in a few observation planes. The pertinent technical information on this weapon can be obtained from the following publications: TM 9-205, TM 9-1205, and SNL A-28.

Having mentioned all the present standard cal .30 and cal .50 machine guns, we can now go ahead and discuss them each in their entirety.

.30 CALIBER MACHINE GUNS

Browning Machine Gun Cal .30 M1919A4

Description. The M1919A4 machine gun is an air-cooled, recoil-operated weapon. It is fed from a fabric web belt, only from the left-hand side. This weapon will be found on various types of armored vehicles and for ground use is mounted on the M2 tripod ground mount. When carried by ground troops, the gun is usually transported separately from the mount, for it can be set up for firing in a matter of seconds. Being an aircooled weapon, its barrel is comparatively heavy; for cooling it depends upon radiating its heat to the atmosphere

Figure 98. Browning Machine Gun Cal .30 M1919A4. Left Side View.

The M1919A4 weighs about 34 pounds without ammunition or mount. While the cyclic rate of fire is about 450 rounds per minute, the sustained rate of fire over a given period of time is about 150 rounds per minute. Ammunition used therein is ball, armor-piercing, and tracer, with a maximum range of about 3,500 yards.

Browning Machine Gun Cal .30 M1917A1

Description. The M1917A1 is a recoil-operated, water-cooled weapon that fires from a fabric web belt, and can only be fed from the left. Being water-cooled, and therefore having a much more efficient system for cooling the barrel, it has a higher sustained rate of fire (about 250 rounds per minute) and is known as the 'heavy' machine gun of the ground forces. It is mounted on the M1917A1 tripod mount, which has a rather intricate and accurate elevating and traversing

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mechanism, making the effective range of this weapon somewhat greater than the M1919A4. This weapon is used considerably for laying down indirect fire.

The water jacket on this weapon holds approximately 7 pints of water which brings the weight up from 32.6 lbs. empty to about 41 pounds when full of water. Contained in the water jacket is a steam tube assembly which is used to conduct the steam created by the heating up of the barrel away from the gun to where it can be condensed and the resulting water used again. By condensing the steam again, the possibility of its giving away the gunner's position by escape into the air is eliminated.

Field Stripping

Inasmuch as the Browning Machine Gun cal .30 M1919A4 and the Browning Machine Gun cal .30 M1917A1 are very similar in disassembly, assembly, and operation, they will be considered as one herein, with points peculiar to each gun enumerated at the proper time.

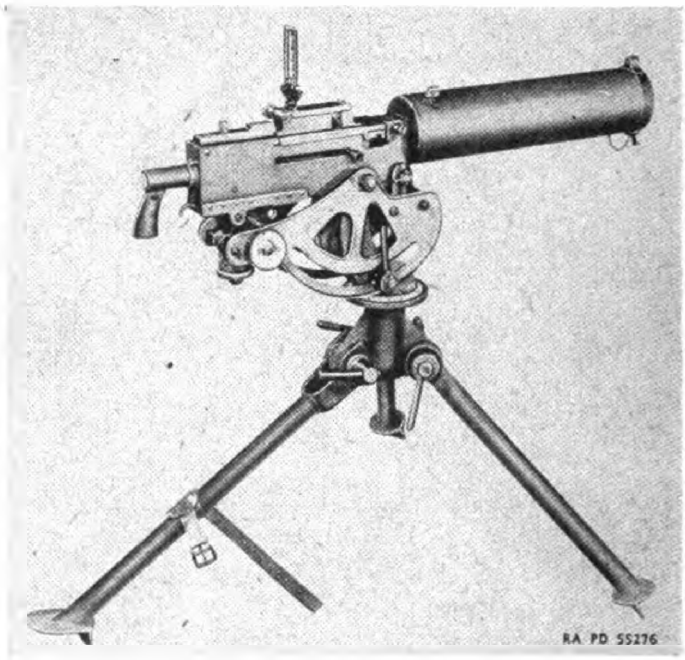

Figure 99. Browning Machine Gun Cal .30 M1917A1, Watercooled, with Mount, Tripod, Machine Gun Cal .30 M1917A1. Right Side View.

For proper preventive maintenance, the using arm is authorized to disassemble the machine gun down to a certain point to permit proper cleaning and lubrication. This, of course, is done after the operator has made certain that the gun is clear, *i.e.*, that there is no ammunition contained therein.

Before raising the cover on the M1917A1 machine gun, the rear sight leaf must be raised to prevent striking it against the water jacket and damaging either the sight or the jacket. The latch on the top plate of the receiver is pulled to the rear sufficiently to clear the cover, and the cover is then raised. The bolt handle on the right side is pulled to the rear and held there while the driving spring rod, which protrudes about ½ inch from the back plate, is pushed forward and then rotated to the right one quarter turn to engage the bolt. When engaged, the slot in the driving spring rod will be vertical. The rod will then stay forward with the bolt, and the tension of the driving spring will be held in this manner so that the bolt will not fly forward. Push the bolt handle forward an inch or two, push the latch on the top plate forward enough to clear the backplate, and the backplate group can then be lifted upward off the receiver.

Next, pull the bolt all the way back and withdraw the bolt handle to the right. The bolt itself can now be withdrawn from the rear of the receiver. It is im-

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perative at this point to be particularly careful not to turn the driving spring rod, which now protrudes from the rear of the bolt, for if this is accidentally released, the rod and spring can fly out with sufficient force to injure a person seriously.

On the right side of the receiver, about an inch from the bottom and about two inches from the rear will be found a small hole. Using a drift or the nose of a cartridge, depress the spring-actuated plunger (trigger pin) found therein. Holding this depressed, reach into the rear of the receiver, grasp the lock frame spacer (round rod) that runs crosswise near the bottom, and pull. From the receiver will come the barrel, barrel extension, and lock frame, in that order from front to rear. On the lock frame, where it joins the barrel extension, will be found a piece that looks like the claws of a hammer. This part is the accelerator. Firmly grasp the lock frame, push forward on the tips of the accelerator, and the lock frame will jump rearward from the barrel extension. The barrel can then be unscrewed from the barrel extension.

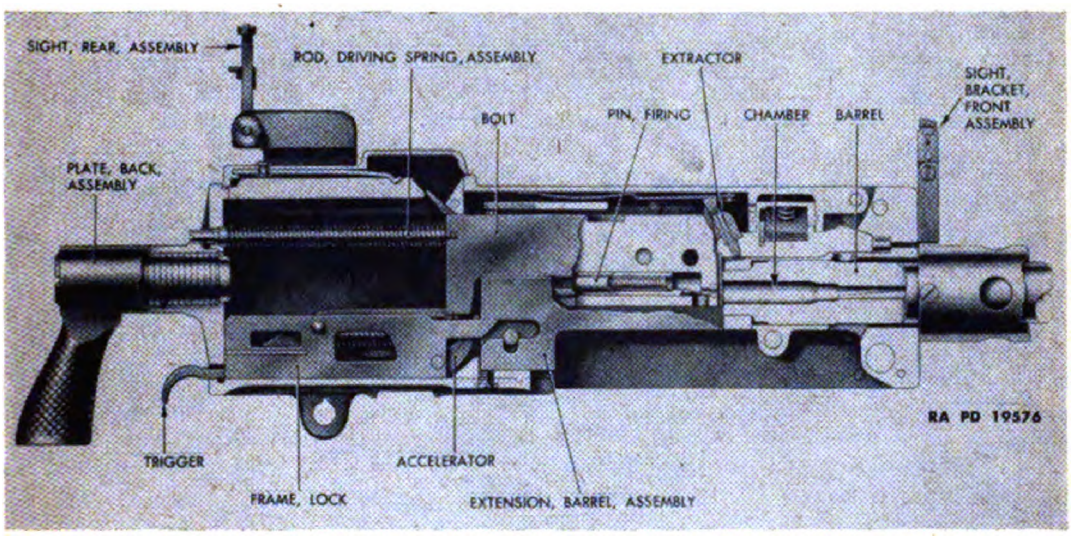

Figure 100. Right Side Sectional View of M1919A4 MG.

Next the cover can be removed. Have the cover down so it will not fall. The cover is held in place by a group of parts consisting of a bolt, a nut, a spring, and two plates, one of which straddles the cover, the other straddling the corner of the receiver all of which make up the cover catch group. Before removing, note carefully how these parts of the cover catch group are assembled. Then remove the nut, and remove the bolt, spring, and two plates. The cover can now be removed from the receiver. Lastly, the latch on the top plate of the receiver can be removed by sliding it to the rear. This can best be done by tapping with the heel of the hand or a rawhide hammer to avoid skinning the knuckles.

Assembly After Field Stripping

In assembling the machine gun it will be necessary to make some adjustment and observe several precautions.

First, the latch can be assembled to the receiver. It will be necessary to depress the latch spring to get it started, and then care should again be taken to prevent skinning the knuckles. This can best be done by tapping the latch back on with the heel of the hand or a rawhide hammer.

In replacing the cover group, assemble the cover catch group, making sure that the fixed and movable plates are in the proper relation to each other, *i.e.*, that the raised portion on the fixed plate faces the recessed portion on the movable plate, with movable plate toward the right, or outside. Set the cover in place, insert the cover bolt, position the fixed and movable plates, and screw on the castellated nut. The nut must then be held in place by means of a small cotter pin.

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Screw the barrel into the barrel extension until the barrel locking spring engages the serrations of the barrel. Do not screw the barrel in all the way. In the rear of the barrel extension is a rectangular metal block known as the breech lock. On the bottom of the bolt is a recess cut across the bolt and located about one inch from the rear. This recess is the breech lock recess, in which the breech lock will fit when the parts are assembled. With the extractor removed from the bolt, engage the bolt and the barrel extension, making *sure* that the bolt is properly engaged. With the bolt all the way forward, push the breech lock all the way up and hold it there firmly. Screw the barrel in until the rear end of the barrel contacts the front of the bolt. At this point the barrel will cease to turn easily. Stop and back off the barrel two clicks. The adjustable headspace is now correct and should not be changed during the further assembly of the weapon.

Remove the bolt from the barrel extension and replace the extractor.

To assemble the lock frame to the barrel extension, hold the accelerator so that the tips point forward and push the lock frame toward the rear of the barrel extension. The tips of the accelerator will be touching the rear of the barrel extension and will have to move upward and rearward in a circular motion as the two groups are pushed together. It is imperative that the lock frame be brought in straight so that the half-round recess in the end of the barrel plunger seats on the stud of the barrel extension 'T'-lug. When the parts are locked together, push the tips of the accelerator down until stopped by the accelerator stop (a round stud on interior of the right lock frame). This leaves them firmly locked together.

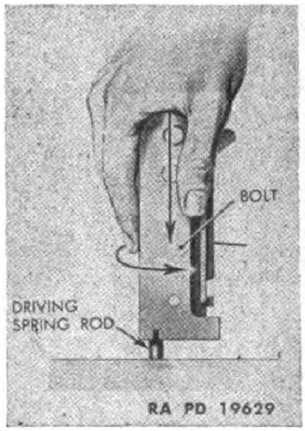

Figure 101. Removing the Driving Spring Rod and Spring. Ground Guns.

Insert the barrel, barrel extension, and lock frame into the rear end of the receiver, depressing the trigger pin as it comes up against the receiver. When the parts are pushed home, the trigger pin will spring out and into its hole in the receiver.

Making sure that the top of the cocking lever is in its foremost position, insert the bolt into the rear of the receiver. Bear down slightly on the rear of the bolt at first so that it does not trip the accelerator. Insert the bolt handle into the bolt, making sure that it is positively engaged. Push forward on the latch and slide the backplate group down into its slots in the rear of the receiver. Release the latch and the backplate will be held in place.

Holding the bolt handle to the rear, release the driving spring rod by rotating it one-quarter turn to the left. Close the cover, making sure that the belt feed lever stud engages in the cam groove in the top of the bolt.

The weapon is completely assembled.

Detail Stripping

Bolt. Remove the cocking lever pin from the bolt and then withdraw the cocking lever. In doing this, note that the hump on the bottom of the cocking lever was toward the rear. Then remove the extractor assembly from the bolt.

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Depress the sear (the vertical part in the rear of the bolt) from the top and the firing pin will be released with a snap.

When removing the driving spring rod from the bolt, take every precaution to be certain that the tension of the driving spring is kept under control. Grasping the bolt firmly, with the driving spring rod toward the table or workbench, and keeping the arm and elbow down against the table to assure steadiness, press the bolt toward the table and rotate it counterclockwise one-quarter turn. Normally the friction of the rod against the table will be sufficient to cause the rod to be disengaged. (In the event that difficulty is encountered in turning the rod in this manner, it can be grasped with the fingers or a pair of pliers while still keeping the bolt in the aforesaid position.) When the driving spring rod has been disengaged from the bolt and the tension of the driving spring tends to push the bolt up from the table, raise the bolt far enough to grasp *both* the rod and the spring with the fingers of the opposite hand, and then lift the bolt very quickly, releasing the spring without giving it a chance to buckle. The driving spring and driving spring rod have now been removed from the bolt.

To remove the sear spring assembly from the bolt, use a combination tool or the cocking lever. Depress the rear of the sear spring and press it to the left side of the bolt. This will disengage the sear, which can now be released from the bottom of the bolt. Center the sear spring assembly and remove it from the top of the bolt. The firing pin assembly can then be removed from the rear of the bolt.

Disassembly of Firing Pin Assembly. (Note: The firing pin assembly is not normally disassembled except when in need of repair.) The firing pin spring is under considerable tension when assembled to the firing pin. In removal, care must be taken to avoid letting the spring fly out and injure personnel.

Place the firing pin assembly in a padded vise, with the front or open end upward. If the special tool for this purpose is available (a round rod the size of the hole with a slot cut in the end to straddle the firing pin spring pin), depress the spring and push out the pin with a small drift. Then carefully release the tension of the spring.

Lock Frame. Remove the trigger pin either by pulling the pin out with the fingers, or by drifting it out from the opposite side. The trigger pin spring can be removed with a pair of needle nose pliers. Upon removal of the pin, the trigger can be removed from the lock frame. Next, remove the accelerator by pushing out the accelerator pin assembly.

To remove the barrel plunger and barrel plunger spring the following procedure can be used: Place the lock frame with its rear against the table. Wrap two or three fingers around the plunger and spring and the left lock frame. With the opposite thumb, depress the plunger and spring slightly, move them out away from the left lock frame to disengage the pin from the slot, and then release the tension of the spring.

The remaining parts of the lock frame group will remain assembled as these parts are riveted together.

Backplate Group. There are three types of backplate groups in the field, the difference being in the contents of the buffer tube. In all cases, the adjusting screw must first be removed, and the adjusting screw plunger and spring taken out of the tube.

(Type I consists of 16 fiber discs, buffer friction cup, buffer friction cone; Type II contains one fiber disk, stop, buffer spring, and filler. Type III (most recent) consists of 22 fiber disks. All of them have a buffer plate.) If stocks must be replaced, remove the stock screws and escutcheons, releasing the handles. Remove the latch stop screw.

Barrel Extension. Remove the breech lock by drifting out the breech lock pin assembly. Remove the barrel locking spring by prying forward with a screwdriver.

Cover. The first thing to be removed from the cover group is the belt feed lever pivot. There are two types of belt feed lever pivot bushing nuts. The old type is squatty and is topped by a stamped metal cap similar to a bottle cap. This cap may be pried off with a screwdriver. The more recent type

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of belt feed lever pivot bushing nut has a belt feed lever screw to retain the pivot This screw can be removed.

The belt feed lever pivot can be removed from the top, allowing the belt feed lever to be removed from the cover group, This will permit removal of the belt feed slide group by sliding it out of the cover.

To disassemble the slide group, drift out the belt feed pawl pin assembly and remove the belt feed pawl and belt feed pawl spring.

This will leave two long parts inside the cover: the cover extractor spring and the cover extractor cam. To remove the spring, press down the rear end and move it sideways out from under the cam. Release the tension carefully and disengage the other end from its stud on the cover. The cover extractor cam will not be taken off; it is riveted to the cover.

Barrel Jacket, Etc. (M1919A4). On the front end of the barrel jacket will be found the front barrel bearing, the front barrel bearing plug, and their corresponding locking rings.

Where the locking rings have been spread to lock the parts in place, drive the protruding sections of the rings out of their notches with a small drift and a hammer. Then unscrew the front barrel bearing plug from the front barrel bearing, and unscrew the bearing from the barrel jacket.

Remove the barrel jacket locking screw and unscrew the barrel jacket from the threaded boss on the trunnion block.

Steam Tube. (M1917A1). The steam tube need never be removed unless it becomes so clogged that steam will not pass off, or the outer tube becomes stuck so that it will not slide back and forth on the inner tube when the gun is held in the hands and tipped forward and backward. Great care must be used to prevent damage to the threads of the steam tube plug.

Stand the gun with the muzzle up and water jacket vertical. Remove the steam tube front plug screw. Place the large screwdriver blade of the combination tool in the slit provided and unscrew the steam tube front plug until the threads are disengaged and the steam tube can be lifted out.

Muzzle Gland. (M1917A1). The muzzle gland can be unscrewed from the front end cap by using the combination tool.

Assembly From a Detail Strip

To assemble the cal .30 Browning Machine Guns, use the reverse of the disassembly procedure, making certain that the following precautions are observed:

When assembling the breech lock to the barrel extension, make sure that the double-beveled corner is up and to the front.

When assembling the cocking lever to the bolt, make sure that the hump on the bottom of the cocking lever is toward the rear.

When assembling the bolt to the receiver, make sure that the top of cocking lever is pointed toward the front.

Do not screw the barrel into the barrel extension tightly, but back it off a click or two so that the field adjustment of headspace may be made.

When assembling the driving spring to the bolt, compress the spring on the rod before sliding the bolt down on the rod. Make sure that the rod is completely engaged in the bolt before raising from the table, *i.e.*, that the slot in the rod is vertical.

Packing the Barrel. (M1917A1). Asbestos packing is applied at the muzzle and breech ends of the barrel to prevent leakage from the water jacket. The packing comes in a strip of about 13 inches for the breech end (approximately once around the water jacket) and about 24 inches for the muzzle end (approximately twice around the water jacket), and must first be thoroughly soaked in oil.

Place the packing in the cannelure at the breech end and press it home with screwdriver and thumb. Wind it around, pressing it up against the wall of the cannelure. As the end is crossed on the first turn, see that it is bound down flat. On the last turn force the end under. Reverse and insert the breech end of the barrel into the hole in the trunnion block and push it forward gently, twisting the barrel until the packing is worked down to fit.

To pack the muzzle end, assemble the gun and allow the bolt to go forward, or trip the accelerator so that the barrel is fully forward. Remove the muzzle

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gland. Wind the packing clockwise in even layers about the barrel with the first coil as close as possible to the end cap. Slip the muzzle gland over the barrel and push the packing back into its seat in the end cap. Screw in the muzzle gland and test friction of the mechanism by pulling and releasing the bolt handle several times. If there appears to be too much friction, remove one or two coils of packing. The muzzle gland must screw in securely but at least three threads should be left exposed to permit it to be tightened as the packing wears.

Functional Operations

The Browning Machine Gun, Cal .30 (all types) is fundamentally an automatic weapon, which once in motion will continue to function as long as ammunition remains in the belt. However, though automatic, it is necessary to load and lock the mechanism manually for the initial round of the ammunition only, and to start its operating sequence by pressure upon the trigger. The functional description which follows is taken from the standpoint that these operations have been performed. The functions of all Browning Cal .30 machine guns are the same except where specifically noted. Training aid plates for the Model M1917A1 and M1919A4 machine guns are used to assist the explanation. At this point, and in the section following dealing with the operation of the weapon, it should be borne in mind that both weapons operate essentially in the same manner.

General. With the cover closed, enter the belt with the metal tab through the feedway until the first round is positioned on the right of the belt-holding pawl. The gun is then prepared for firing by pulling the bolt handle to the rear and releasing twice. This procedure places a round in the chamber. After the gun has been loaded and cocked manually, the automatic operation is started with the action of the trigger releasing the firing mechanism, which in turn strikes and fires the cartridge. Upon this action the burning powder within the cartridge case violently generates gas. Since the gas is confined by the cartridge and bullet, a tremendous pressure is exerted. This pressure exerts itself against the rear face of the projectile, forces it through the barrel and tends to force the empty cartridge case out of the chamber toward the rear. Such tendency is prevented by having the bolt positively locked against the rear of the cartridge at the instant of firing.

As the bullet travels out of the barrel, the force of recoil carries the barrel, barrel extension, and bolt (the recoiling parts) rearward. During the first ⅜ inch of this travel, the recoiling parts are locked together. After the ⅜ inch rearward movement, the bolt is unlocked from the barrel and barrel extension (allowing the bolt to travel rearward compressing the driving spring until the bolt is stopped by the buffer plate in the back plate assembly). The rearward travel of the barrel and barrel extension is stopped by the lock frame group. The accelerator acting upon the 'T'-lug of the barrel extension holds the barrel extension to the lock frame. Simultaneously with unlocking, the bolt assembly extracts the empty cartridge case from the chamber. From the beginning of rearward movement the extractor assembly withdraws a live cartridge from the loaded belt. The empty cartridge case is expelled from the bottom of the gun by the ejector, while the extractor positions the succeeding cartridge in the T-slot of the bolt.

The bolt is driven forward by the rebound action of the backplate and the compressed driving spring. As the bolt assembly travels forward, the barrel extension is released from the lock frame and the barrel plunger spring which was compressed during the recoil motion. The accelerator forces the barrel and barrel extension forward into the firing position. During this movement the bolt is again locked to the barrel extension and barrel. If the trigger action is maintained the firing pin is then released and strikes the primer of the cartridge case just before the recoiling parts reach the battery position. As the firing pin strikes the cartridge, another cycle is started and succeeding cycles will continue as long as ammunition is supplied and trigger action is maintained.

Detail Functioning

The following description exemplifies the cycle operations of a manually exerted trigger activated cal .30 Browning machine gun. This description is identical with that of the trigger bar, solenoid, or trigger motor activated machine gun except for the actual manner in which the sear is depressed.

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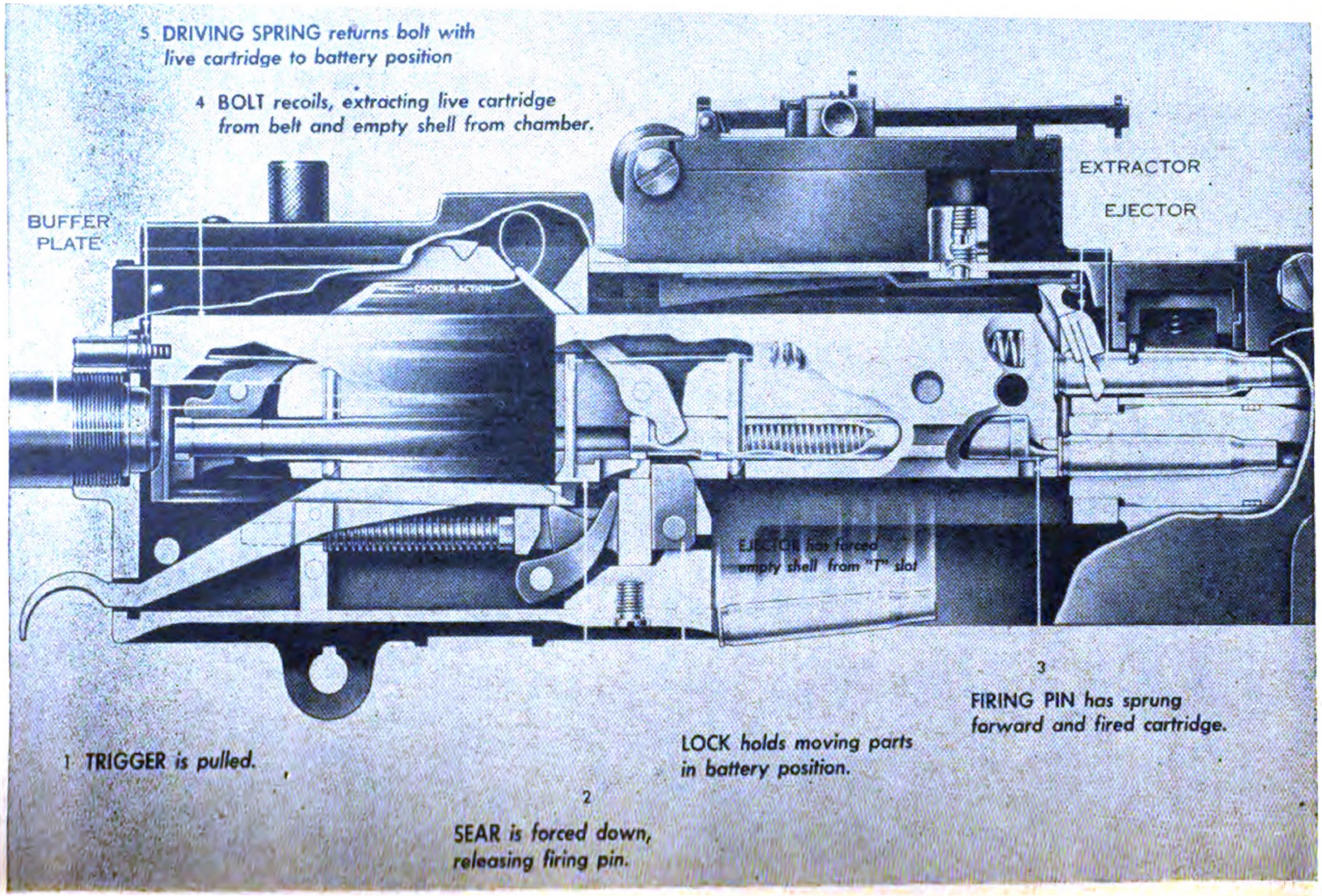

Figure 102. Basic Functioning, BMG Cal .30 M1917A1 Watercooled.

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Every cycle of the gun entails certain simultaneous movements or parts functions which must be performed in perfect relationship. In order for these functions to be more fully explained, it is deemed advisable that they be treated individually. These phases will be discussed in the following order:

1. Firing
2. Unlocking
3. Extraction
4. Ejection
5. Cocking
6. Feeding
7. Loading
8. Locking

Firing. Firing is the process of igniting the propelling charge of the round in the chamber. With the gun loaded and the firing pin spring cocked, the gun is ready for firing.

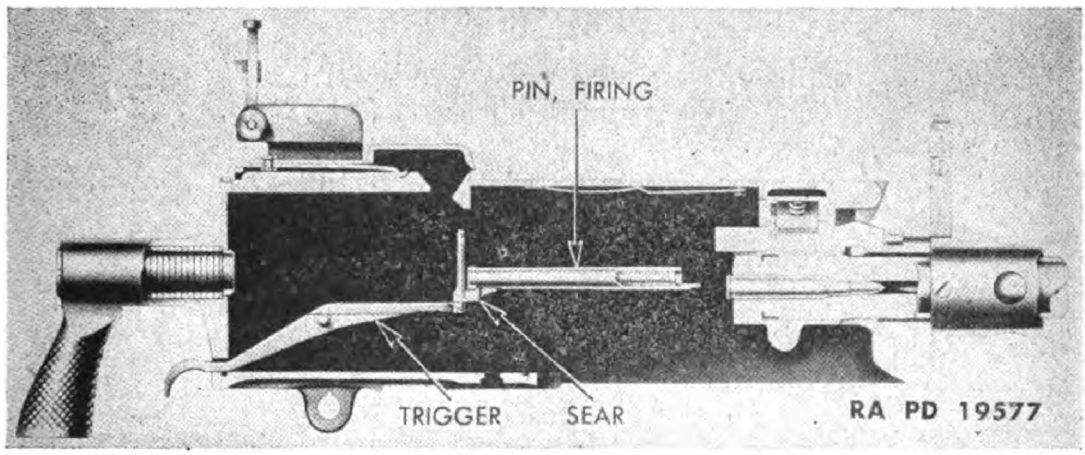

Figure 103. Ready to Fire.

When the trigger is pressed it pivots on the trigger pin and the forward end moves downward. When firing the first round, the trigger cams on the front end of the trigger are engaged with the T-cam in the bottom of the sear and force the sear downward. The sear is pulled downward against the resistance of the sear spring until the shoulder of the firing pin is released by the sear notch which allows the firing pin spring to force the firing pin forward.

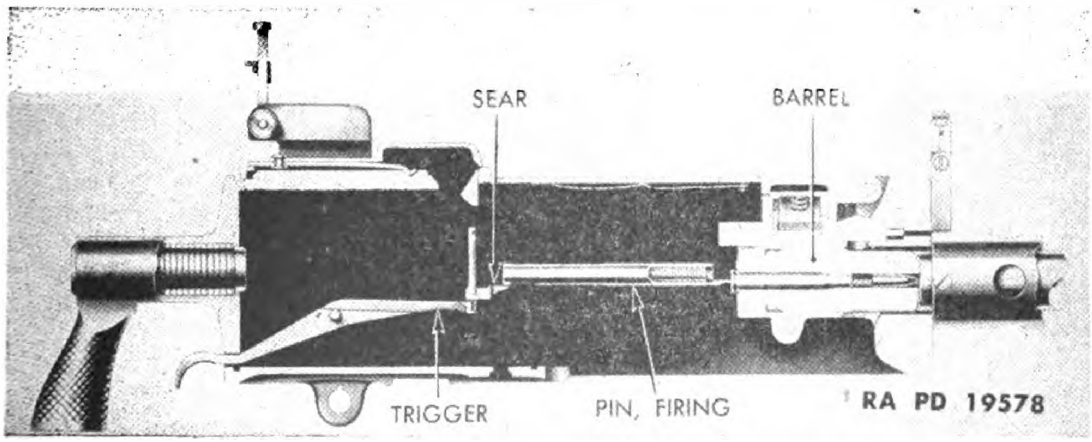

Figure 104. Firing Position.

Prior to its release, the firing pin was held to the rear by the sear, and the firing pin spring was compressed between the firing pin spring pin and the sear spring pin. Therefore, when the sear releases the firing pin, the firing pin spring expands and carries the firing pin forward. The rear end of the spring is held stationary against the sear spring pin.

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As the firing pin is forced forward, it strikes the primer of the round and crushes the primer mixture between two metal surfaces. This causes the primer mixture to ignite and in turn set off the propelling charge. As the propelling charge burns, a large quantity of gas is produced which forces the bullet forward and out of the barrel. (At the same time the gas exerts equal pressure to the sides and rear.)

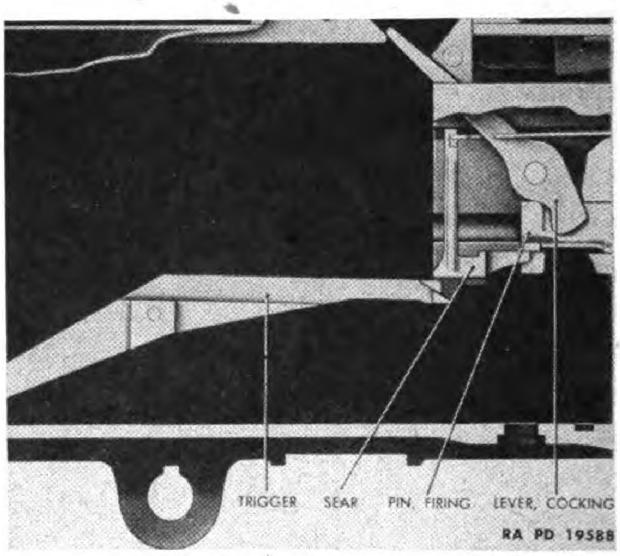

Figure 105. Automatic Firing.

As successive rounds are fired, the trigger remains depressed and the sear is cammed down every time the recoiling parts come forward into battery position. This is accomplished as the trigger cams remain depressed and as the 'T'-cams in the bottom of the sear come forward into contact with the trigger cams. The sear is thus forced downward and the firing pin is forced forward by the firing pin spring.

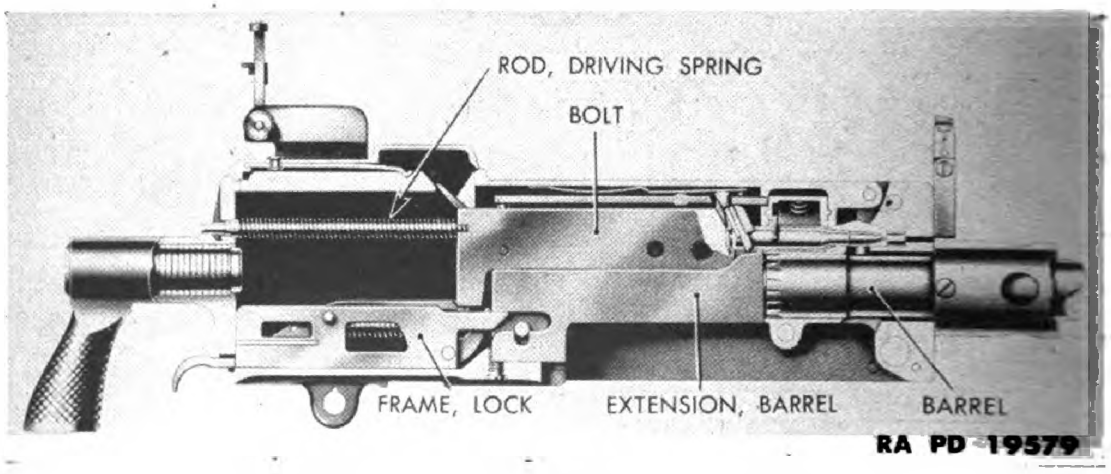

Figure 106. Recoiling Portion in Firing Position.

In automatic fire the firing pin is released from the sear when the recoiling parts are approximately $\frac{1}{8}$ inch from battery position. Therefore, the explosion occurs shortly before the barrel extension strikes the trunnion blocks at the end of its forward motion. The blow of the barrel extension against the trunnion block is cushioned as the explosion tends to force the recoiling parts to the rear

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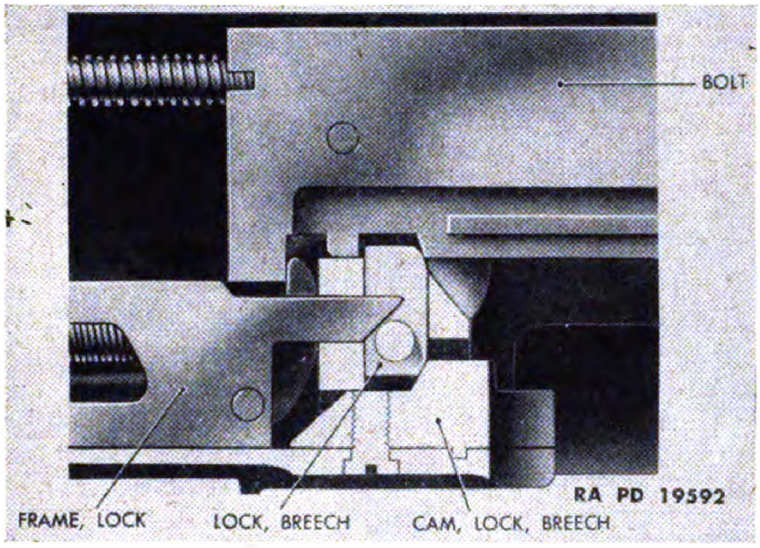
while the driving spring and the inertia of the recoiling parts tend to drive them forward.

When a round is fired, the breech end of the barrel must be tightly closed until the high pressure of the powder gases has subsided.



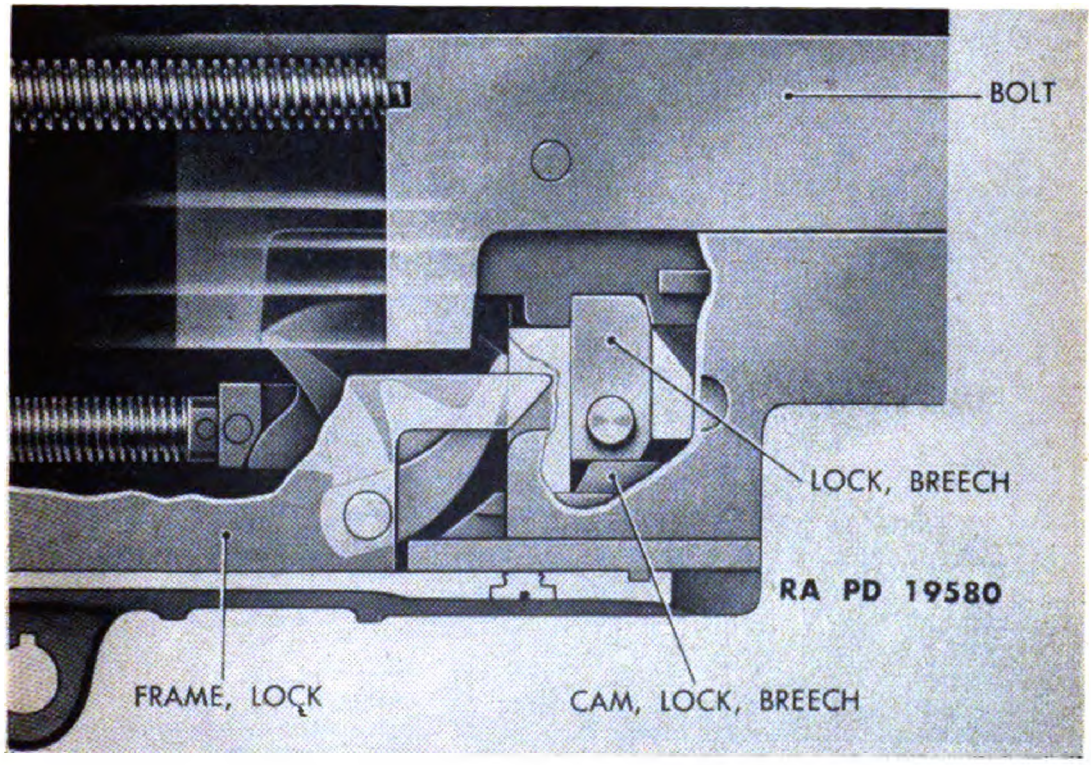


Figure 107. Beginning of Breech Lock Unlocking. Breech Lock in Locked Position.

Unlocking. This is the process of opening the breech of the barrel. It occurs as the recoiling parts move rearward. At the moment of firing, the recoiling parts (barrel, barrel extension, and bolt) are locked together because the barrel is screwed into the barrel extension and the bolt is securely held to the barrel extension by the breech lock. The breech lock slides up and down in grooves

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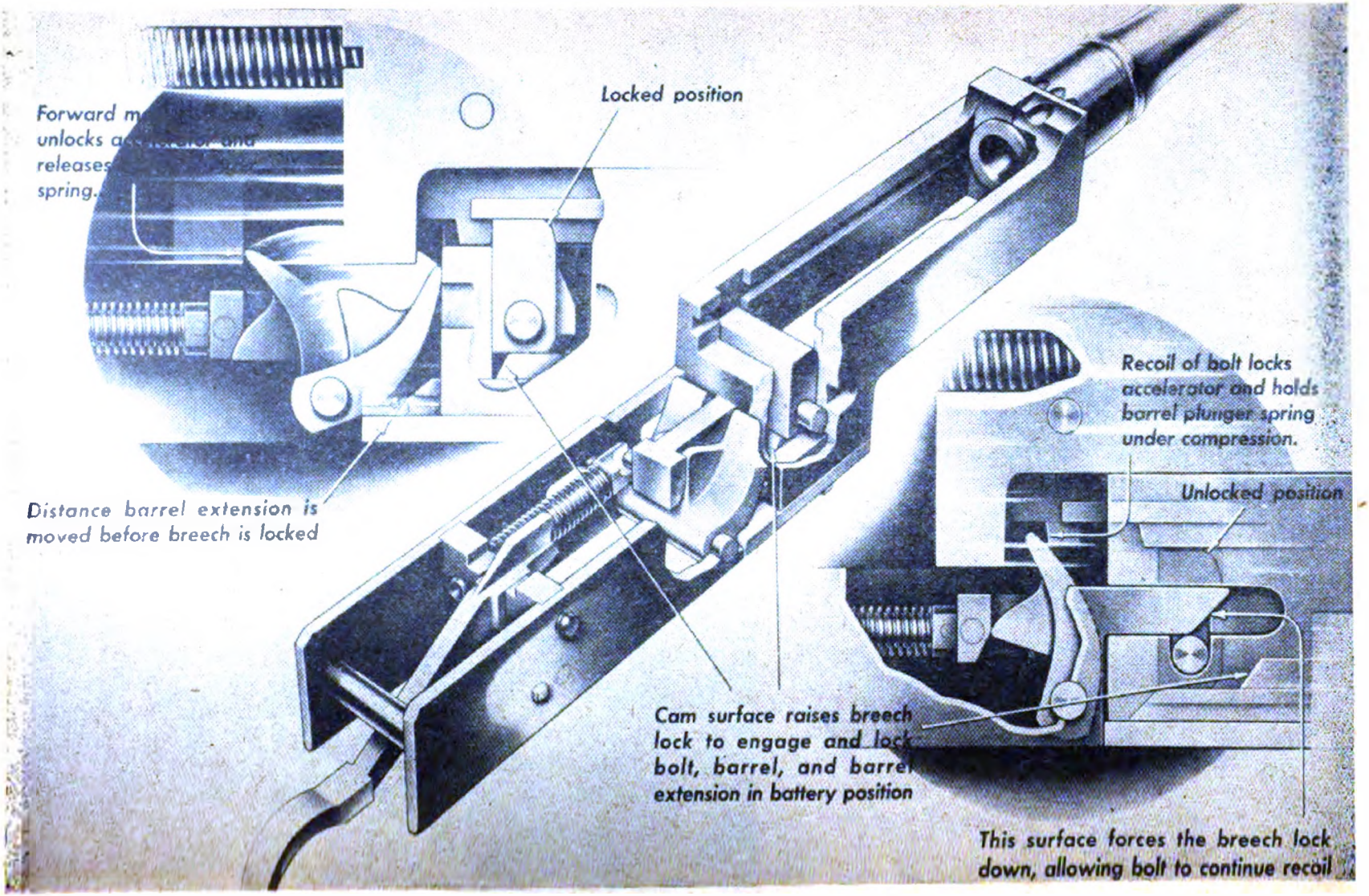

Figure 108. Lock Frame and Barrel Extension Functioning.

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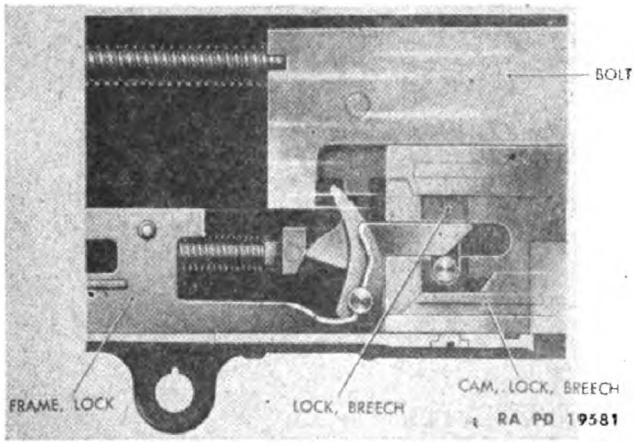
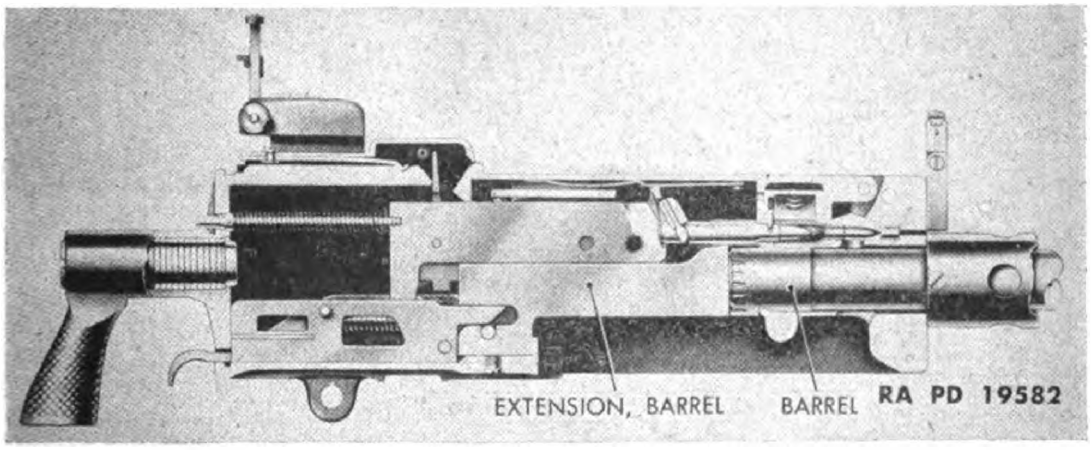
in the barrel extension. At the moment of firing the top portion of the breech lock is held securely in a mating recess in the bottom of the bolt, and the bottom of the breech lock is supported by the breech lock cam. (The surface upon which the breech lock rests is referred to as the 'supporting surface.') Therefore, the bolt cannot move relative to the barrel extension at the moment of firing.

When the round is fired, the force of the expanding gases acts in a forward direction to drive the bullet through the barrel and in a rearward direction





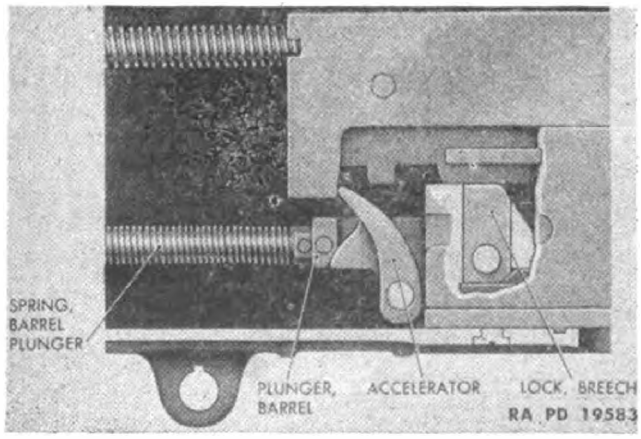


Figure 109. Barrel Plunger and Spring Compressed, Recoiling of Barrel and Barrel Extension, Breech Lock in Unlocked Position.

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against the base of the cartridge case. This rearward force is transmitted from the cartridge case to the bolt and so forces the recoiling parts to the rear against the resistance of the driving spring and barrel plunger spring.

When the barrel and barrel extension have moved to the rear approximately ⅜ inch, the breech lock pin strikes the forward projections of the lock frame and is cammed downward. (As the breech lock pin extends through the breech lock, the breech lock must also be forced downward at this point.) Opportunity for the breech lock to be forced downward exists at this time, since the breech lock is no longer above the 'supporting surface' of the breech lock cam, but is above the 'camming surface' of the breech lock cam which slopes downward steeply.

As the breech lock is forced downward by the action of the forward projections of the lock frame, it is withdrawn completely from the breech lock recess in the bottom of the bolt. (The breech lock is completely withdrawn from this recess when the barrel and barrel extension have moved ⅝ inch from their battery position.) Unlocking is thus completed and the bolt is free to move to the rear, independent of the barrel and barrel extension.

After unlocking has taken place the bolt continues to the rear against the resistance of the driving spring and strikes the buffer plate. The barrel and barrel extension come in contact with the front edges of the lock frame. When the barrel and barrel extension have reached this position they are caught and held to the lock frame by the action of the accelerator on the 'T'-lug of the barrel extension.

Extraction. This is a process of withdrawing the empty cartridge case from the chamber. It occurs as the bolt moves to the rear independently of the barrel and barrel extension.

At the moment of firing, the cartridge case is in the chamber with its base held securely, as the extracting groove of the cartridge is in the 'T'-slot of the bolt. When the round is fired, the gases force the cartridge case against the walls of the chamber and there is a definite tendency for the case to stick in the chamber.

Before the cartridge case can be withdrawn from the chamber, it is necessary to break the 'seal' which exists between the cartridge case and the walls of the chamber. This cannot be done hurriedly as it might cause a ruptured cartridge case malfunction which takes some little effort to be cleared. For this reason, the cartridge case must be drawn to the rear slowly and steadily until the 'seal' is broken.

After the recoiling parts have moved to the rear ⅜ inch, the process of unlocking begins and the bolt starts to move slightly to the rear relative to the barrel and barrel extension. Extraction, therefore, begins immediately upon unlocking since the empty case is held securely by the 'T'-slot of the bolt and the bolt carries the empty case back with it as it moves to the rear.

When the recoiling parts have moved far enough to the rear so that the breech lock is over the camming surface of the breech lock cam, there is no longer much pressure in the barrel, and the previously acquired inertia of the bolt will cause the bolt to be drawn back on the barrel extension relatively slowly. This movement is controlled by the lower bevel of the double-beveled surface of the breech lock. It should be noted that the initial 'seal' which existed between the cartridge case and the wall of the chamber has been broken. The inertia of the bolt will continue to carry it to the rear until the accelerator acts on the bolt. This force is normally sufficient to enable the bolt to continue to the rear, further withdrawing the empty cartridge case from the chamber and continuing extraction.

In the event that the inertia of the bolt cannot complete extraction of the empty case, the action of the accelerator will aid the bolt in this function. As the barrel and barrel extension move to the rear, the barrel extension rotates the accelerator about its pin and the tips of the accelerator contact the lower projection of the bolt. (This contact is established shortly after the process of unlocking has begun).

As the barrel and barrel extension continue rearward, these parts continue to rotate the accelerator about its pin and the accelerator exerts a prying action on the bolt. In the event of a cartridge case which adheres firmly to the wall of the chamber, this action of the accelerator will help the bolt extract the empty

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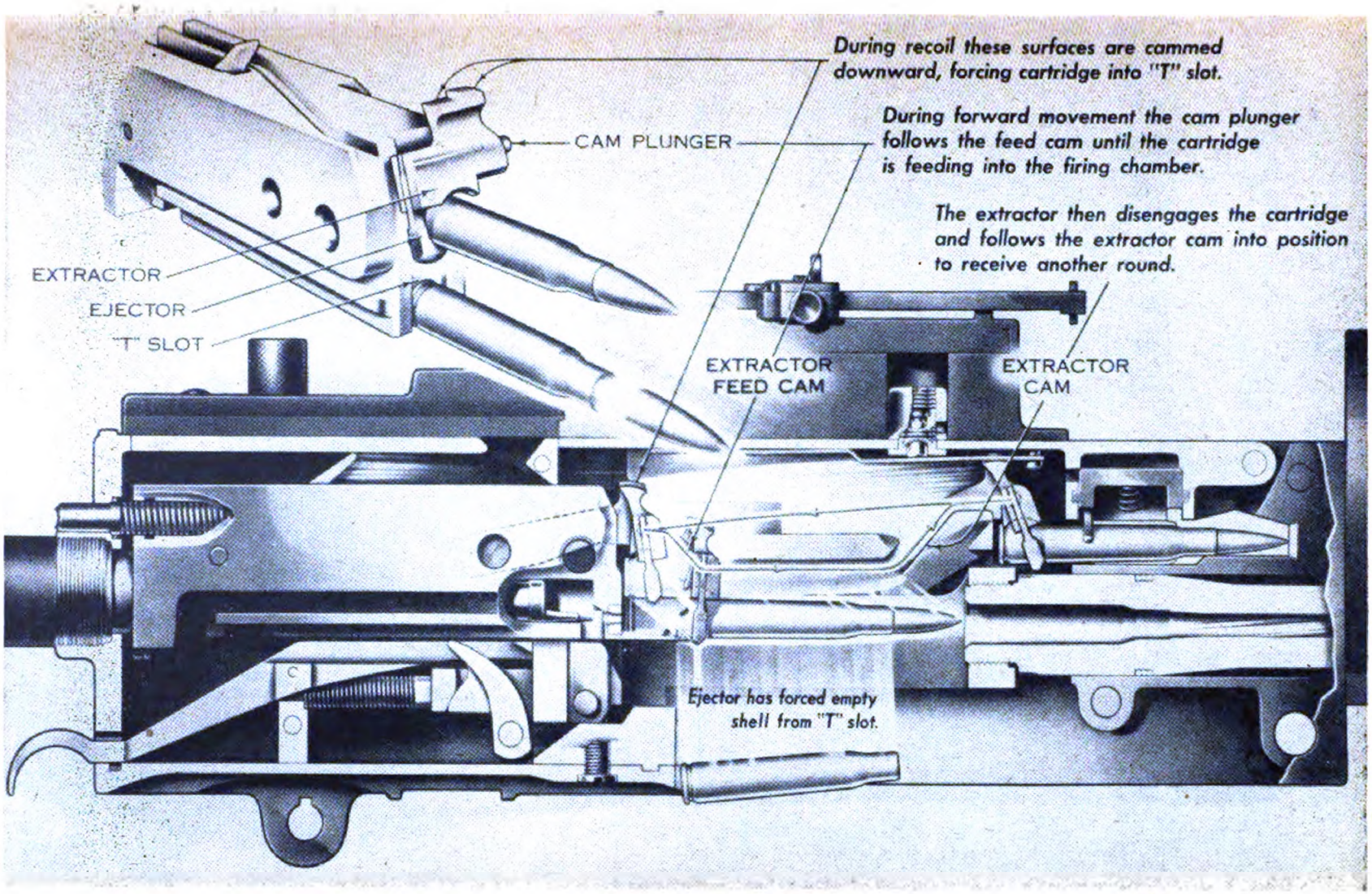

Figure 110. Extractor and Ejector Functioning.

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case. If the cartridge case does not adhere, the action of the accelerator in the process of extraction is negligible.

As the accelerator tips continue to act on the bolt, the bolt is accelerated in its rearward movement. (It is from this function that the accelerator derives its name.)

Ejection is the process of expelling the empty cartridge case from the receiver after the case has been withdrawn from the chamber. The process of ejection occurs on counter-recoil.

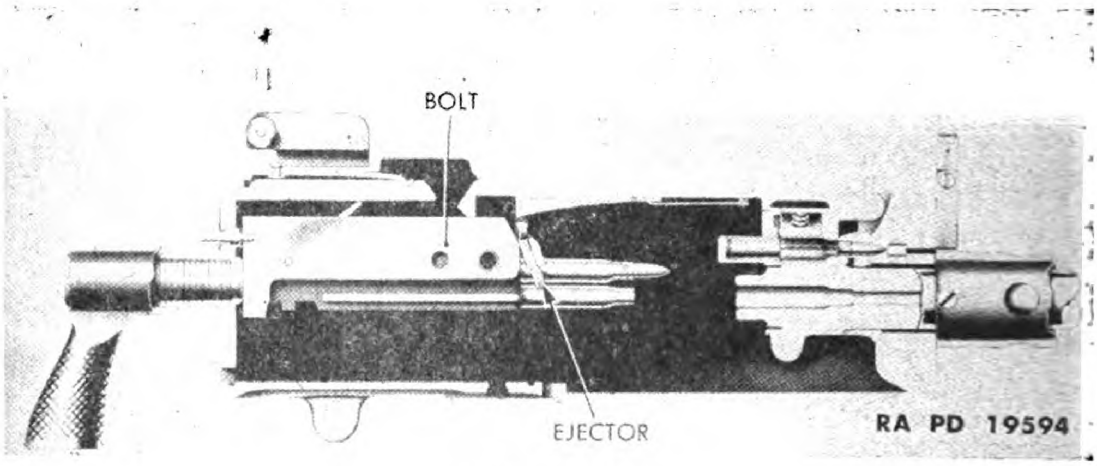

Figure 111. Ejecting.

As the bolt is forced to the rear, the extractor assembly withdraws a new round from the belt in the feedway and carries it to the rear. As this round moves rearward with the bolt, the extractor is forced downward by the cover extractor cam and a new round is guided into the 'T'-slot of the bolt.

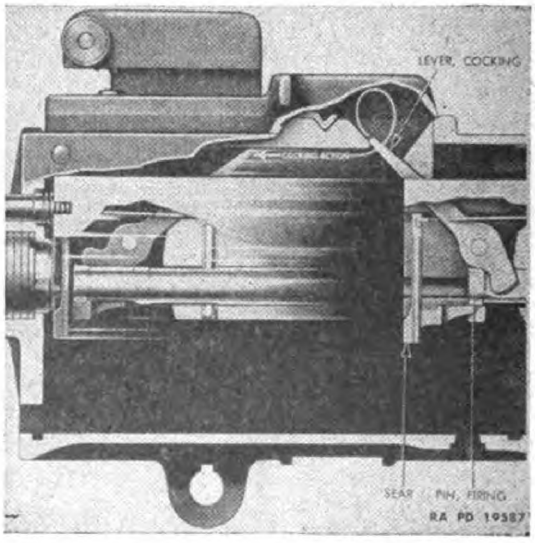

Figure 112. Cocking Action During Recoil.

When the bolt moves forward on the rebound derived from its striking the buffer plate and from the impulsion of the driving spring, the extractor is forced still further downward by the action of the extractor cam plunger on the rear lower cam surface of the extractor feed cam. The round is thereby forced still further down into the 'T'-slot of the bolt, and the bottom of the new round in its downward movement strikes the empty cartridge case which has just been extracted and ejects it from the receiver.

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When the last round has been fired, there is, of course, no new round to eject the empty case as described above. However, the movement of the extractor assembly is exactly as described above, and the curved lowermost portion of the ejector strikes the empty case as the extractor assembly is forced downward, ejecting it from the receiver.

Cocking. This is the process of retracting the firing pin until it is caught and held by the sear so that it may later be released to fire a new round. It is begun immediately after the bolt starts to recoil after firing, and is completed on counter-recoil.

At the moment of firing, the top of the cocking lever is in the 'V'-recess in the top plate of the receiver, and the bottom is directly in front of the cocking lever camming recess of the firing pin.

As the recoiling parts move to the rear, the cocking lever is pivoted so that the lower end forces the firing pin rearward and slightly past the point at which the sear will catch and hold it. (This is known as 'overtravel' and is present to insure positive engagement between the firing pin and sear.) The firing pin spring is thus compressed between the firing pin spring pin and the sear spring pin. As the firing pin was drawn to the rear, the sear was held downward by the shoulder of the firing pin, allowing the firing pin shoulder to clear the sear notch.

After the cocking lever is thus pivoted, it is withdrawn from the 'V'-recess and, as the bolt goes to the rear, the top of the cocking lever bears against the top of the receiver and holds the firing pin in its most rearward position. As the bolt rebounds from the buffer plate and is forced forward under impulsion of the driving spring, the top of the cocking lever continues to bear against the bottom of the top plate.

As the bolt continues forward, the top of the cocking lever re-enters the 'V'-recess of the top plate, and this action swings the bottom of the cocking lever forward. The firing pin is thus permitted to go forward slightly and is caught by the sear which has been forced upward by the sear spring. It should be noted that the firing pin has been held to the rear and out of contact with the sear until the cocking lever again entered the 'V'-recess on counter recoil.

Feeding. This is the process of drawing a round into the receiver and aligning it with the chamber of the barrel.

Loading is the process of placing the round in the chamber after it has been so aligned.

It will be assumed in the following discussion that the weapon has been manually loaded as previously explained, and that there is an unfired round in the chamber. When these conditions exist, there will be a round drawn up against the cartridge stops, and the claw of the extractor will be in the extracting groove of the cartridge case. The extractor exerts firm pressure on the cartridge case since it is forced downward by the cover extractor spring.

When the gun is fired, the recoiling parts move to the rear and the extractor draws a round, which it is gripping, from the fabric belt. As the extractor moves to the rear with the recoiling bolt, it is forced downward by the action of the cover extractor cam into the 'T'-slot of the bolt where the lips of the 'T'-slot fit into the extracting groove of the case. During this rearward movement, the extractor cam plunger on the left side of the extractor passes over the extractor feed cam on the left side of the receiver (the plunger being depressed), when it is cammed inward by the long bevel on the extractor feed cam.

When the bolt starts its forward movement, the plunger (which has since sprung out to its normal position) strikes the rear lower cam of the extractor feed cam and the extractor is forced downward. As this takes place, the round which is held in the 'T'-slot of the bolt is also forced downward and is now aligned with the chamber. During the process of feeding described above, the round has been held between the lips of the 'T'-slot of the bolt and has been partially supported by the ejector.

As the bolt continues its forward motion, the round is carried into the chamber and loading is completed. When loading is almost completed, and shortly before the recoiling parts reach battery position, the extractor cam plunger strikes the extractor cam and the extractor assembly is forced upward and away from the round.

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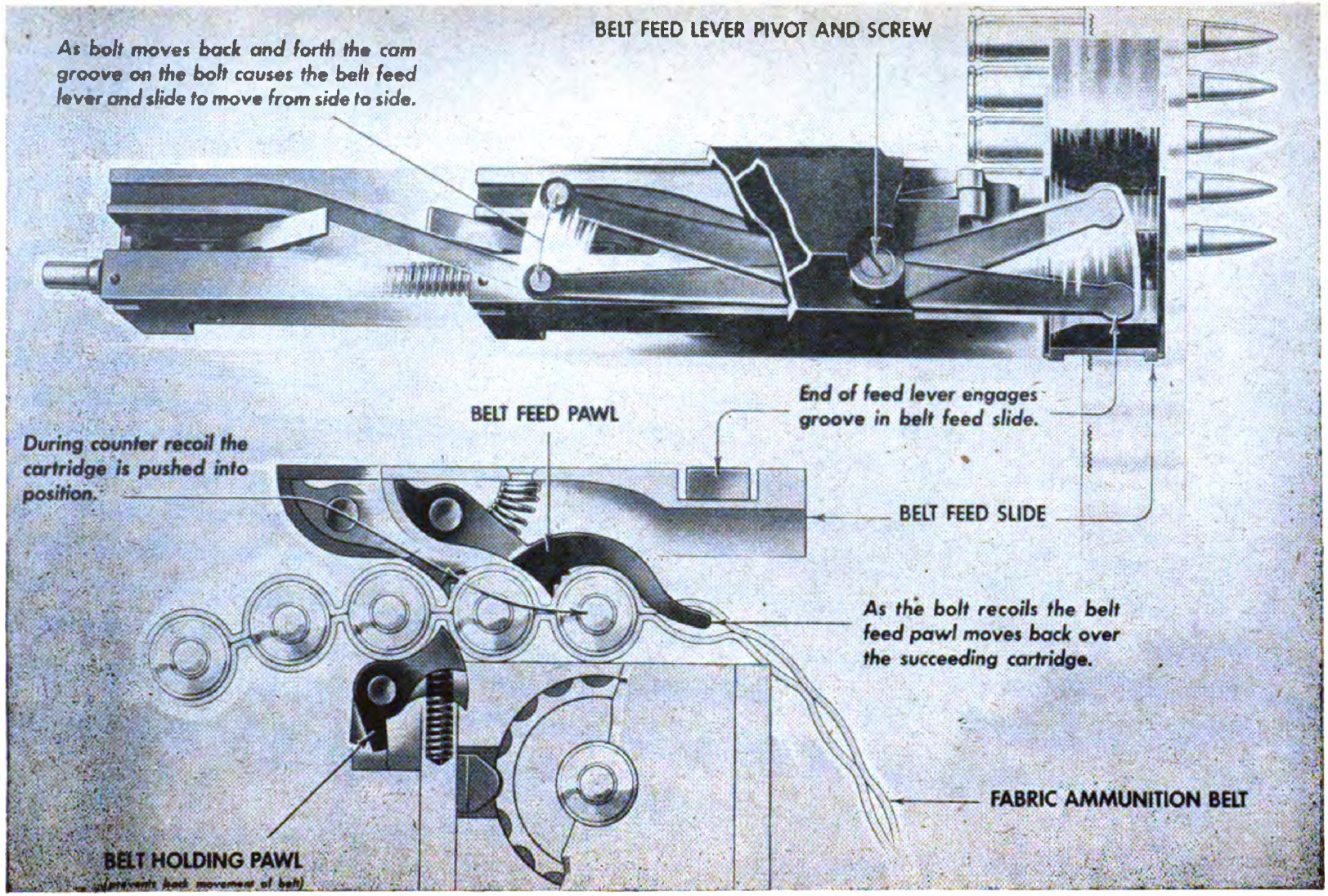

Figure 113. Feed Functioning and Parts, Browning Machine Gun Cal .30 M1917A1 W/C.

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As the extractor cam plunger rides along the extractor cam, the extractor is carried upward until it contacts and compresses the cover extractor spring. As the bolt goes into battery position, the extractor cam plunger passes off the extractor cam, and the extractor claw is forced by the compressed cover extractor spring into the extracting groove of the round immediately next to the cartridge stops.

Up to this point nothing has been said as to the manner in which the belt was pulled into the gun. This procedure is as follows: The belt is pulled into the gun by the belt feed pawl which is attached to the belt feed slide. When the bolt is forward, the belt feed pawl has positioned a round immediately next to the cartridge stops. As the bolt recoils, the stud of the belt feed lever travels in the camway of the bolt; the belt feed lever is pivoted so that it moves the belt feed slide out over the belt and the belt feed pawl pivots so as to ride over the next cartridge. As the belt feed slide moves outward, the belt holding pawl prevents the belt from shifting with the belt feed slide.

At the end of the bolt's rearward movement, the travel of the belt feed slide is sufficient to permit the belt feed pawl to snap down behind the next round, which is to be positioned next to the cartridge stops.

As the bolt moves forward in counterrecoil, the belt feed slide is pulled into the gun and the belt feed pawl pushes the belt into the receiver and aligns the new round against the cartridge stops. When the belt has been pulled into the gun, the belt holding pawl snaps up between the second and third rounds of the belt and is again in position to prevent shifting of the belt.

If for any reason the extractor does not withdraw a round from the belt, the end of the belt feed pawl arm will rest on the round left in the feedway. When this condition exists the belt feed pawl will not be allowed to snap down between the rounds. Therefore, when the belt feed slide is pulled into the gun as the bolt comes forward in counterrecoil, the belt feed pawl will not pull the belt into the gun. The above described action of the belt feed pawl arm prevents double feeding and bending of the belt feed lever.

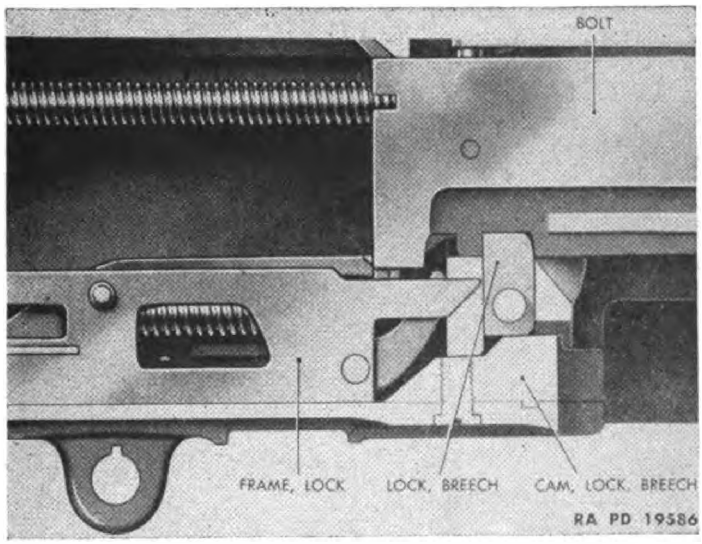

Figure 114. Breech Lock Engaged.

Locking. When a round is fired, the breech end of the barrel must be tightly closed until the high pressure of the powder gases has subsided. The process of closing the breech end of the barrel is called locking. It occurs on counterrecoil.

As the bolt moves forward after striking the buffer plate, the lower projection of the bolt strikes the accelerator tips. The accelerator is rotated forward by this action and releases the barrel and barrel extension from the lock frame group.

The barrel and barrel extension are forced by two things; the actions of the accelerator and the barrel plunger spring. When the accelerator is struck by the

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bolt and rotated forward, the front side of the accelerator strikes the barrel extension and cams the barrel and barrel extension forward as the accelerator continues to rotate.

As the barrel and barrel extension go forward, the bottom of the breech lock contacts the camming surface of the breech lock cam and is cammed upward. The forward movement of the recoiling parts is so timed that the mating recess for the breech lock, which is on the underside of the bolt, is directly above the breech lock as the breech lock is forced upward by the breech lock cam. As the recoiling parts continue forward, the bottom of the breech lock is forced forward along the 'supporting surface' of the breech lock cam. This last mentioned action insures that the recoiling parts are fully locked together.

Front Barrel Bearing Plug

Because the barrel in the M1919A4 is considerably heavier than the other caliber .30 machine guns, it was found that the force of recoil from the burning of the powder gases was not sufficient to drive the recoiling parts to the rear far enough for the weapon to function. For this reason the front barrel bearing plug is mounted on the front barrel bearing in front of the muzzle of the barrel to trap a certain amount of the escaping gas and divert it rearward against the muzzle.

There are three types of plug in existence: the 30 in. M1, which has the largest hole; the 30 in. '06 M2, with the medium size hole; and the .718 in. DIA, with the smallest hole.

The 30 in. M1 was designed for use with M1 ammunition which is no longer in use, so its use is discontinued because the parts will not recoil sufficiently with any other ammunition.

The 30 in. '06 M2 was designed for use in the earlier guns that had the driving spring made of .041 inch wire. With this spring in the gun, the '06 M2 plug can be used.

The .718 Dia. plug was designed to be used in conjunction with the heavier driving spring of .047 inch wire (for antiaircraft use and high-angle firing). Since this plug has the smallest hole of the three and consequently will give the greatest amount of rearward force to the barrel, it is considered an all-purpose plug and can be used on all types of ammunition and all M1919A4 machine guns.

Headspace Adjustment

With Recoiling Parts Out of Gun. Remove extractor from bolt. Engage bolt on barrel extension. Push breech lock up into recess in bolt and hold there firmly. Screw barrel into barrel extension until resistance is met. Back off one click.

To adjust headspace of M1919A4, M1919A5, M1919A6, and M1917A1 Guns, with guns assembled, proceed as follows:

Have barrel screwed in nearly all the way. By inspection, see if the barrel and barrel extension have gone fully forward. If they have, the front end of the barrel extension will be against the trunnion block. If they have not gone fully forward, there will be a space between the front of the barrel extension and the rear of the trunnion block, and the barrel locking notches will be visible. This condition indicates tight headspace. Pull the bolt to the rear three-quarters inch, unscrew barrel from barrel extension (by using point of a cartridge or combination tool in barrel locking notches) one notch at a time (checking after each notch), until barrel and barrel extension will just go fully forward without being forced. Now back off barrel one additional notch. (In the case of the M1917A1 Gun, make sure barrel packing does not bind and cause a false headspace adjustment.) On the 1919A6 Gun, unscrew the barrel with Combination Wrench M6, after removing the booster cap.

.50 CALIBER MACHINE GUNS

The Browning Machine Gun, cal .50, M2, aircraft, basic, is an air-cooled, recoil-operated, alternate feed gun which may be mounted on either a rigid turret, or a hand-operated mount. It is adaptable for any type of installation in aircraft by the addition of the proper parts and accessories. The gun may be

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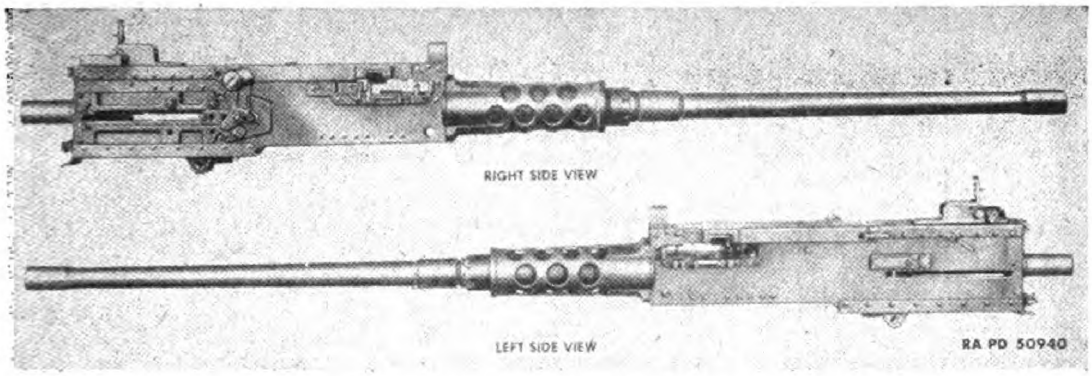
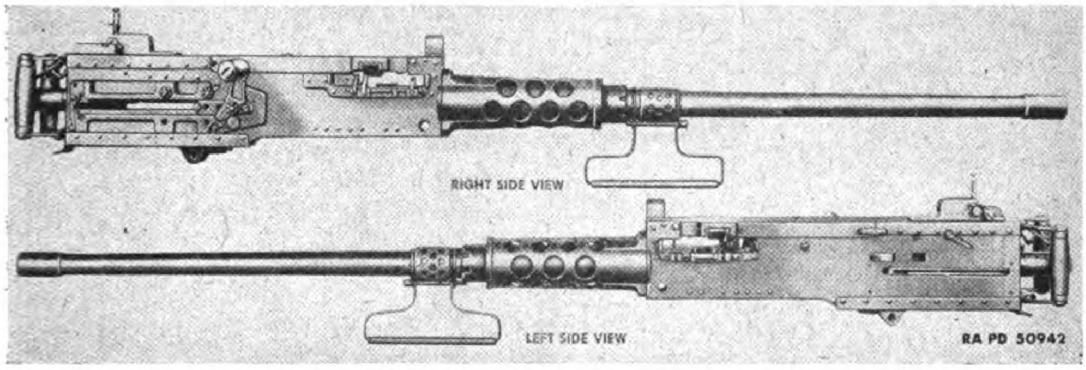
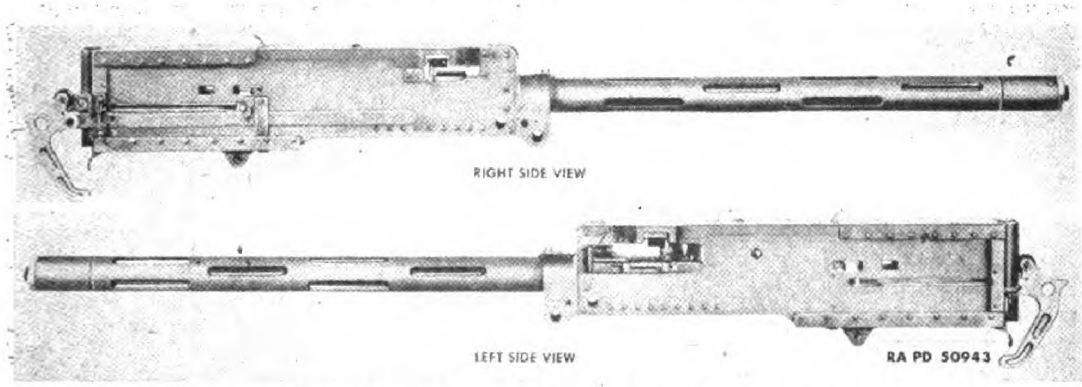


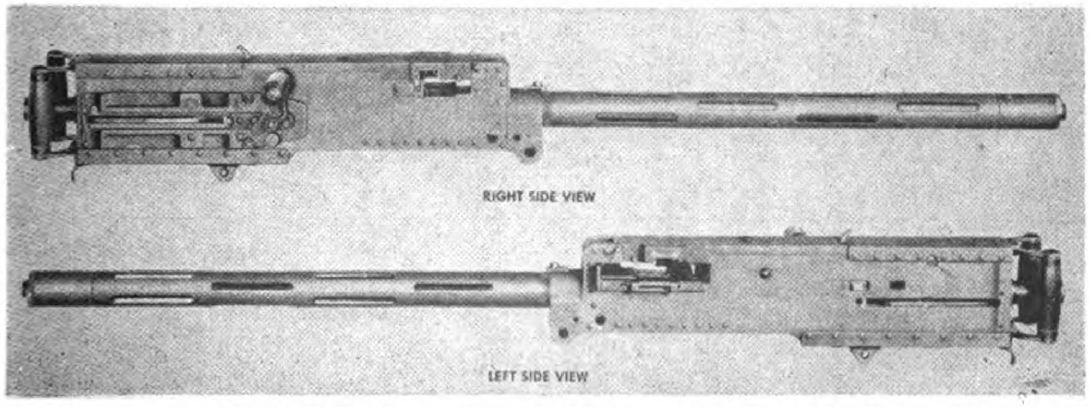
Browning Machine Gun, Cal. .50 M2 Heavy Barrel, Fixed.



Browning Machine Gun Cal. .50 M2 Heavy Barrel, Flexible.



Browning Machine Gun Col. .50 M1921 Aircraft, Fixed.



Browning Machine Gun Cal. .50 M1921 Aircraft, Flexible.

Figure 115. The .50 Caliber Machine Gun.

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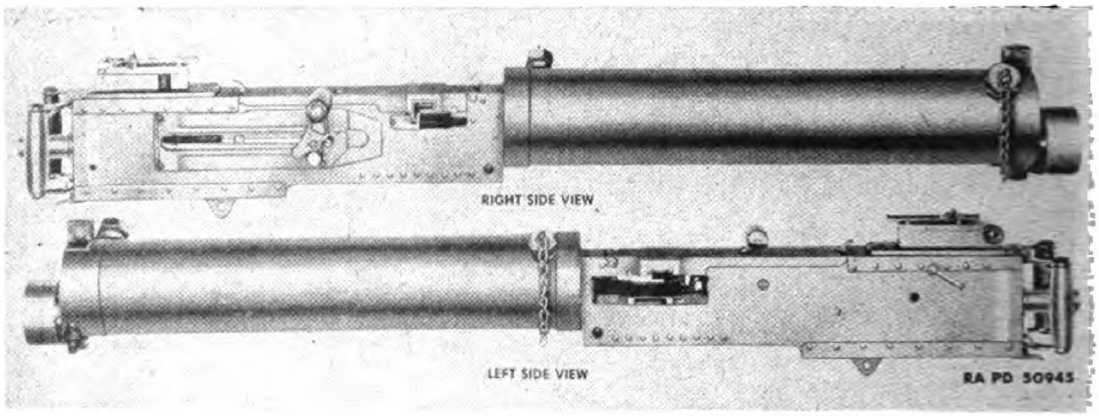
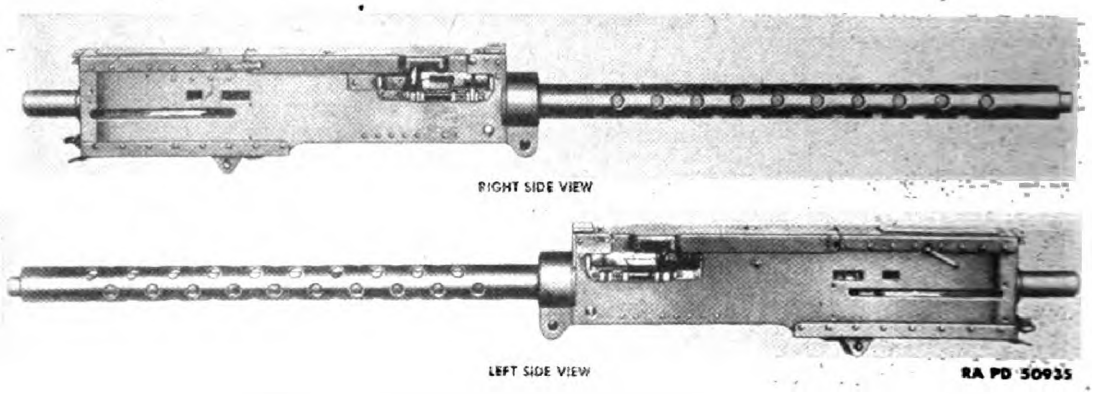
fired by a mechanical or electrical accessory or by a manual trigger and trigger bar.

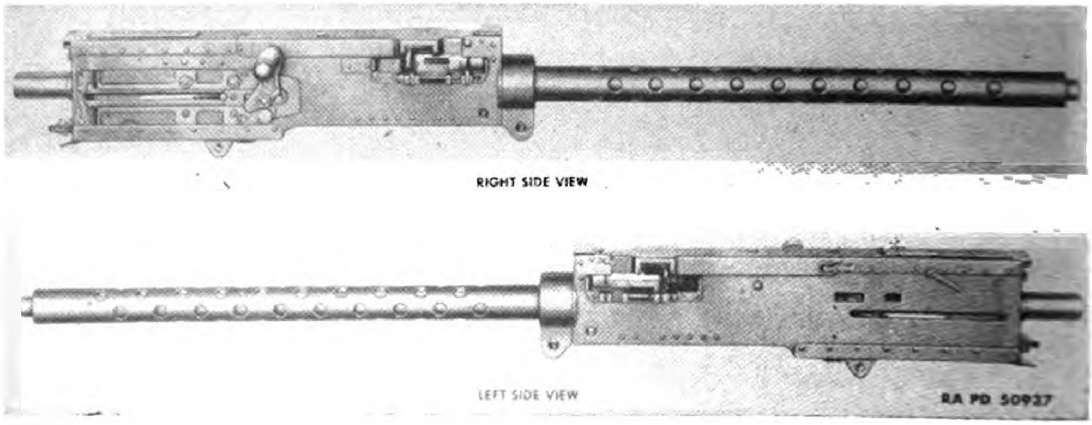
The basic gun is equipped with a trigger bar, trigger bar pin assembly, bolt latch bracket, and a basic back plate with horizontal buffer assembly. It is installed in the wings, fuselage, or in the nose of the airplane. The Army Air



Browning Machine Gun Cal. .50 M1921A1, Watercooled.



Browning Machine Gun Cal. .50 M2 Aircraft Basic.



Browning Machine Gun Cal. .50 M2 Aircraft Basic, with retracting slide group Assembly.
Figure 115. The .50 Caliber Machine Guns. (Continued)

Forces will supply the mechanism to retract the recoiling portion of the gun if required in turrets and also will supply solenoids to fire the gun.

In some installations, as in a turret of the airplane, the basic gun with retracting slide will be used. In this case, the means of firing the gun may be by

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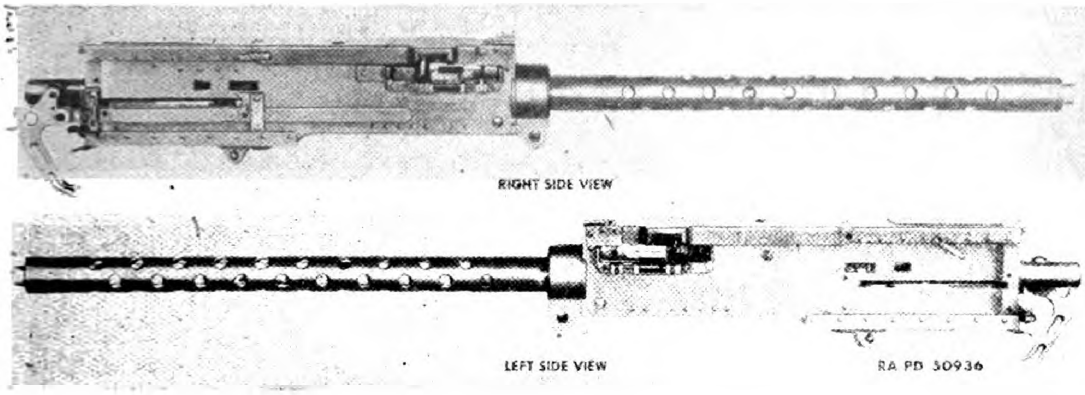
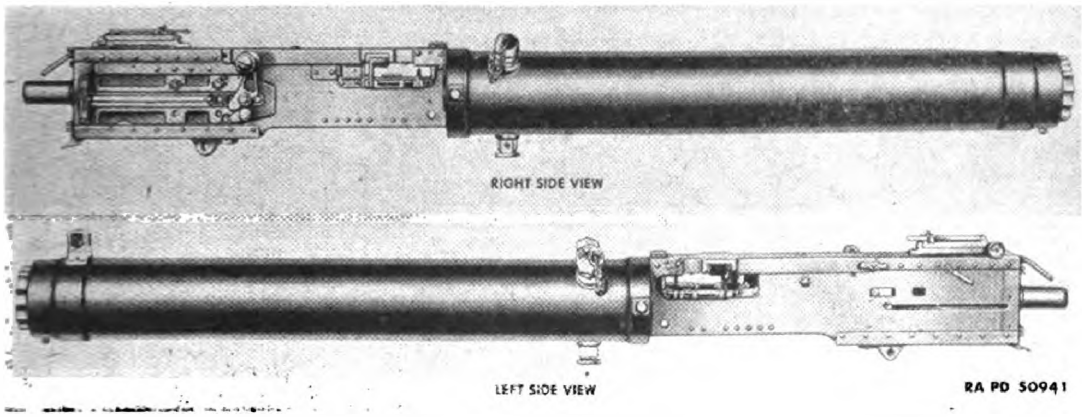
hand through the mechanism which is part of the adapter or by means of a solenoid attached to the receiver.

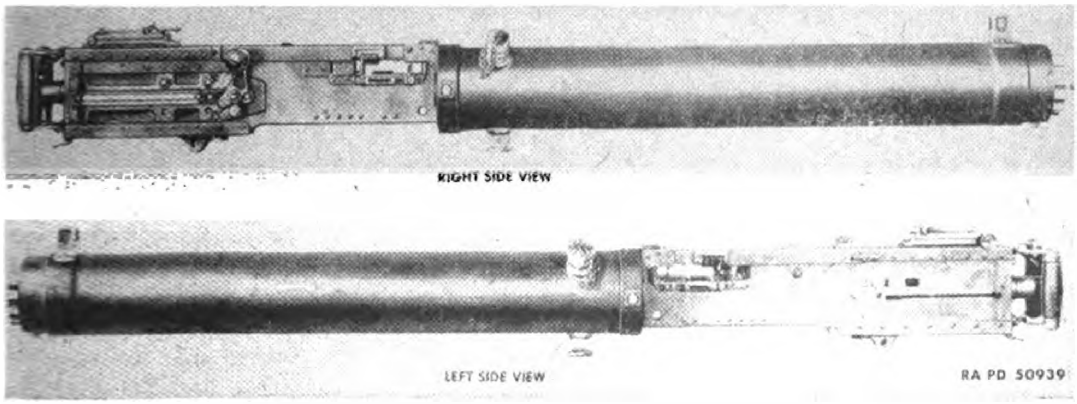
The basic gun may be equipped with an operating slide group assembly for rigid installation forward of the pilot's cockpit with the breech end of the gun



Browning Machine Gun Cal. .50 M2 Aircraft Basic, with Operating Slide Group Assembly.



Browning Machine Gun, Cal. .50 M2, Watercooled Flexible (for use in Antiaircraft Mounts)



Browning Machine Gun, Cal. .50 M2, Watercooled, Flexible.
Figure 115. The .50 Caliber Machine Guns. (Concluded)

extending into the cockpit. The operating slide connects with the bolt by means of the bolt stud, and provides the means of retracting the breech mechanism by hand for loading and unloading the gun. The bolt also can be drawn back to its extreme rearward position and retained there by engaging the slot provided in the lower surface of the operating slide bar with the operating slide rear

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guide. If the gun is firing through the propeller, it must be fired by means of a synchronized mechanical trigger motor attached to the gun receiver, and this will be supplied by the Army Air Forces.

Under unusual circumstances, the basic gun may be equipped with a retracting slide group assembly and a spade grip back plate assembly having a hand trigger. This is actually a flexible gun as listed in previous standard nomenclature lists. The retracting slide connects with the bolt by means of the bolt stud, and provides the means of retracting the recoiling parts by hand for loading and unloading the gun. The retracting slide grip remains stationary and in a forward position while the gun is firing.

The Browning Machine Gun, cal .50 M2, water-cooled, flexible type, is a recoil-operated, water-cooled alternate feed gun. The cooling system for the gun consists of a water jacket surrounding the barrel, and a water chest with pump for supplying and circulating water through the water jacket. This gun is used extensively against aircraft, and this method of cooling permits long bursts without overheating the barrel.

The water-cooled, flexible, M2 Gun is equipped with a retracting slide group assembly and a flexible back plate having a trigger and a trigger safety, but the spade grips are omitted. The gun is installed in antiaircraft mounts and the spade grips are removed for needed clearance. A picture of this same gun with a spade grip back plate assembly for use in those mounts where this equipment is needed is shown in figure 115. The rear sights and rear sight bases have been removed from water-cooled flexible guns.

The Browning Machine Gun, cal .50 M2, heavy barrel, fixed and flexible types, are air-cooled, recoil-operated, alternate feed guns. The main difference between this type of gun and other types of cal .50 M2 guns is the heavy barrel, the barrel support, and the oil buffer assembly. The barrel of this type of gun must be unscrewed and removed through the front of the gun before the oil buffer group and barrel extension can be removed from the gun. The heavy barrel does not recoil with as much force as the lighter barrels; therefore, it has been the practice in the past to omit the oil buffer piston valve assembly. This allowed the oil to pass more freely through the openings in the oil buffer piston rod head and offered less resistance to the recoil of the barrel. Present manufacturer is omitting the oil buffer gland packing, packing gland ring, packing gland spring, and oil, in addition to the oil buffer piston valve assembly (TM9-1221 C.) but leaving in relief valve, relief valve spring, relief valve screw, tube filler screws. These heavy barrel guns are installed in mounts of several different types, in combat vehicles and tanks, or are used as ground guns mounted on the Machine Gun Tripod Mount, cal .50 M3.

The heavy barrel, fixed, M2 Gun is equipped with a side plate trigger, basic back plate, with horizontal buffer assembly (vertical buffer assembly may be used), and retracting slide group assembly for fixed installations in tanks.

The heavy barrel, flexible, M2 Gun is equipped with a spade grip back plate assembly and retracting slide group assembly for flexible mounting in combat vehicles and tanks, or on the M3 Tripod Mount.

The Browning Machine Gun, cal .50 M1921, aircraft, fixed and flexible types, is a recoil-operated, air-cooled, single feed gun which feeds from the left-hand side only.

The aircraft, fixed, M1921 Gun, is equipped with a back plate with vertical buffer assembly (horizontal buffer assembly may be used), and an operating slide group assembly. The gun was originally designed solely for use as a fixed, synchronized gun.

The aircraft, flexible, M1921 Gun, is equipped with a spade grip back plate assembly and a retracting slide group assembly. This gun was installed on a flexible mount in the aircraft.

The Browning Machine Guns, cal .50 M1921 and M1921A1, water-cooled, are recoil-operated, water-cooled, single feed guns which feed from the left-hand side only. The M1921 Gun was originally designed for use with Antiaircraft Machine Gun Tripod Mount, cal .50 M1. A large number of these guns are still in use in the Navy; however, all such weapons in the hands of the Army have been modified to the M1921A1 type.

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The water-cooled M1921A1 type gun is equipped with a spade grip back plate assembly and a retracting slide group assembly. It will be noted that the retracting slide is mounted at the top center of the side plate rather than lower rear corner as on other guns. This gun is used in the Antiaircraft Tripod Mount, cal .50 M1.

General Data and Characteristics

All types of Browning Machine Guns, cal .50, M2 are alterable as follows:

Ammunition can be fed from left or right side by repositioning of the parts in the belt feed group, the feedway, and the bolt.

Operating and retracting slides can be changed from right to left side of receiver by repositioning and changing the necessary parts. The cover latch lever may be changed from right to left side of receiver by changing the necessary parts.

The aircraft, basic type gun is equipped with a 36-inch barrel which weighs 10 pounds. The water-cooled gun is equipped with a 45-inch barrel which weighs 15.2 pounds. The heavy barrel gun is equipped with a 45-inch barrel which weighs 28 pounds.

The rate of fire for the aircraft, basic type of gun is 750 to 850 rounds per minute; for the water-cooled type of gun, 550 to 700 rounds per minute; and for the heavy barrel type of gun, 400 to 500 rounds per minute. It has a maximum range of 7,200 yards; the effective range being determined by the type of particular gun installation. Depending upon gunsight coordination the fixed aircraft gun has an effective range of 200 to 400 yards. The effective range for the flexible gun is set only by the gunner's ability to lead the target and may be effective at 500 yards, although in some theaters accurate shooting has been carried out at even longer distances. In turret installations its effective range is 500 to 1,000 yards depending upon the type of sight used. Gunners furnished the Sperry computing sight have delivered deadly accurate fire at distance of 1,000 yards. Using armor-piercing ammunition caliber .50 bullets will perforate ¾-inch armor plate at a distance of 600 yards.

Ammunition for the guns discussed here is covered in chapter 4.

Disassembly and Assembly

Disassembly of Browning caliber .50 machine guns closely follows in method and sequence that procedure used in disassembling caliber .30 type machine guns although certain phases and parts nomenclature in some instances are slightly different. Oil buffer groups are used in the caliber .50. This mechanism is discussed separately. The following is the procedure for the disassembly and assembly of the watercooled ground type machine guns and the caliber .50 aircraft machine guns and, therefore, disassembly of parts, groups, and assemblies peculiar to each type of the caliber .50 Machine Gun.

M2, Water-cooled

Disassembly. Remove the front end cap thread cover. Turn the gun bottom side up and loosen the front barrel bearing lock screw jam nut and remove the front barrel bearing lock screw and muzzle gland lock. Unscrew the muzzle gland using the combination wrench, and remove the muzzle packing ring and packing. Unscrew the front barrel bearing lock and after removing it, unscrew the front barrel bearing using the combination wrench, or other tool.

Remove the front steam tube support lock screw. The notch in the steam tube support should be noted and placed in the same relative position when reassembled. Loosen the front steam tube support using the combination wrench or a large screw driver. The front of the water jacket should be slanted downward as this is done.

Before removing the water jacket, make alining mark on the water jacket and trunnion with a cold chisel. Pull the trunnion block lock to the rear and give it a quarter turn so that the cotter pin will hold it out of engagement. Use a strap pipe wrench to unscrew the water jacket from the trunnion. Remove the shim, take out the cotter pin, and remove the trunnion block lock and spring. Some guns of recent manufacture have a steam tube of improved design that is rigidly and permanently mounted in the water jacket. Such guns may be

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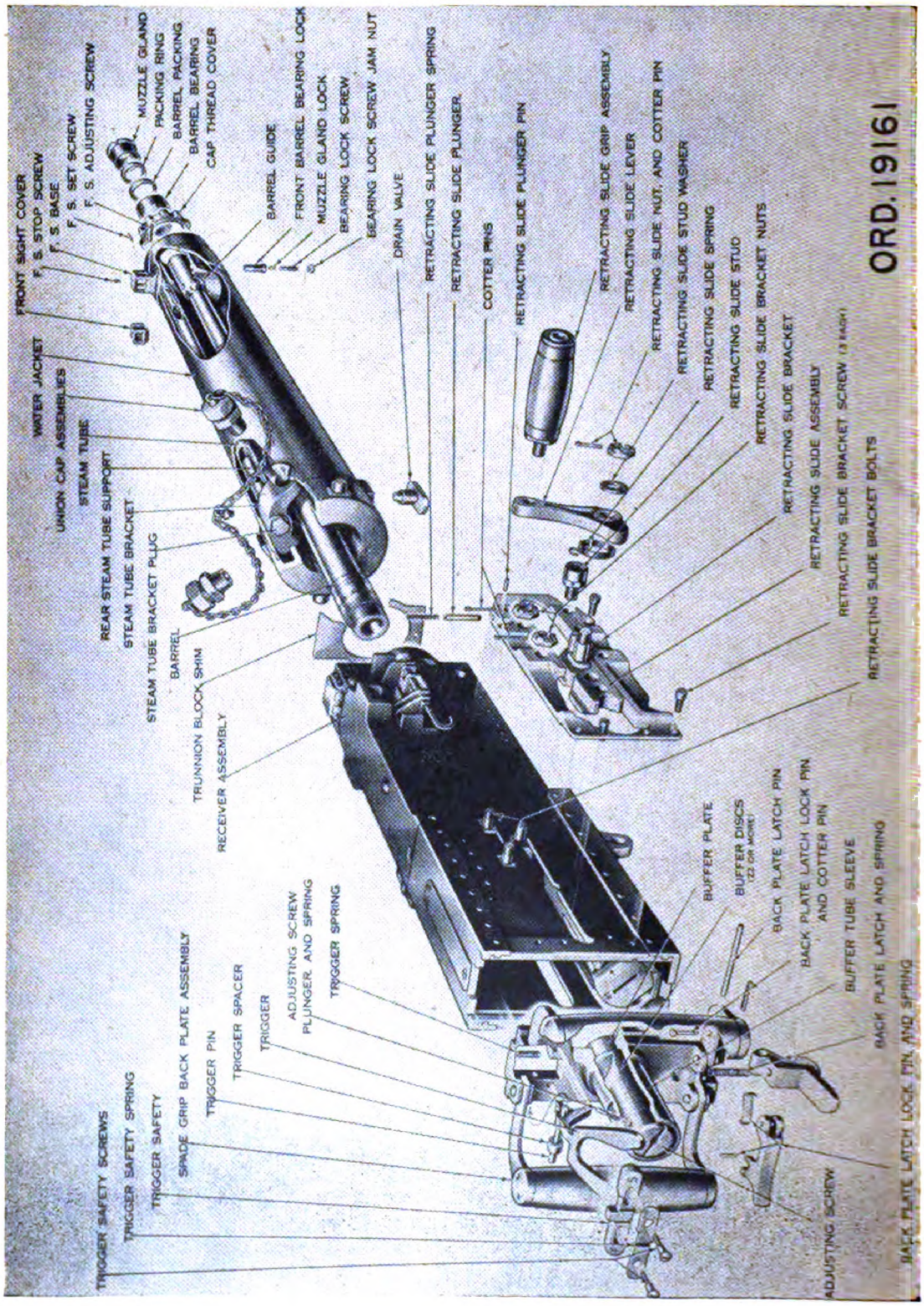

Figure 116. Watercooled Adaptation—Browning Machine Gun Cal .50 M2.

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identified by the absence of the front steam tube support on the front end cap. Inasmuch as there are no moving parts, the only possible repair is of leaks in the water jacket.

Assembly. In assembly the reverse procedure will be used with the following additions:

When a gun is reassembled it is usually necessary to use a shim of the next higher number than the one previously used.

After placing the proper shim in position against the trunnion, apply an even coating of white lead to the threaded section of the trunnion.

Screw on the water jacket and tighten until the alinement marks come together.

M2, Heavy Barrel

Bolt Latch. *Disassembly.* If the gun is set up for single-shot, semiautomatic operation, it will be equipped with a bolt latch. If necessary to disassemble the bolt latch, first remove trigger bar, then reach into the rear of the opening in the top of the receiver and withdraw the cotter pin and slowly unscrew the bolt latch rod nut until the bottom of the slot in the nut is flush with the end of the rod. Hold the bolt latch assembly firmly from the rear of the receiver while unscrewing the nut. This can be best done by inserting a large screwdriver or rod through the rear of the bolt stud slots in both side plates, and using the long arm of the combination tool with the lug hooked over the screwdriver or rod and the edge of the wrench against the right lower corner of the bolt latch. When the bolt latch comes in contact with the trigger bar stop, press down on the bolt latch as it is eased rearward. *(Caution:* Great care must be used to prevent injury to personnel because of the strong spring pressure.) When the nut has been removed, withdraw the bolt latch assembly from the mounting bracket. Be careful not to lose the bolt latch plunger and latch plunger spring. When assembly has been removed, disassemble by pushing out the bolt latch pin.

Assembly. If a bolt latch is being used, it must be assembled before the trigger bar is installed. Assemble the bolt latch and rod and insert the bolt latch pin. Insert the bolt latch spring in the bracket attached to the top plate as far as it will go. Next put the bolt latch rod into the spring as far as it will go without trying to compress the spring. Insert the plunger and plunger spring into the latch. Using the combination wrench and screwdriver as before, push up on the wrench moving the bolt latch forward. It will be necessary to guide the bolt latch forward and then upward as the spring is compressed in order for the bolt latch plunger and latch plunger spring. When assembly has been removed, the bolt latch rod nut can be screwed on far enough for a cotter pin to be inserted.

Basic Weapon. *Disassembly.* Unscrew the barrel from the barrel extension and move it forward. Pull back the trunnion block lock and give it a quarter turn so that the cotter pin holds it out of engagement. Using the combination wrench, unscrew the barrel support. Remove the shim, take out the cotter pin, and remove the trunnion block lock and spring. Remove the breech bearing lock screw and unscrew the breech bearing from the trunnion block using the combination wrench.

Assembly. In assembly the reverse procedure will be used with the following addition. If a new bearing is being installed, screw it tightly into place and then drill a hole for the lock screw by drilling down through the hole in the trunnion block with a No. 7 drill.

Feed Change Over. The assembly sequence and the changes which must be made in the feed mechanism to adjust the aircraft machine guns for right or left hand feed are indicated in figure 138.

When the belt feed slide is assembled for either right- or left-hand feed, the belt feed pawl arm must be placed over the belt feed pawl pin and locating pin so that the arm will be toward the rear when the cover is closed. The pawl and pawl arm, properly assembled, are placed in the belt feed slide with the spring held by the spring stud and recess in the pawl. The spring is depressed to aline the holes and the pin inserted. The belt feed slide is placed in its way or groove in the cover with the pawl end of the slide toward the side from which the gun is to be fed.

Insert the belt feed lever plunger and spring in the hole in the belt feed lever

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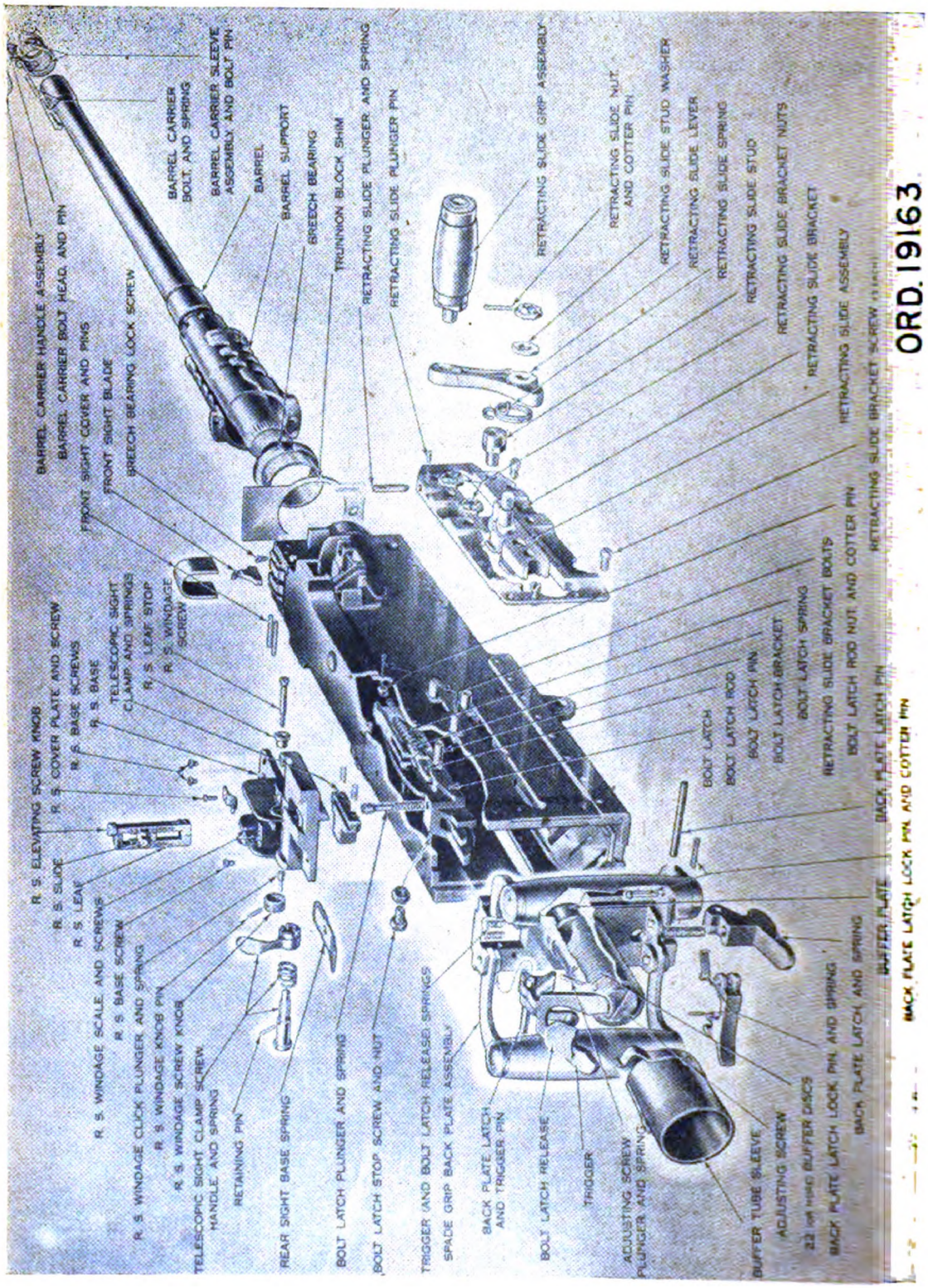

Figure 117. Heavy-Barreled Adaptation—Browning Machine Gun Cal .50 M2.

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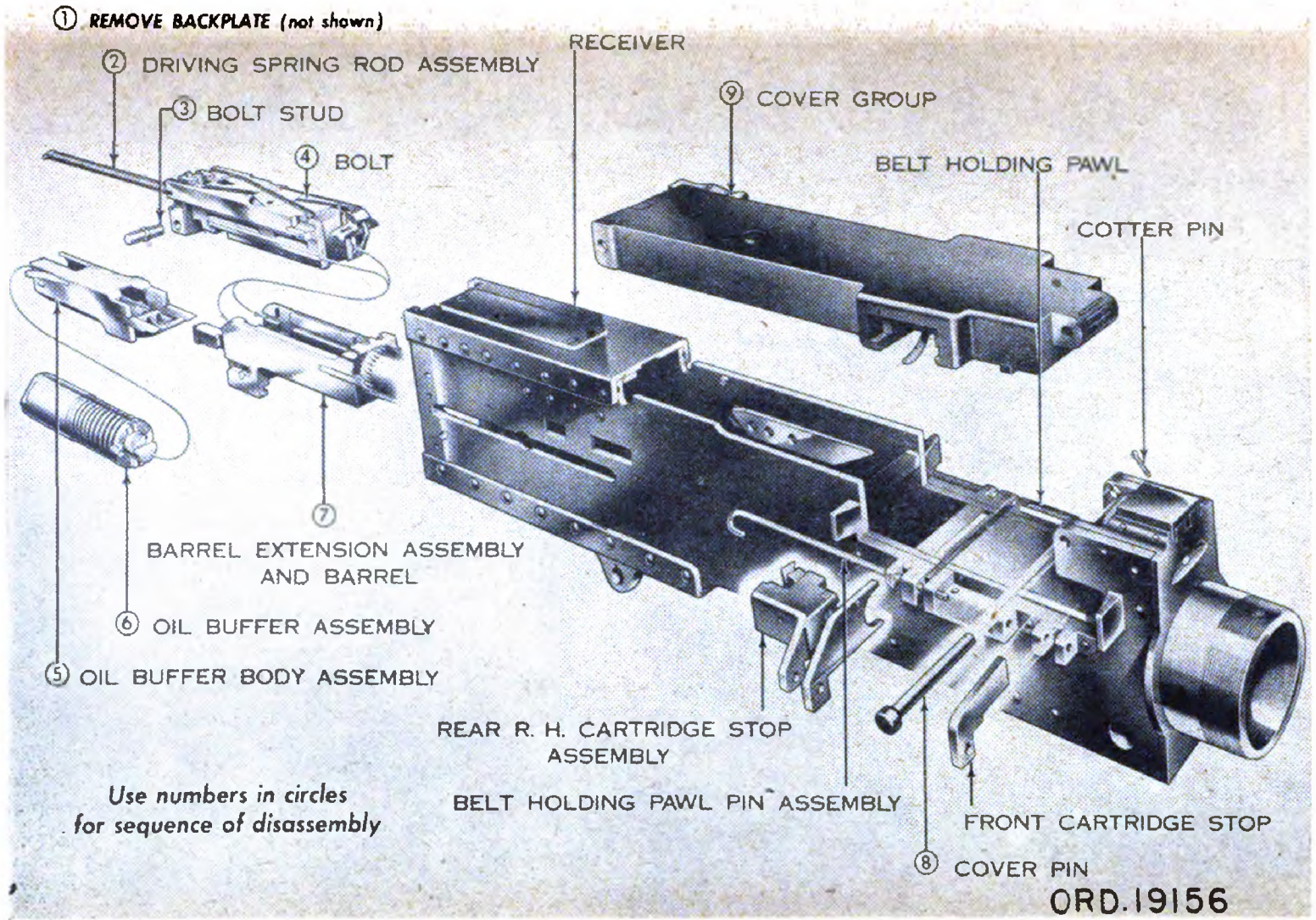

Figure 118. Groups Disassembly—Browning Machine Gun Cal .50 M2.

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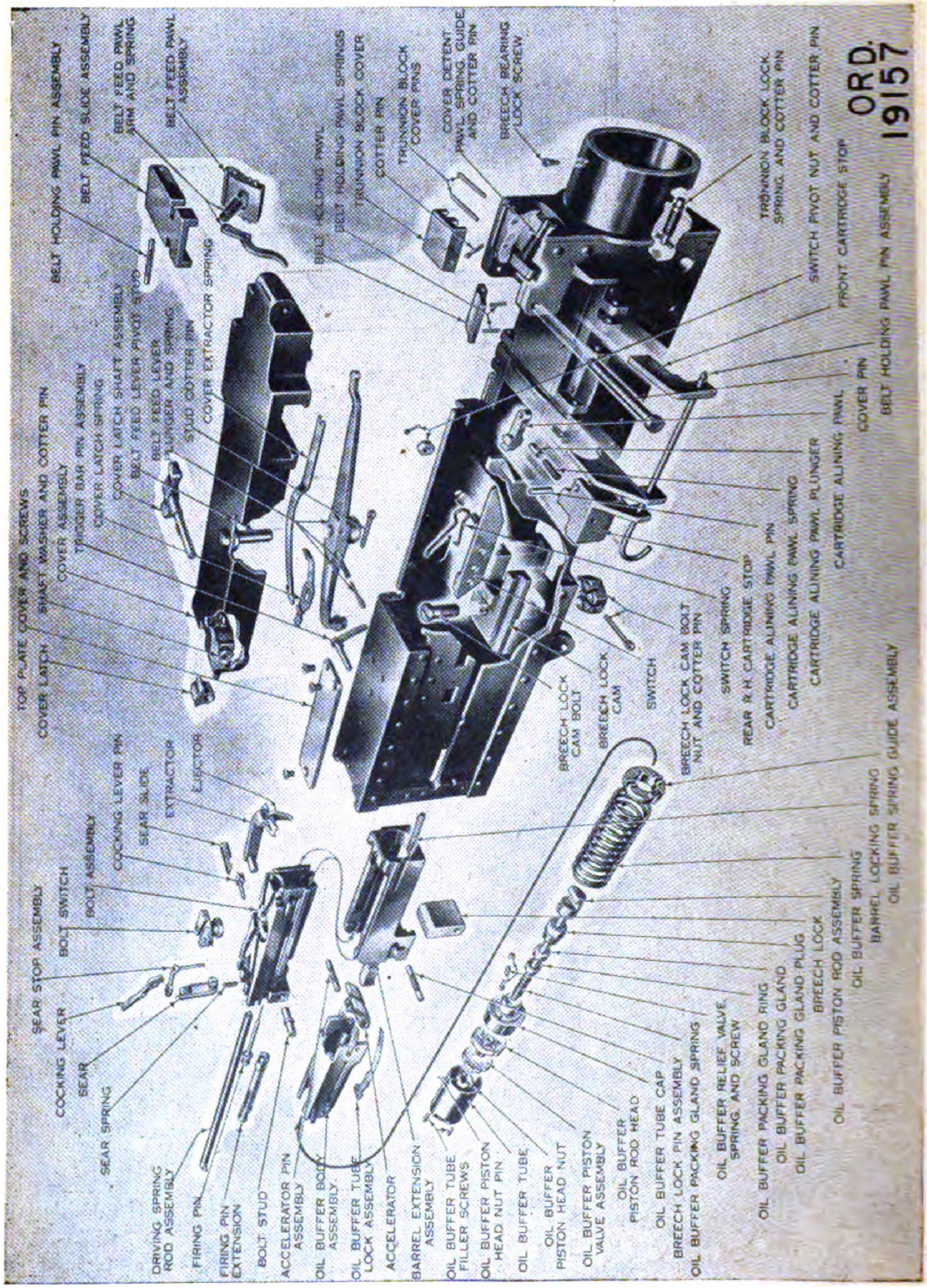

Figure 119. Detail Stripping—Browning Machine Gun Cal .50 M2.

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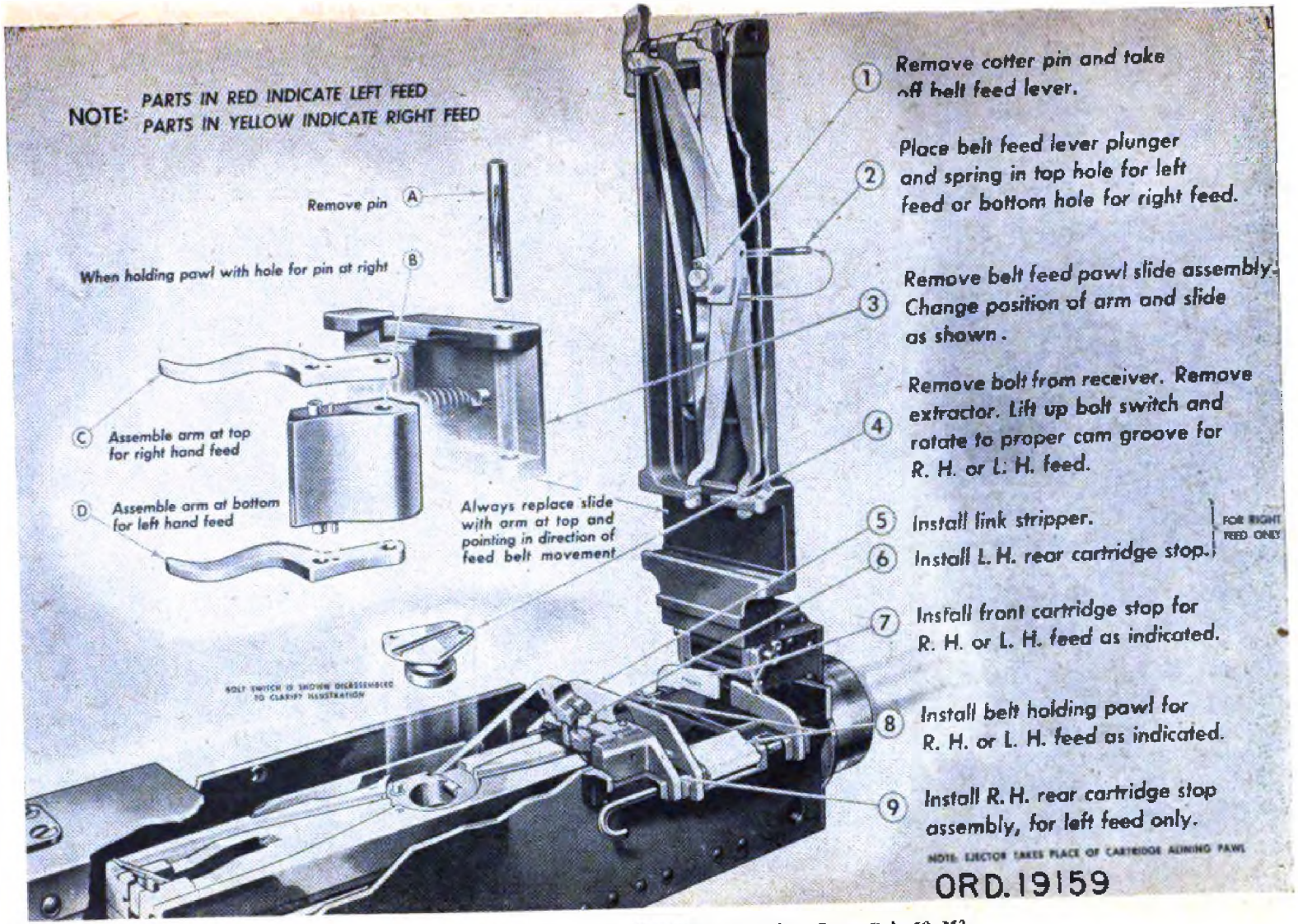

Figure 120. Feed Change Over, Browning Machine Gun, Cal .50 M2.

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toward the latch end for left-hand feed and in the hole toward the hinge end for right-hand feed. Aline the notch in the belt feed slide with the slot in the cover. Place the belt feed lever, with the shoulder up, over the pivot stud and, after depressing the lever plunger and spring, push the lever completely down on the stud so that the toe of the lever can work to and fro in the slot in the cover. Replace the belt feed lever cotter pin.

Oil Buffer Group Disassembly and Assembly

Disassembly. Remove oil buffer assembly from the oil buffer body by pressing on the end of the piston rod with the forefinger. Turn oil buffer body over and place upside down on the table. To remove the tube lock, elevate the tips of the accelerator with the forefinger of the left hand, and press down on the end of the tube lock with the thumb. Using a screwdriver in the right hand, raise the rear end of the tube lock so that the protrusion will clear the oil buffer body. Rotate the accelerator rearward and the tube lock will be pushed out of its recess. The left thumb will keep the tube lock from springing out suddenly. With a drift, push out the accelerator pin and remove the accelerator. In most cases the oil buffer body spring lock is staked and not removed in disassembly.

The oil buffer assembly is not usually disassembled unless repair or replacement of parts is necessary. If disassembly is necessary, proceed as follows: Place oil buffer on a bench, compress the oil buffer spring, and rotate oil buffer spring and guide through 90° in either direction to aline the piston rod pin with the slots in the spring guide. Exercise care to avoid injury. Release pressure slowly and remove the spring guide and spring.

Note: If a vise is available, grasp the spring guide in the vise, and the operations outlined above can be performed with greater ease and safety.

Remove the filler screws, using a screwdriver which fits the slots exactly, and drain out the oil. Remove the oil buffer tube cap with the projection of the combination wrench marked "OIL BUFFER CAP." After removal of the cap, the piston rod and related parts may be withdrawn from the tube. Take out the piston head nut pin and unscrew the piston head nut. Remove the piston valve assembly and unscrew the piston rod head. Unscrew the gland plug from the cap. The oil buffer packing, packing gland ring, and packing gland spring can then be taken out.

Assembly. Present manufacture of heavy barrel guns is omitting the oil buffer gland packing, packing gland ring, packing gland spring, and oil, in addition to the oil buffer piston valve assembly but leaving in relief valve, relief valve spring, relief valve screw, tube filler screws.

Place the packing gland plug, gland packing, gland ring, gland spring and tube cap on the piston rod in the order named, being sure the bevel on the packing (conical type) fits into the gland ring. (The new (cylindrical type) packing A153162 is assembled in the same order, but with a washer A153161 and spring A153163 in place of the gland ring and spring used with the old conical type packing.) Screw gland plug into tube cap and tighten, using combination wrench. Then screw piston head on rod, with the shoulder away from the cap, until the end of the threaded shoulder is flush with the end of the rod. The distance from the forward face of the piston rod head to the forward face of the shank engaging notch on the end of the piston rod should not be less than 3.970+0.014 inches. Place valve assembly on the shoulder of the rod head with the flat face toward the rod head. Screw the piston head nut on the rod head allowing a clearance of approximately 0.050 inch between the rod head and valve assembly. (A tube lock or a new dime may be used as a thickness gage) Adjust, if necessary, to provide this clearance, aline the slots in the nut and shoulder of the rod head with the hole in the rod, insert the piston head nut pin, and bend both ends of the pin.

Insert the rod and its assembled parts into the oil buffer tube with the valve keys riding in the grooves in the tube wall. Tighten the tube cap securely with the combination wrench. In order for the oil buffer spring to function properly in the gun during the complete recoil stroke, the assembled length of the oil buffer assembly must be within the proper dimensions. The distance

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from the rear of the oil buffer tube to the extreme forward face of the oil buffer piston rod (over-all length) must be between 6.525 inches and 6.553 inches. Turn the oil buffer assembly so that the openings for the filler screws are on top. Pull the piston rod out of tube as far as possible. With OIL, recoil, light, flowing freely from the spout of an oil can, insert the spout in one of the filler holes and fill until the oil flows out of the other filler hole. Insert filler screws and tighten securely with a screwdriver which fits the slots exactly.

Note: It is necessary that the over-all length of the buffer should be between the above dimensions for proper functioning of the gun.

To assemble the spring to the oil buffer assembly, place the oil buffer on bench with the piston rod fully extended. Place the spring on the cap, and the flat surface of the spring guide on top of the spring with the guide key in line with the pin on the cutout side of the rod. Taking care to avoid injury, press the guide down over the rod. When the ends of the pin have passed through the slots in the guide, give the guide a quarter turn in counterclockwise direction and allow the pin to seat in the recess in the guide. If a vise is available, these operations may be performed more conveniently and safely by fastening the guide in a vise and assembling the parts as outlined above.

Insert the accelerator pin through the holes in the oil buffer body and accelerator. Turn the oil buffer body upside down. Lay the tube lock on the body with the bowed side away from the buffer body. Depress the tube lock so as to force the projecting ears into the circular recess in the groove in the oil buffer body. Holding the tube lock down in this position, grasp the projecting end of the lock and slide it toward the accelerator, lifting the projecting end slightly so that the lug on the tube lock clears the oil buffer body. The lug should engage in the hole in the bottom of the oil buffer body.

Replace the spring lock in the side of the oil buffer body and insert the oil buffer in the body with the guide key engaging in the slot in the side of the buffer body.

Procedures and adjustments of the oil buffer assembly described above are performed only by ordnance personnel.

Functional Operation

General. Although the Browning machine gun is an automatic weapon, it is necessary to load and cock it manually to start the operating sequence. The following description assumes that this has been done.

The mechanical or automatic operation is started by releasing the firing mechanism which fires or explodes a cartridge. This is released by means of a manual trigger, solenoid, trigger motor, or other means. When any cartridge is fired, the burning powder violently generates gas. Since the gas is confined by the cartridge case and bullet, it exerts a tremendous pressure. This pressure, which exceeds 50,000 pounds per square inch, pushes against the rear face of the bullet which up to this moment is still held in the cartridge case. Considering the actual area of the back of the bullet, a driving force of about 5 tons pushes the bullet out of the cartridge case and out of the barrel. This same force tries to drive the empty cartridge case out of the chamber toward the rear. Such action is prevented by having the bolt assembly positively locked against the rear of the cartridge at the instant of firing.

As the bullet travels out of the barrel, the force of recoil carries the barrel, barrel extension, and bolt (known as the recoiling portion) backward about 1⅛ inches. During this movement, the bolt is unlocked from the barrel and barrel extension. The rearward travel of the barrel and barrel extension is stopped by the oil buffer assembly, and held by the accelerator acting upon the barrel extension shank. The bolt assembly continues its rearward travel for an additional 6 inches until it is stopped by the driving spring rod assembly and the back plate. During this rearward motion the bolt assembly withdraws the empty cartridge case from the chamber, and also extracts a second live cartridge from the supply belt.

The bolt assembly is driven forward by the driving spring, and during this forward motion the empty cartridge is ejected from the bottom of the gun. At

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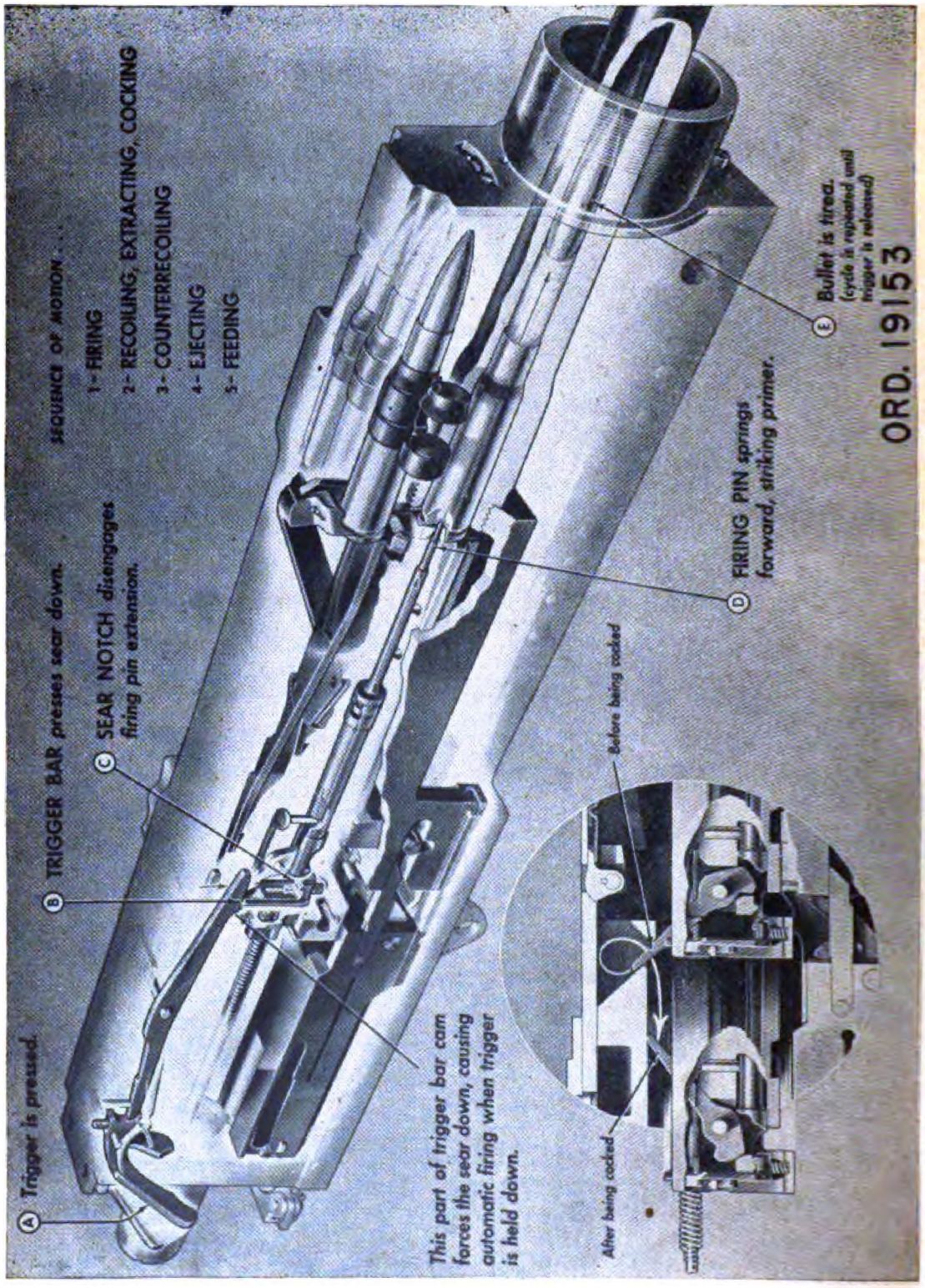

Figure 121 Basic Functioning—Browning Machine Gun, Cal .50 M2.

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the same time, the second live cartridge is started into the barrel chamber. The oil buffer spring shoves the barrel extension and barrel forward. During this movement, the bolt assembly is again locked to the barrel extension and barrel, so as to prevent the cartridge case from being driven rearward after firing. If trigger action has been maintained, the firing pin is released just before the recoiling portion reaches its foremost position. This fires the second cartridge and another cycle is started. This cycle is repeated automatically as long as trigger action is maintained and as long as ammunition is supplied.

Detailed Functioning

General. In the following exposition, a gun employing a manual trigger is used. Except for the actual manner in which the sear is depressed, whether by a manual trigger and trigger bar, or by a solenoid or trigger motor in combination with the sear slide, the functional operation of all guns is identical.

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 to each other can be explained more clearly if the action is separated into various phases. These phases will be explained in the following order:

Firing.
Recoiling.
Counterrecoiling.
Cocking.
Automatic firing.
Feeding.
Extracting and ejecting.

Firing. When the gun has been loaded and the firing pin spring has been cocked or compressed by hand, the firing mechanism is in the position shown in figure 122.

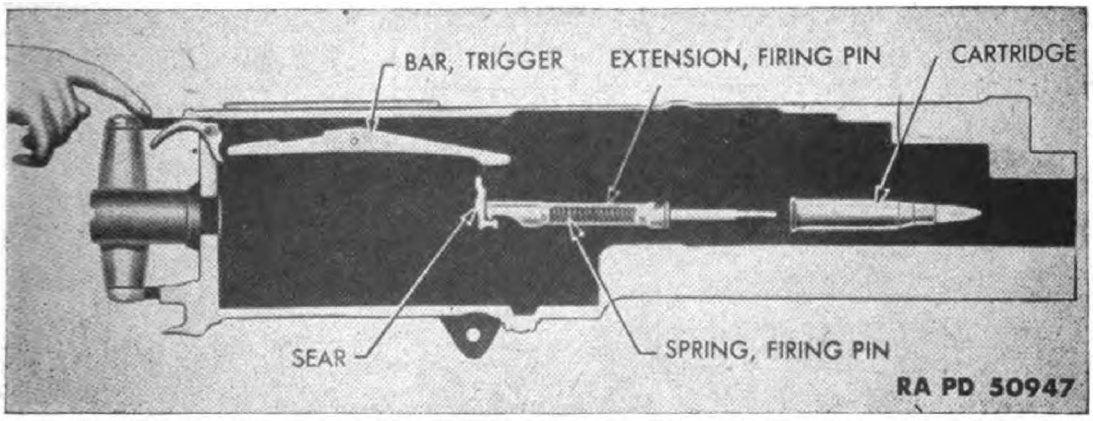

Figure 122. Ready To Fire Position.

When the trigger is pressed, it raises the back end of the trigger bar. The trigger bar pivots on the trigger bar pin, causing the front end to press down on the top of the sear. The sear is forced down 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.

Recoiling. The complete cycle of the recoiling portion of the gun, which takes place as each cartridge is fired, consists of the recoil stroke when certain parts of the gun move rearward, and the counterrecoil stroke when these same parts move forward. At the instant of firing, the barrel, barrel extension, and bolt, known as the recoiling parts, are in [illegible] forward position in the gun.

At this time, the bolt is held [illegible] the base of the cartridge by the

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breech lock, which extends up from the barrel extension into a notch in the underside of the bolt.

After the cartridge explodes, and as the bullet travels out of the barrel, the force of recoil drives the recoiling portion rearward. During the first three-quarter inch of travel, the breech lock is pushed back off the breech lock cam step. This permits the breech lock to be forced down out of the notch in the bolt

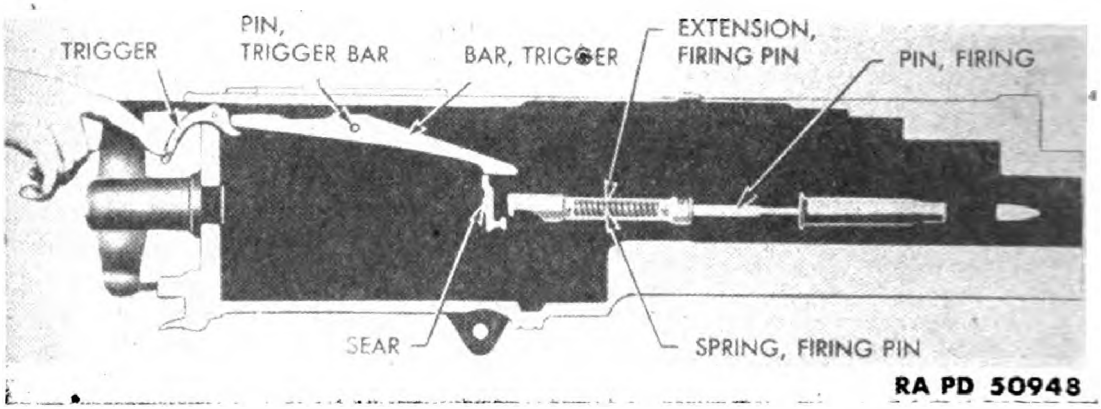

Figure 123. Firing Position.

by the breech lock depressors engaging the breech lock pin, and by the bolt's action on the double beveled forward face of the breech lock. This unlocks the bolt. Figure 125 shows the unlocking action taking place.

As the recoiling portion moves toward the rear, the barrel extension rolls the accelerator rearward. The tip of the accelerator strikes the lower projection on the bolt and hastens or accelerates the bolt to the rear. In figure 126, the breech lock is completely unlocked from the bolt.

The barrel and barrel extension have a total rearward travel of 1⅛ inches at which time they are completely stopped by the oil buffer body assembly.

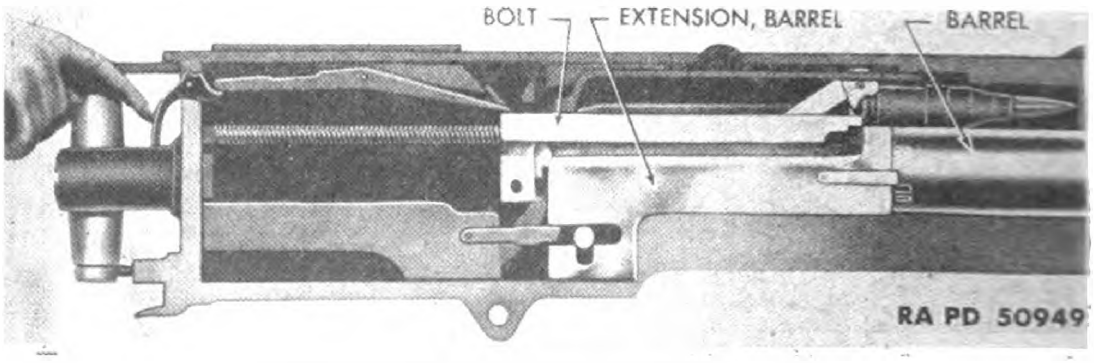

Figure 124. Recoiling Portion In Forward Position.

During this recoil of 1⅛ inches, the oil buffer spring is compressed in the oil buffer body by the barrel extension shank. The spring is locked in the compressed position by the claws of the accelerator, which are moved against the shoulders of the barrel extension shank.

The oil buffer assists the oil buffer spring in bringing the barrel and barrel extension to rest during the recoil stroke. During the 1⅛ inches of rearward travel, the piston rod head is forced from the forward end of the oil buffer tube

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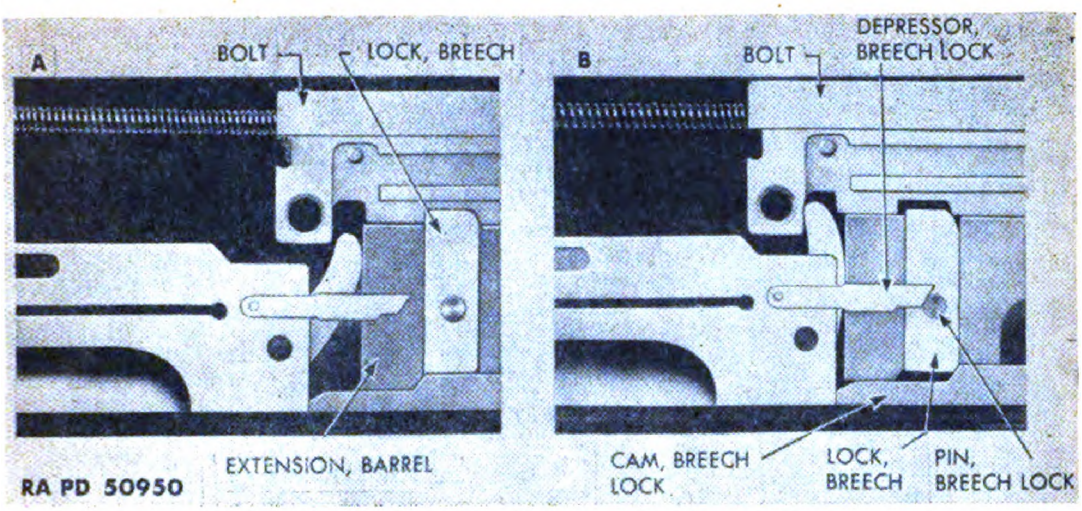

Figure 125. Breech Lock Locked "A" and Unlocking "B"

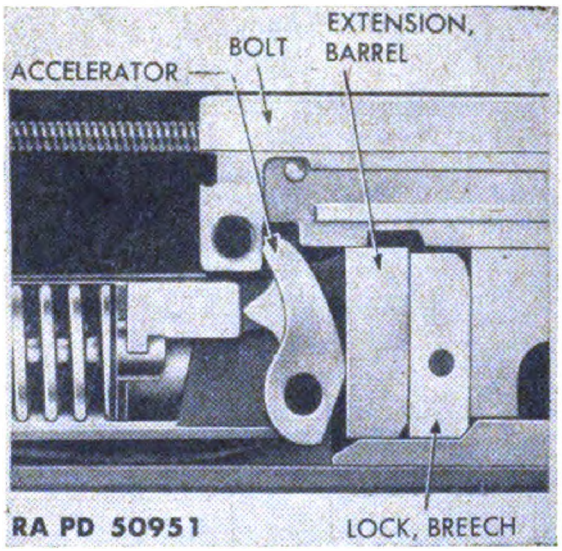

Figure 126. Breech Lock Unlocked

to the rear. The oil at the rear of the oil buffer tube, under pressure of the piston, escapes to the front side of the piston. Its only path is through restricted notches between the edge of the piston rod head and valve, and the oil buffer tube.

The bolt travels rearward for a total of 7⅛ inches. During this travel, the driving spring assembly is compressed. The rearward stroke of the bolt is finally stopped as the bolt strikes the buffer plate. Thus, part of the recoil energy of the bolt is stored in the driving spring assembly, and the remainder is absorbed by the buffer disks in the back plate. At the end of the recoil movement, the parts are in the position shown in figure 127.

Counterrecoiling. After completion of the recoil stroke, the bolt is forced forward by the energy stored in the driving spring and the compressed buffer disks. When the bolt has moved forward about 5 inches, the tip of the accelerator

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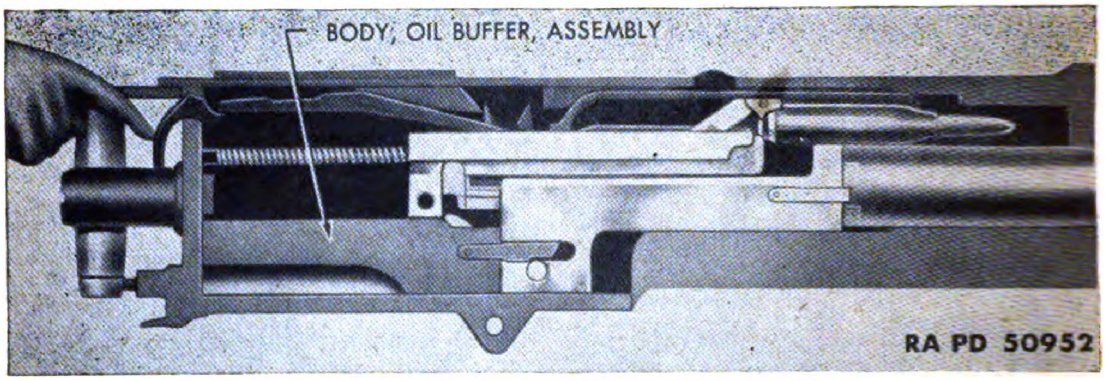

Figure 127. Recoiling of Barrel and Barrel Extension.

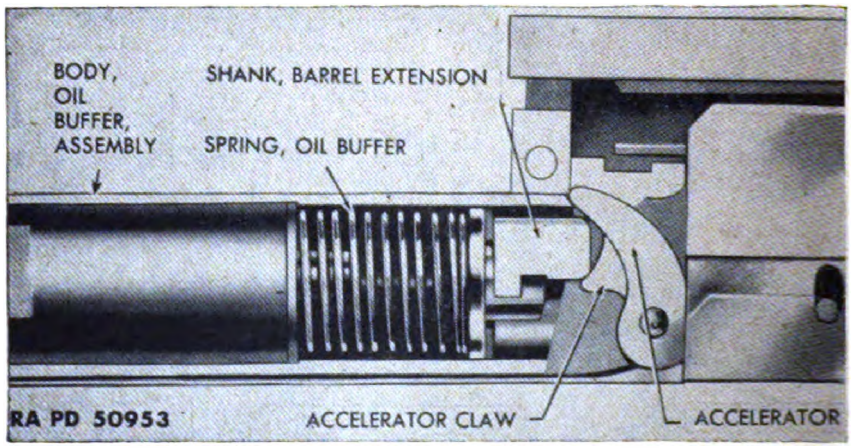

Figure 128. Oil Buffer Spring Compressed and Locked.

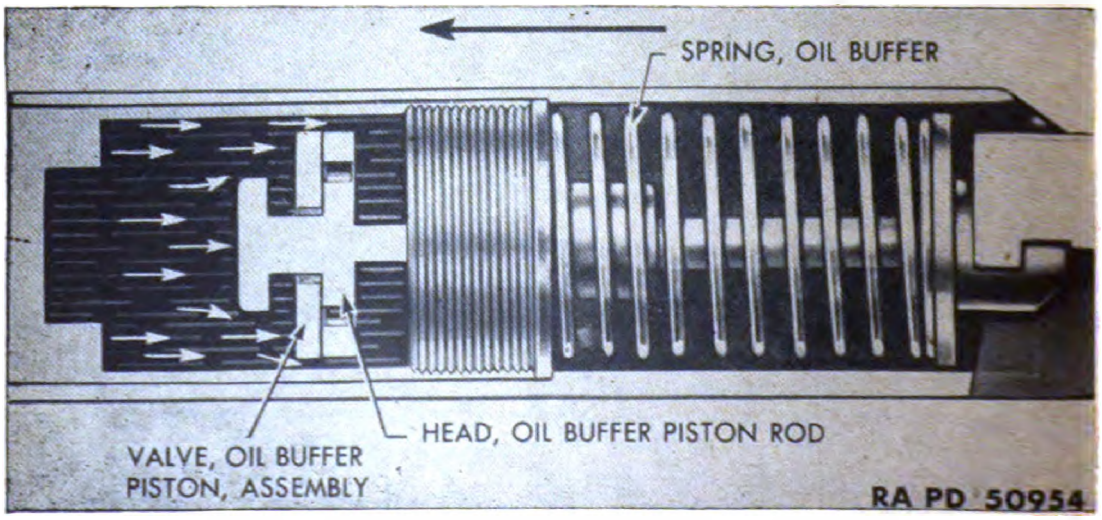

Figure 129. Action of Oil Buffer Assembly During Recoil.

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is struck by a projection on the bottom of the bolt. This rolls the accelerator forward.

As the accelerator rolls forward, the accelerator claws are moved away from the shoulders of the barrel extension shank. This releases the oil buffer spring. The accelerator rolling forward and the energy stored in the spring shove the barrel extension and barrel forward.

No restriction to motion is desired on the forward or counterrecoil stroke of the barrel and barrel extension; therefore, on the forward stroke, additional openings for oil flow are provided in the piston rod head of the oil buffer assembly. The piston valve is forced away from the piston rod head as the parts move for-

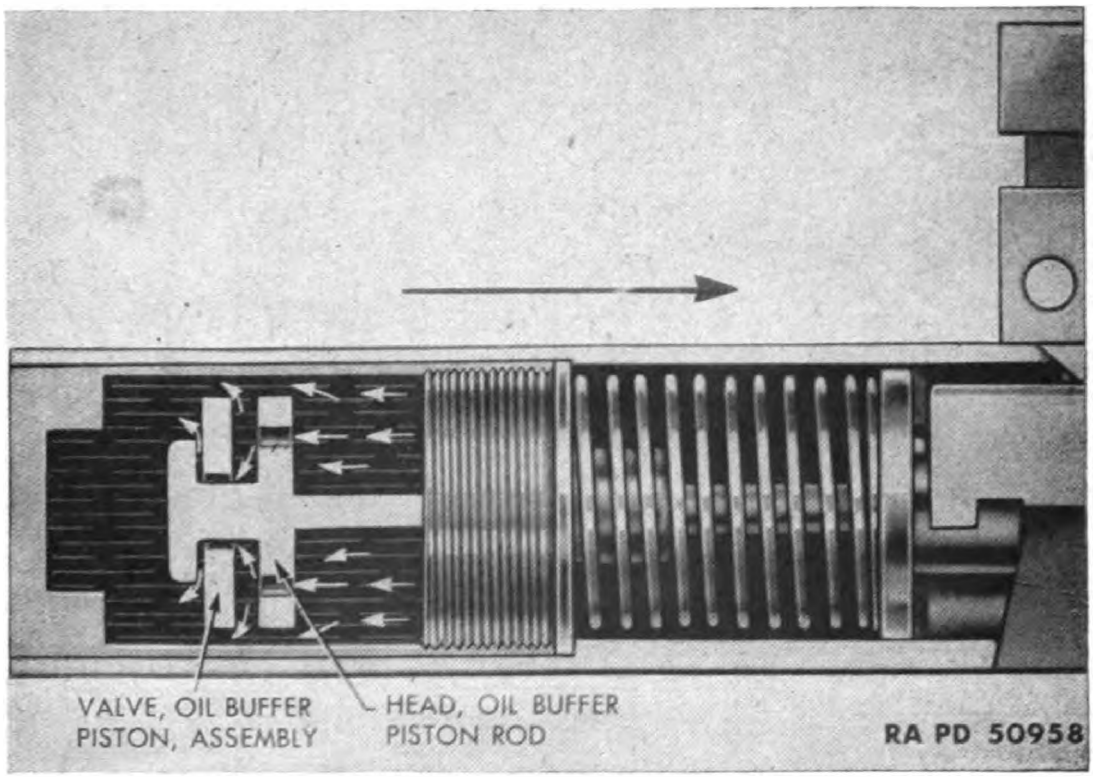

Figure 130. Action of Oil Buffer Assembly During Counterrecoil.

ward, uncovering these additional openings. This provides an additional path and permits oil to escape freely at the opening in the center of the piston valve as well as at the edge of the piston valve next to the tube wall.

As the barrel extension moves forward, the breech lock engages 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 on the underside is directly above the breech lock, thus permitting the breech lock to engage the bolt. The bolt is thereby locked to the barrel extension and barrel just before the recoiling portion reaches the firing position.

Cocking. The act of cocking the gun is begun 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. At the time of firing, the parts are positioned as shown in figure 134.

The cocking lever is pivoted so that the lower end forces the firing pin extension rearward. The firing pin spring is thus compressed against the sear stop pin.

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The firing pin extension moves rearward until the shoulder at its back hooks over the notch at the bottom of the sear under pressure of the sear spring.

During the forward motion of the bolt, the tip of the cocking lever enters the V-slot of the top plate bracket. This action swings the bottom of the cocking

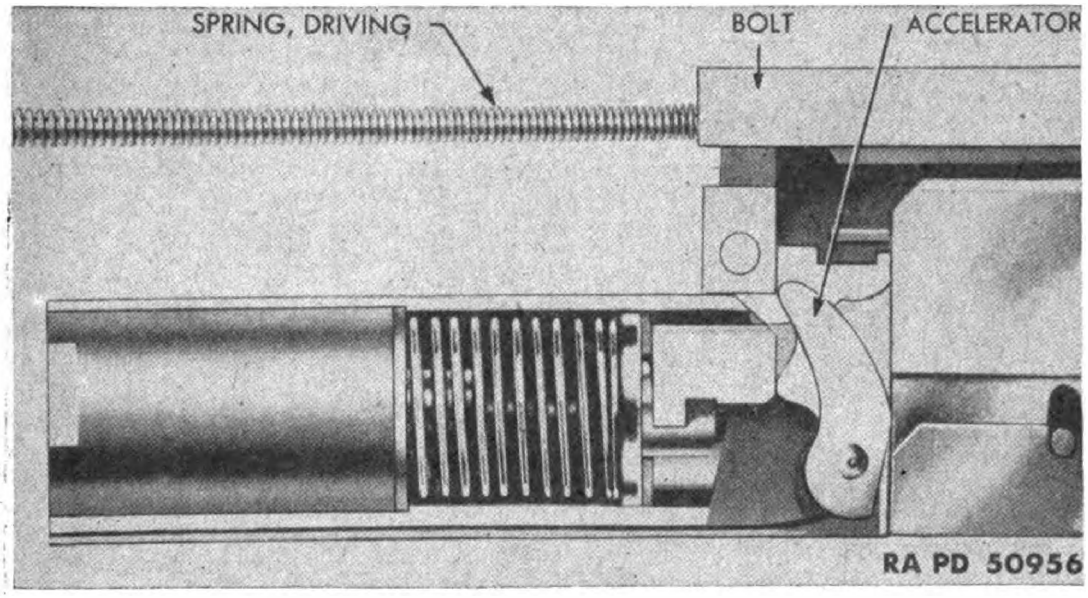

Figure 131. Bolt Striking Accelerator To Release Buffer Spring.

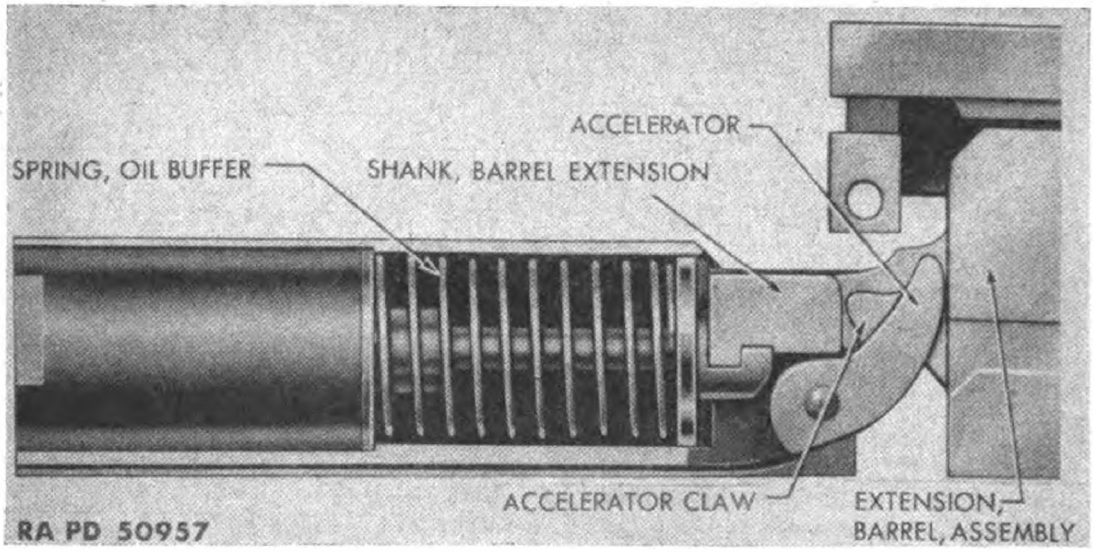

Figure 132. Oil Buffer Spring Released.

lever out of the path of the firing pin extension, thus permitting the firing pin to snap forward when released by the sear. Figure 135 shows the cocking lever being rotated as the bolt moves forward.

When the recoiling portion is approximately one-sixteenth inch from the forward position, the gun is ready to fire. If the trigger is not depressed at this

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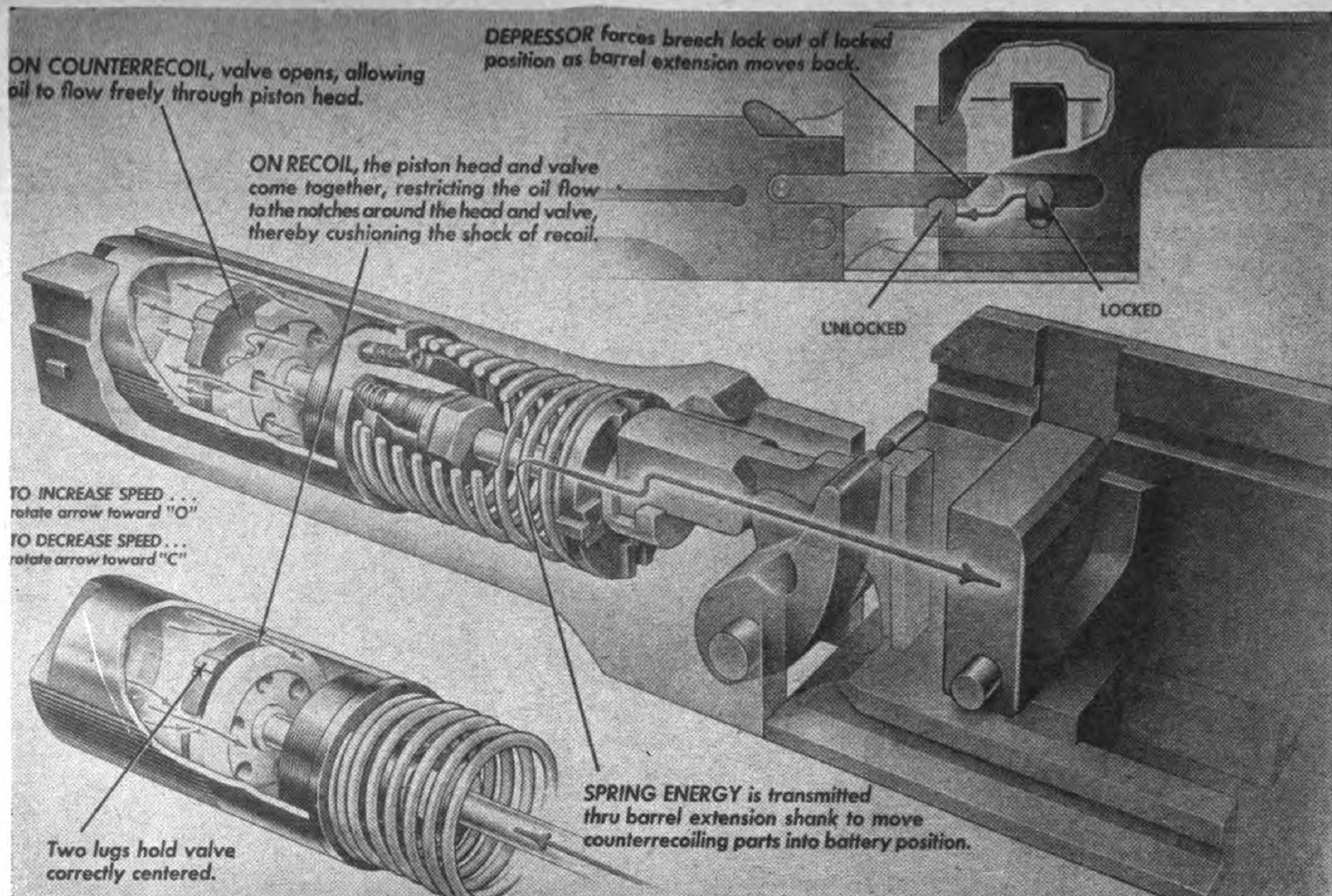

Figure 133. Action of Oil Buffer Assembly During Recoil and Counterrecoil.

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instant, the recoiling portion assumes its final forward position and the gun cease to fire. The parts are now in the firing position and the gun is again ready to fire.

Automatic Firing. For automatic firing, the trigger is pressed and held down.

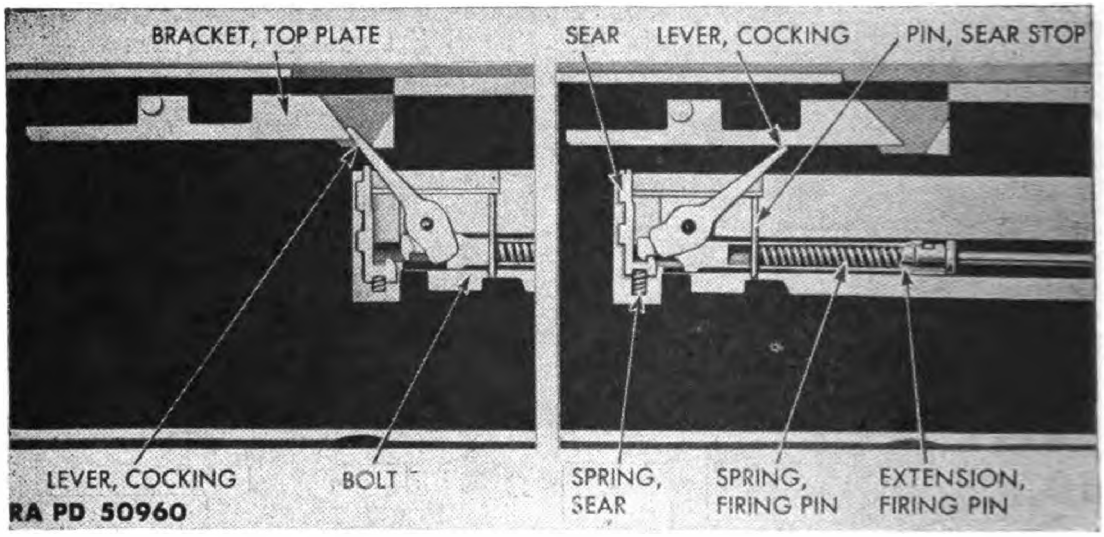

Figure 134. Cocking Action During Recoil.

The sear is depressed as its tip is carried against the cam surface of the trigger bar by the forward movement of the bolt near the end of the counterrecoil stroke. The notch in the bottom of the sear releases the firing pin extension and the firing pin, thus automatically firing the next cartridge at the completion of the forward stroke. The gun fires automatically as long as the trigger is held down and until the ammunition supply is exhausted.

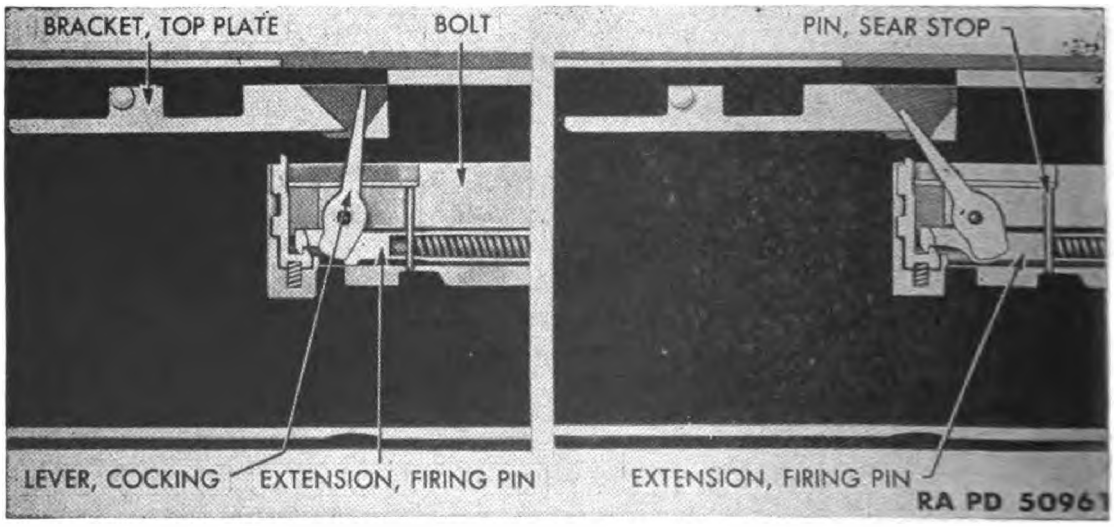

Figure 135. Cocking Action During Counterrecoil.

Feeding. The belt feed mechanism is actuated by the bolt. When the bolt is in the forward position, the belt feed slide is within the confines of the gun. A lug on the rear of the belt feed lever is engaged in the diagonal cam groove in the top of the bolt.

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As the bolt moves rearward during recoil, the belt feed lever is pivoted. The forward end of the belt feed lever moves the belt feed slide out of the side of the gun and over the ammunition belt. Ammunition feed, as shown, is from the left side of the gun. Feed from either side is possible with all cal .50 M2 Guns.

Note: On previous models, namely, the M1921 and M1921A1, ammunition could be fed from only the left side.

The ammunition belt is pulled into the gun by the belt feed pawl which is attached to the belt feed slide. When the belt is forward, the belt feed pawl has positioned a cartridge directly above the chamber. The belt holding pawl is in a raised position to prevent the ammunition belt from falling out of the gun.

As the bolt recoils, the belt feed slide is moved out over the belt, and the belt feed pawl pivots so as to ride over the link holding the next cartridge in the belt.

At the end of the recoil stroke, 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.

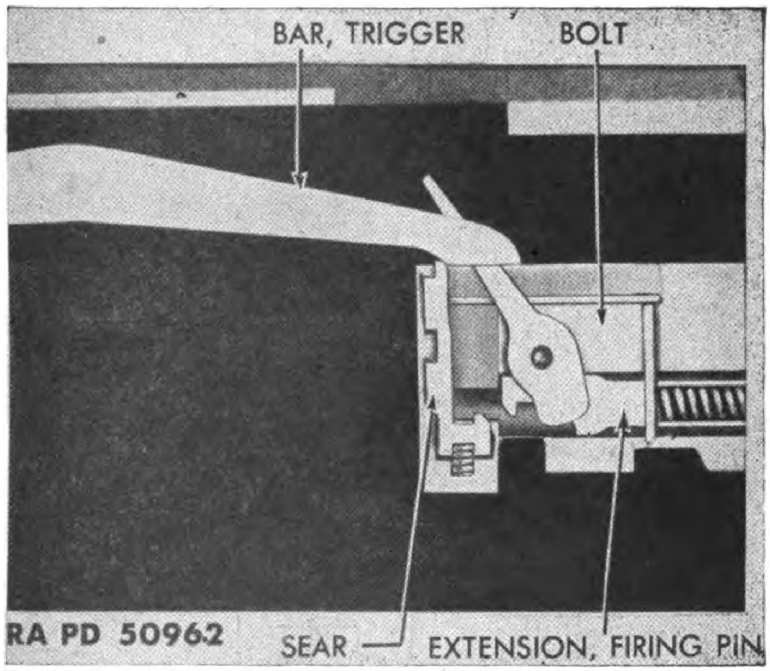

Figure 136. Automatic Firing.

As the bolt moves forward on the counterrecoil stroke, 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. When the forward stroke of the bolt is completed, the belt holding pawl snaps up behind the next cartridge, as shown in figure 138.

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.

The empty case, having been expanded by the force of explosion, fits the chamber very snugly, 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 front side of the notch in the bolt are beveled. Thus, as the breech lock is unlocked, the bolt moves away from the barrel and barrel extension 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 switch, causing the switch to pivot downward at the rear. Near the end of the rearward movement of the bolt, the lug on the extractor overrides the end of the switch, and the switch snaps to its normal position.

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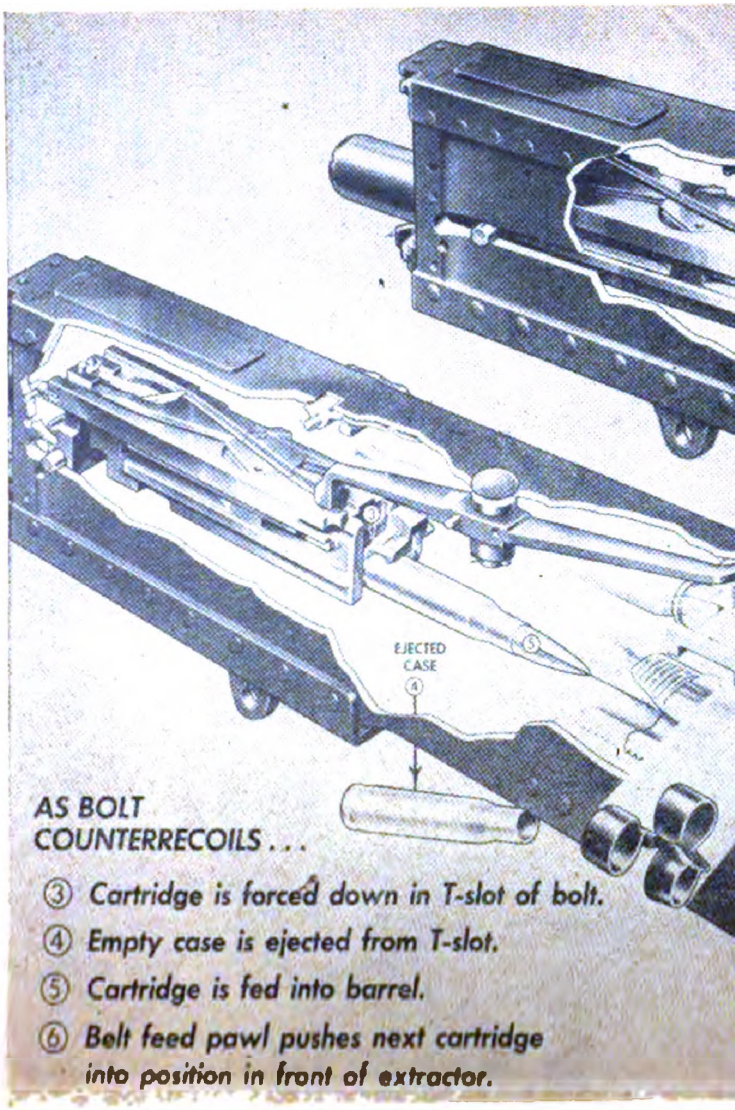

Figure 137. Feeding Extra

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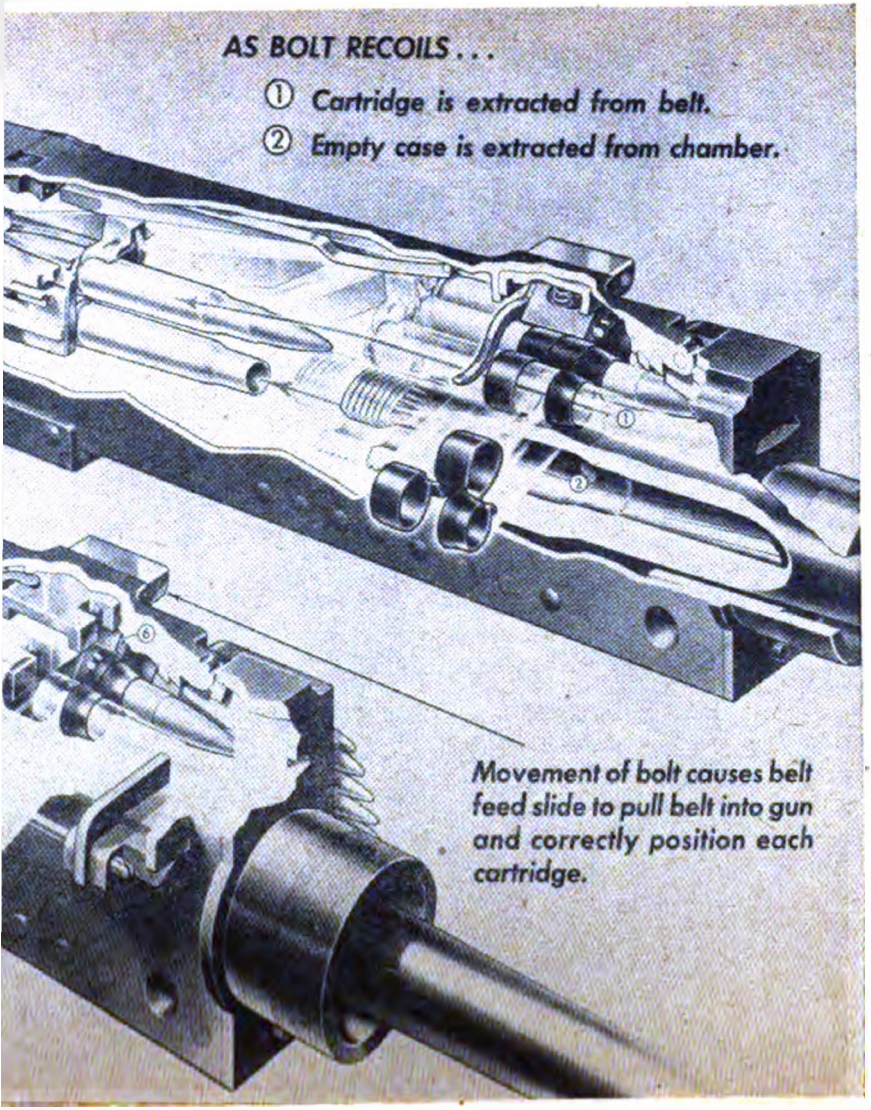

action and Ejection—BMG Cal .50 M2.

On the counterrecoil stroke, the extractor is forced farther down by the extractor lug riding under the switch. The cartridge expels the empty case. The extractor stop pin in the bolt limits the downward travel of the extractor so that the cartridge, assisted by the ejector, enters the chamber. When the cartridge is nearly chambered, the extractor rides up the extractor cam, compresses the cover extractor spring, and snaps into the groove in the next cartridge.

Single-Shot, Semiautomatic Operation

Under some conditions, it is desirable to operate this gun as a single-shot, semiautomatic weapon. To meet this condition, the gun may be equipped with a

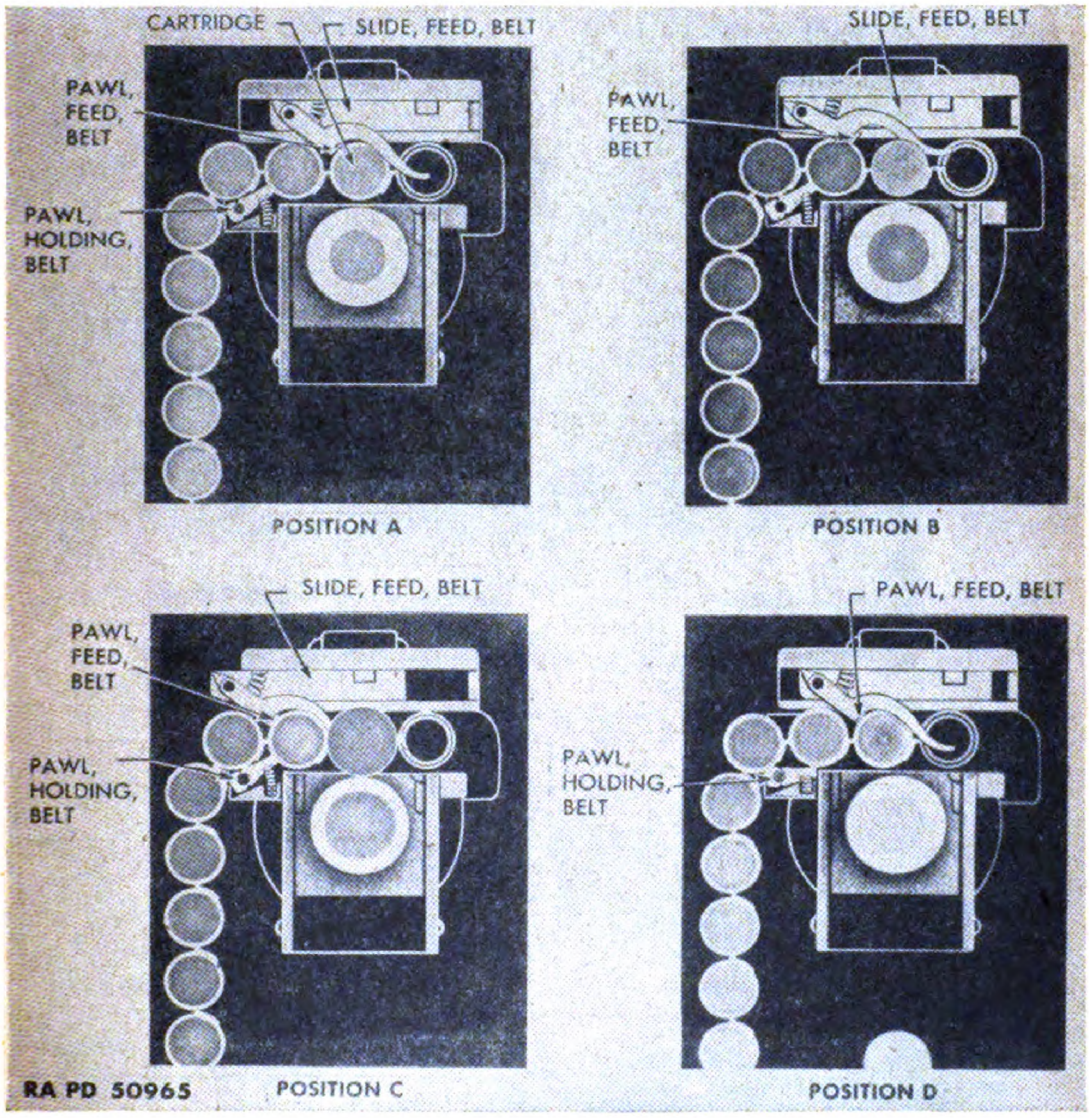

Figure 138. Belt Feed Mechanism.

bolt latch. At present, the heavy barrel gun is the only gun so equipped. The bolt latch is attached to the bolt latch bracket, which is riveted to the underside of the top plate and the right-hand side plate. The latch engages a shoulder on the top of the bolt when the bolt is in its rearward position. A bolt latch release which controls the latch is provided.

With the bolt latch installed, the bolt, as it moves to the rear, is engaged and held there. When the bolt latch release is pressed down, the latch assembly is raised to allow the bolt to be driven forward to the battery position. The gun

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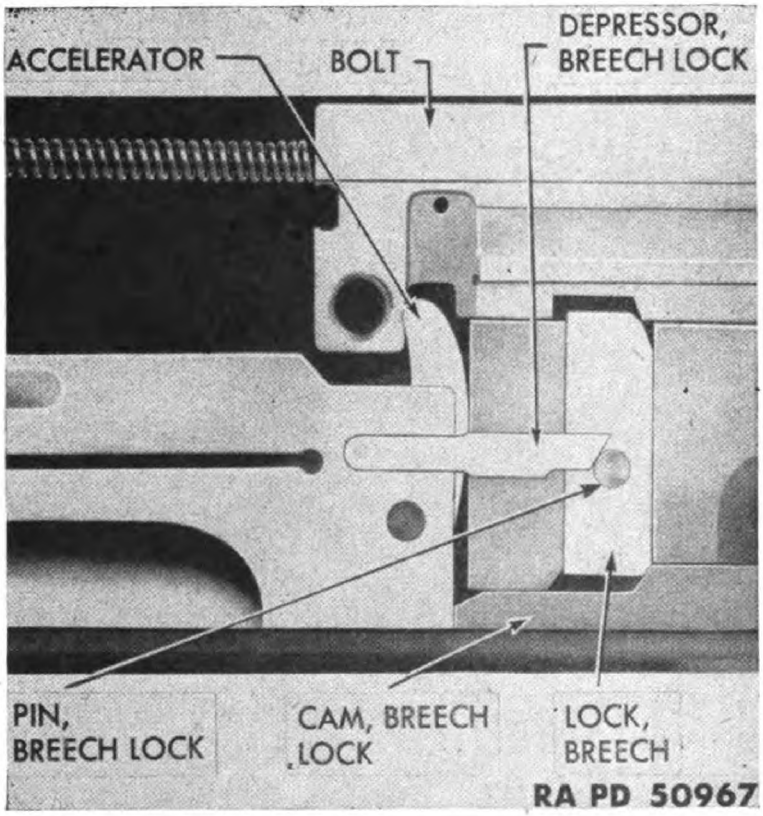

Figure 139. Beginning Of Unlocking.

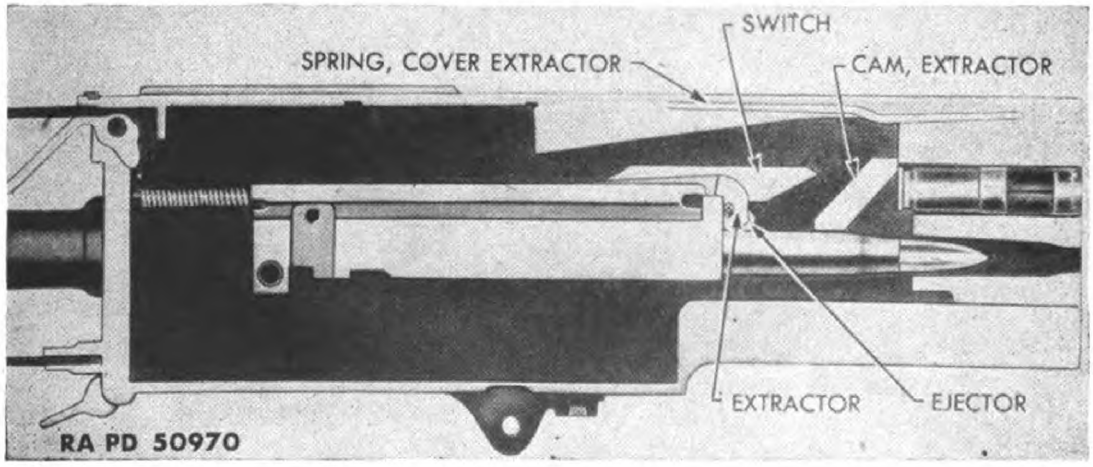

Figure 140. Chambering.

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may then be fired by pressing the trigger. If both the bolt latch release and trigger are held down, the gun will function as an automatic weapon. The bolt latch release may be locked in the depressed position by means of a lock secured to the back plate group.

Malfunctions and Stoppages of Machine Guns

Introduction. Analysis of the available data indicates that a number of stoppages and malfunctions can be attributed to improper field adjustments such as headspace adjustment, buffer adjustment, improper timing, improper or complete lack of preventive maintenance, and lack of supervised inspection.

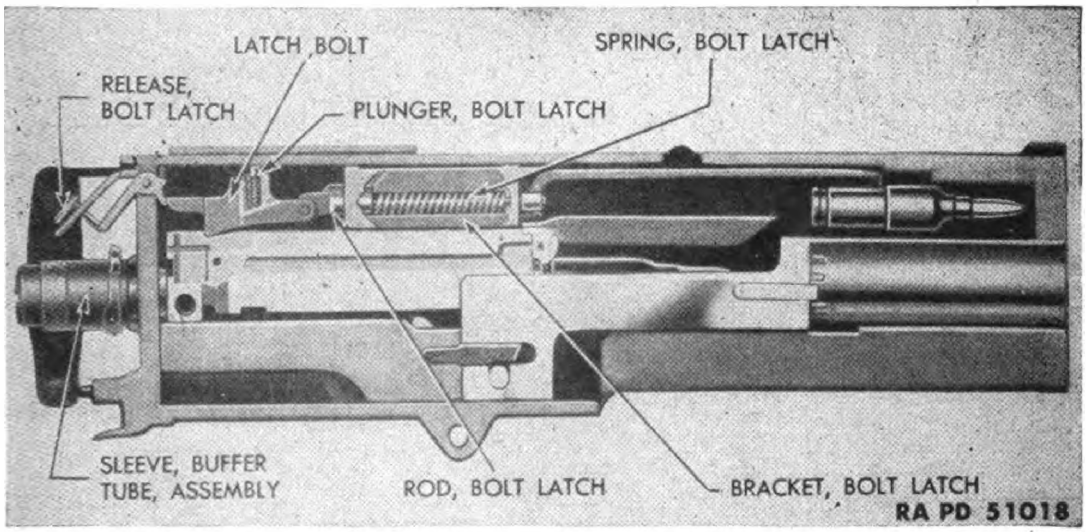

Figure 141. Bolt Latched In Rear Position.

1. **Malfunction:** Failure to feed.

Stoppage: 1st.

Caused By: Worn cartridge stops.

A worn cartridge stop, front or rear, may cause a failure to feed. This is due to the round being improperly positioned in the feed way. If the round is not held in the approximate center of the feed way, but allowed to go past center by worn cartridge stops, the extractor or the bolt may strike the base of the round and drive it forward. This will result in a short round.

Corrective Action: Remove short round from the bolt, replace worn cartridge stop and recharge the gun.

Preventive Maintenance: Periodic routine inspection of these parts. Examination of all new parts for defects. Check vertical play, approximately 1/16 inch of rear cartridge stop and link stripper (Cal .50).

2. **Malfunction:** Failure to feed.

Stoppage: 1st.

Caused By: Worn or bent belt feed lever.

Improper positioning of rounds in the feed way. Either pulling the round too far into the feed way or not far enough. In either case, the result would be short rounds. The bolt or the extractor may strike the cartridge case and drive it forward against the bunter plug or plate or the portion of the trunnion block around the bunter plug.

Corrective Action: Replace worn belt feed lever or straighten bent one.

Preventive Maintenance: Check for binding action in the feeding mechanism. Check cam ways on the top of the bolt for burrs and rough spots. Check clearance between the top of the bolt and the diamond stud on the belt feed lever. There should be clearance. If the T-slot in the cover in which the belt feed lever works is short, there will be rapid wear on the lever or it may even bend.

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3. **Malfunction:** Failure to feed.

Stoppage: 1st.

Caused By: Weak belt feed pawl spring.

Gun will function perfectly by hand but due to the fast action during firing, the belt feed pawl does not move down fast enough for positive action. The result is that the gun will usually fire two rounds and stop. Sometimes it will fire more than this but will eventually malfunction.

Corrective Action: Replace the belt feed pawl spring; also check pawl for freedom of action.

Preventive Maintenance: Check to see that the spring is properly seated. Check to see that the belt feed pawl is not binding in the belt feed slide. Check proper length and tension of belt feed pawl spring.

4. **Malfunction:** Failure to feed.

Stoppage: 1st.

Caused By: Weak, broken, or missing belt holding pawl springs.

Gun may fail to feed, depending on whether the spring is weak, broken, or missing. If the spring is weak, the gun may fire a few rounds and then fail to feed. This is caused by the belt sliding backward with the outward movement of the belt feed slide. If the belt is not held in position by the belt holding pawl, the gun will not feed.

Corrective Action: Replace weak or broken spring. Check pawl for free action. Check belt holding pawl spring recess for dirt, rust, grease, burrs, and rough spots.

Preventive Maintenance: Check pawl for binding action.

5. **Malfunction:** Failure to feed.

Stoppage: 1st.

Caused By: Worn bunter plug or bunter plate.

A worn bunter plug would allow the round to slip forward out of reach of the extractor. Each round would act the same as a short round, although the rounds would not actually be short.

Corrective Action: Replace the worn bunter plug.

Preventive Maintenance: Check smooth surface of trunnion block upon which the tip of the round may ride, and especially the bunter plug or plate

6. **Malfunction:** Failure to feed.

Stoppage: 1st or 2nd.

Caused By: Worn extractor claw.

Extractor may slip off the round, failing to remove it from the belt (1st position), or the extractor may partially remove the round and then slip off. The stoppage would be 2nd position as the bolt could not go all the way forward again.

Corrective Action: Replace extractor assembly.

Preventive Maintenance: Make sure the extractor claw is free from burrs and the two points are of equal length.

7. **Malfunction.** Failure to feed.

Stoppage: 1st or 2nd.

Caused By: Weak or broken cover extractor springs.

If the cover extractor spring is weak or broken, the extractor may slip off the cartridge case and fail to extract it from the belt.

Corrective Action: Check cover extractor spring, and replace if defective Also check cam portion of extractor that contacts spring for wear and burrs.

Preventive Maintenance: Check to see that the extractor cam is not too high or loose. If the cam is too high, the extractor will bear too much on the cover extractor spring and will cause rapid wear of both parts and may even break the spring. Special points to observe during disassembly and assembly.

8. **Malfunction:** Failure to feed. (Cal .50)

Stoppage: 2nd or 3rd.

Caused By: Defective switch, loose switch pivot nut, foreign matter behind switch.

Bolt binds against switch. Switch may be improperly assembled, or may be defective. Foreign matter behind switch preventing pivoting movement of the switch. Switch spring jumped out of recess due to loose switch pivot nut or missing cotter pin and binding the switch between the side plate and bolt.

Corrective Action: Reassemble the switch correctly. Check to see that switch

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spring is correctly assembled. See that there is about .002 inch to .006 inch clearance between the switch pivot nut and the side plate.

Preventive Maintenance: Check all switch pivots to see that the shoulder is not too high. If it is, it may be impossible to obtain the correct clearance between the pivot nut and the side plate. This can be corrected by filing down the shoulder to the set specifications. (.190 inch-.192 inch from the base of the stud to the shoulder on the stud portion.) See that it is straight and does not bind. Should work freely. See that nut can be tightened sufficiently to properly adjust switch. There should be a clearance of .002 inch to .006 inch between nut and side plate. Prevent unauthorized disassembly. Check for missing cotter pin.

9. **Malfunction:** Failure to feed. (Cal .50)

Stoppage: 1st.

Caused By: Weak, broken, or missing cover latch spring.

This may allow the cover to come open. If this happens, the extractor will not be held down on the extractor groove of the cartridge and will cause a failure to extract the round from the belt.

Corrective Action: Check spring for correct assembly. Replace this part, place the belt into the feed way and re-charge the gun.

Preventive Maintenance: See that the cover latch is not excessively worn. See that spring is correctly assembled. Check pin of cover latch lever to see that it is set and staked. Prevent unauthorized disassembly of the cover latch assembly.

10. **Malfunction:** Failure to feed.

Stoppage: 1st.

Caused By: Gun being improperly timed (firing too early).

If the gun is out of time, firing too early, it may cause a failure to feed. This is due to the recoiling parts being driven back in recoil before the extractor has come far enough forward to engage and remove another round from the belt.

Corrective Action: Re-time the gun using either a feeler gage (.020 inch fire) (.116 inch no-fire) cal .50 or (.020 inch fire .074 inch no-fire) cal .30 or the gage designed for this purpose.

Preventive Maintenance: Check timing before firing.

11. **Malfunction:** Failure to feed. (Cal .50)

Stoppage: 2nd.

Caused By: Broken or missing switch spring.

A broken or missing switch spring will prevent the extractor from following the correct path in its rearward movements. This will cause the extractor lug to catch and bind under the front of the switch. On initial charge, the extractor will not go under the switch on counterrecoil, but will ride back forward on the top of the switch as the back end of the switch is down.

Corrective Action: Replace the switch spring. Check to see that the spring is correctly assembled.

Preventive Maintenance: Prevent unauthorized disassembly. Special points to observe during disassembly and assembly.

12. **Malfunction:** Failure to feed.

Stoppage: 1st.

Caused By: Improperly loaded belts.

There has been some feeding trouble because of loose rounds in belt and positions of belt in relation to co-axial guns.

Corrective Action: Remove loaded belt and reload.

Preventive Maintenance: Proper loading of ammunition belt. Inspect belt before primary loading.

13. **Malfunction:** Failure to feed. (Cal .50)

Stoppage: 2nd.

Caused By: Bent belt feed pawl arm.

Belt feed pawl arm comes in contact with the link stripper and prevents the free movement of the belt feed slide.

Corrective Action: Straighten belt feed pawl arm or replace defective belt feed pawl arm.

Preventive Maintenance: Special points to observe during disassembly and assembly.

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14. **Malfunction:** Failure to feed. (Cal .50)
Stoppage: 2nd.
Caused By: Rear right hand cartridge stop assembly.
Clearance between link stripper and rear cartridge stop is not sufficient. Belt feed pawl arm bends and prevents the free movement of the belt feed slide.
Corrective Action: Replacement of defective rear right hand cartridge stop assembly.
Preventive Maintenance: Check smoothness of operation prior to initial use.

15. **Malfunction:** Failure to load. (Cal .50)
Stoppage: 2nd.
Caused By: Broken extractor lug or broken extractor cam.
A broken extractor cam, or extractor lug may cause the extractor to jam between the front of the bolt and the breech end of the barrel.
Corrective Action: Replace the extractor if broken, replace the extractor cam if loose, cracked, or broken.
Preventive Maintenance: See that the extractor cam is riveted tight to the side plate, and check to see that the extractor lug is rounded in the front so that it does not dig into the extractor cam.

16. **Malfunction:** Failure to load.
Stoppage: 2nd.
Caused By: Excessive headspace in bolt or in the barrel or by excessive adjustable headspace.
May cause ruptured cartridge cases. If the cartridge case ruptures, the ruptured half may remain in the chamber. If this happens, it will not be possible to load another round into chamber.
Corrective Action: Recharge the gun. Sometimes the ruptured case will come out with the live round that could not be loaded. If it does not, the ruptured case may be removed by using a special tool, called a ruptured case extractor. Check barrel by gage. Readjust headspace.
Preventive Maintenance: Check headspace by gages issued for this purpose. Keep barrel as cool and clean as possible.

17. **Malfunction:** Failure to load.
Stoppage: 2nd or 3rd.
Caused By: Binding action of the recoiling parts.
If the recoiling parts fail to return to the battery position, it may be due to many things. The parts may be binding against the side plates, the breech lock cam, (due to improper headspace adjustment), or against the driving spring rod (may be bent or there may be burrs or dirt in this assembly), or the bolt may be binding against the barrel extension due to burrs or dirt. The barrel or the barrel jacket may be bent. This will cause the alignment of the barrel bearing and trunnion block to be out and the barrel to freeze or bind on these bearings.
Corrective Action: If the parts are binding due to dirt or burrs, the burrs and dirt must be removed. If the side plates are bent or the barrel jacket or barrel are bent, they should be replaced (straightened in an emergency).
Preventive Maintenance: Check clearance between the bolt and the side plates using a feeler gage (.012 inch Min.; .023 inch Max., Cal .50) (.010 inch Min.; .018 inch Max., Cal .30) Proper care, cleaning, and lubrication.

18. **Malfunction:** Failure to load. (Cal .50)
Stoppage: 2nd.
Caused By: Defective oil buffer tube lock, or defective accelerator.
The oil buffer tube lock is designed to prevent the accelerator from catching in the locking recess in the bottom of the bolt. If this lock is short, broken, burred, missing or otherwise damaged, or if the notch in the bottom of the accelerator is worn or defective, the accelerator may catch in the locking recess in the bottom of the bolt. This is caused by the vibration of the gun bouncing the accelerator up into the locking recess on the bottom of the bolt. This recess is not deep enough to allow the accelerator to rotate forward, so causes a bad jam and often serious damage.
Corrective Action: If this lock is defective, replace it. If the accelerator is worn or the recess in the bottom of the accelerator is not at the correct angle, replace it. Make sure the lock is correctly assembled to the oil buffer body.

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Preventive Maintenance: Check this part for action before use. Special points to be observed during disassembly and assembly. A new type oil buffer tube lock assembly has been designed, and it is planned to replace all present locks with this new type.

19. **Malfunction:** Failure to load.

Stoppage: 2nd or 3rd.

Caused By: Weak or broken driving spring or a bent driving spring rod.

Defective driving spring rod assembly will not force the bolt forward with sufficient force to counterrecoil or the driving spring rod may bind within the bolt and not allow the bolt to counterrecoil.

Corrective Action: Replace defective spring. Carefully clean recess of bolt.

Preventive Maintenance: Special points to observe during disassembly and assembly. Proper cleaning of spring and recess of bolt.

20. **Malfunction:** Failure to load. (Cal .30)

Stoppage: 2nd.

Caused By: Weak or broken barrel plunger spring.

Defective barrel plunger spring will not force the barrel extension forward with sufficient force to counterrecoil.

Corrective Action: Replace defective barrel plunger spring.

Preventive Maintenance: Prevent unauthorized disassembly of the lock frame group.

21. **Malfunction:** Failure to load. (Cal .30)

Stoppage: 2nd or 3rd.

Caused By: Missing or broken extractor cam plunger or extractor came plunger spring, broken or burred extractor cam.

A broken extractor cam, or defective extractor cam plunger or spring may cause the extractor to ride under the extractor cam instead of up and over the cam, therefore the extractor will jam between the front of the bolt and the breech end of the barrel or strike the safety stud of the extractor.

Corrective Action: Replace or correctly assemble extractor plunger spring. Remove burrs from extractor cam.

Preventive Maintenance: Prevent unauthorized disassembly of the extractor assembly. Proper care, cleaning, and lubrication.

22. **Malfunction:** Failure to load. (Cal .30)

Stoppage: 2nd.

Caused By: Broken accelerator stop.

Defective stop will allow the accelerator to pivot too far to the rear and when the bolt counterrecoils it will not be able to trip the accelerator forward.

Corrective Action: Replace lock frame.

Preventive Maintenance: Proper care in handling. Do not force recoiling parts during manual operation. Check smoothness of operation prior to initial use.

23. **Malfunction:** Failure to load. (Cal .50)

Stoppage: 2nd or 3rd.

Caused By: Weak ejector spring.

Ejector rotates too far to the rear and the lower nose of the ejector comes in contact with the upper portion of the lips of the T-slot and binds the ejector, preventing the extractor assembly from being forced down behind the switch.

Corrective Action: Replace defective ejector spring.

Preventive Maintenance: Check smoothness of operation prior to initial use. Prevent unauthorized disassembly of the extractor assembly.

24. **Malfunction:** Failure to load.

Stoppage: 2nd.

Caused By: Bent extractor.

Extractor arm bends against the side of the bolt and prevents the extractor from being forced down during counterrecoil.

Corrective Action: Replace defective extractor.

Preventive Maintenance: Check smoothness of operation prior to initial use. Special points to observe during disassembly and assembly.

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25. **Malfunction:** Failure to load.

Stoppage: 2nd or 3rd.

Caused By: Round being improperly alined with the chamber of the barrel due to a weak or missing ejector spring.

This will allow the live round to be cammed too far down into the T-slot out of alignment with the chamber of the barrel. As the bolt goes forward, the round will be driven into the back of the barrel extension stopping the bolt in the 3rd position, or sometimes the 2nd. Worn ejector could cause same thing.

Corrective Action: Replace the ejector spring or ejector if worn.

Preventive Maintenance: Check the ejector spring by pulling the ejector against its spring and see if it always returns to the neutral position. If not, check spring and check for burrs or a binding action of the ejector. Also check ejector for wear.

26. **Malfunction:** Failure to load.

Stoppage: 2nd or 3rd.

Caused By: Undercut of T-slot worn excessively.

This will allow the round to hang down below the line of the chamber of the barrel. The bolt cannot load a round into the chamber if the round is not properly aligned with the chamber.

Corrective Action: Replace defective bolt.

Preventive Maintenance: Correct lubrication and cleaning of the T-slot, removal of carbon, all burrs, and rough spots will also cut down this wear.

27. **Malfunction:** Failure to load.

Stoppage: 2nd or 3rd.

Caused By: A broken or missing extractor stop pin.

This will allow the extractor to be cammed down below the line of the chamber of the barrel and the round cannot be properly chambered. This will again result in a damaged round.

Corrective Action: Replace defective bolt or remove extractor stop pin. Check action of the extractor, and see that it is not binding against this pin causing it to break.

Preventive Maintenance: Prevent unauthorized disassembly of extractor stop pin, unless for repair. Check smoothness of operation prior to initial use.

28. **Malfunction:** Failure to recoil. (Cal .50)

Stoppage: 1st, 2nd, 3rd.

Caused By: Burrs, dirt, bent parts, incorrect adjustments.

Binding action caused by dirt or burrs can cause a stoppage in any position. If the oil buffer valve is closed too much, the gun will stop in the 2nd position. This is due to the gun not being able to overcome the resistance set up by this buffer action. The gun will only recoil about one-half inch and stop.

Corrective Action: Clean gun, remove all burrs. Readjust the oil buffer by turning it about 2 clicks past the "0" on the back of the oil buffer body.

Preventive Maintenance: Correct adjustments on the gun before use. Careful cleaning and lubrication.

29. **Malfunction:** Failure to recoil.

Stoppage: 1st, 2nd, 3rd.

Caused By: Burrs, dirt, and bent parts.

Binding action caused by dirt or burrs on bearing surface of barrel, binding against the front barrel bearing and trunnion block, or burrs on the bolt and barrel extension, not permitting the bolt to move freely in the guideways of the barrel extension.

Corrective Action: Clean, lubricate, and remove burrs.

Preventive Maintenance: Special points and care in disassembly and assembly. Proper care, cleaning, and lubrication.

30. **Malfunction:** Failure to recoil. (Cal .30)

Stoppage: 1st, 2nd, 3rd.

Caused By: Carbon in the front barrel bearing or wrong front barrel bearing plug assembled in relation to the type of driving spring.

The front barrel bearing is inclined to seize up because of dust, carbon, and moisture getting in which binds the free movement of the barrel within the bear-

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ing. The front barrel bearing plug, M2 and .718 are both satisfactory for use if the driving spring .047 wire, B147227, is used, but the .718 plug may be used satisfactory with either spring. The M1 plug is obsolete and cannot be used.

Corrective Action: Remove carbon from bearing and check plugs with respect to driving springs. Replace front barrel bearing plug.

Preventive Maintenance: Proper cleaning after firing. Inspect weapon prior to initial use.

31. **Malfunction:** Failure to recoil. (Cal .50)

Stoppage: 2nd or 3rd.

Caused By: Oil buffer gland packing plug unscrewing.

During the mechanical operation of the gun, the oil buffer gland packing plug unscrews and leakage of the oil develops. Excessive oil within the receiver plus foreign matter prevents sufficient recoil.

Corrective Action: Replace oil buffer tube assembly or tighten oil buffer gland packing plug.

Preventive Maintenance: Prevent unauthorized disassembly of oil buffer tube assembly. Check smoothness of operation prior to initial use.

32. **Malfunction:** Failure to cock. (Cal .50)

Stoppage: 1st.

Caused By: Weak, broken, kinked, or missing sear spring.

If the sear spring is defective or missing, the firing pin extension may not engage with the sear, as the sear would not be pushed up into engagement with the notch on the firing pin extension. Kinked sear spring prevents the sear from being actuated down far enough to release the firing pin extension.

Corrective Action: Replace the sear spring. Check to see that the sear spring is not binding in the sear spring recess. Also check to see that the sear is not binding against the sear slide, or sear ways in the bolt.

Preventive Maintenance: See that the sear is free moving at all times. Be sure that the sear spring is seated in the recess in the bottom of the sear as well as the recess in the bolt. Special points to observe during disassembly and assembly.

33. **Malfunction:** Failure to cock.

Stoppage: 1st.

Caused By: Broken or worn cocking lever.

If the cocking lever is broken or badly worn, the firing pin extension may not be pulled far enough to the rear to be caught and held by the sear. Note: If for any reason the firing pin extension is not caught and held by the sear, the gun will not fire.

Corrective Action: Replace the cocking lever. (Note over travel—there should be over travel.)

Preventive Maintenance: Check for wear; see that the firing pin extension overrides the sear notch. If it does not, replace the cocking lever or the firing pin extension as it may be the part that is worn or it may be a combination of both. Check smoothness of operation prior to initial use.

34. **Malfunction:** Failure to cock.

Stoppage: 1st.

Caused By: Sear notch, or firing pin extension notch broken off.

If the notches on either of these parts are broken off there will be no engagement between the two.

Corrective Action: Replace the damaged part.

Preventive Maintenance: Check smoothness of operation prior to initial use. Proper care, cleaning, and lubrication.

35. **Malfunction:** Uncontrolled fire.

Stoppage: None.

Caused By: Worn sear notch, worn firing pin extension notch, bent trigger bar, weak sear spring, dirt or burrs in the firing mechanism.

If due to the above stated reasons, there is only a partial engagement of the sear with the firing pin extension; it is possible for the gun to continue to fire after the trigger is released. This is caused by the counterrecoiling parts striking the trunnion block hard enough to cause the firing pin extension to slip off the sear and fire a few rounds or even fire all remaining rounds in the belt. Or in the case

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of the bent trigger bar, front end bent down, you get the same effect as though you were holding the trigger bar down with the trigger.

Corrective Action: First stop the gun by opening the cover. Then check the sear and firing pin extension for wear, burrs; check the sear spring and see that the trigger bar is not bent. If any of these parts are so affected, replace them.

Preventive Maintenance: Test fire the gun before using if possible; if not, check by using a dummy round in hand operation.

36. **Malfunction:** Failure to fire.

Stoppage: 1st.

Caused By: Weak firing pin spring, or obstruction in the firing pin hole. If the firing pin spring is weak, the firing pin may not be driven forward sufficiently to fire the round. The spring may be weak or the firing pin may be binding in the bolt. Foreign matter from metal fouling, excessive oil or grease may prevent the protusion of the firing pin.

Corrective Action: Check spring, and if weak replace it; check bolt for burrs and dirt or grease in the firing pin hole.

Preventive Maintenance: Special points to observe during disassembly and assembly. Proper cleaning and lubrication.

37. **Malfunction:** Failure to fire.

Stoppage: 1st.

Caused By: Short or broken firing pin, or firing pin assembly.

If the firing pin is short, it will result in a light blow on the primer of the round. Pin may be binding in the bolt.

Corrective Action: Replace the firing pin, examine to make sure that the new pin is not short. In some cases, it may be found that some obstruction is preventing the firing pin from going all the way forward.

Preventive Maintenance: Check firing pin protrusion. Special points to observe during disassembly and assembly.

38. **Malfunction:** Failure to eject the spent case.

Stoppage: 3rd.

Caused By: Burred or damaged T-slot, thick rim on cartridge case.

A T-slot that is badly burred may cause the cartridge case to hang up in the T-slot and not be ejected. A thick rim on the cartridge case could cause the same thing. Recoil plate may be protruding.

Corrective Action: Remove the case from the T-slot and stone off all burrs and rough spots from the T-slot. Check undercut of T-slot. Check depth of T-slot. (Max: .199, Min: .196, Cal .50) (Max: .126, Min: .121, Cal .30)

Preventive Maintenance: Special points to observe during disassembly and assembly. Check smoothness of operation prior to initial use.

39. **Malfunction:** Failure to eject spent cartridge case.

Stoppage: 3rd.

Caused By: Enlarged firing pin hole.

An enlarged firing pin hole may allow the primer to be ruptured and set back; this will cause the case to hang up in the T-slot and may not eject.

Corrective Action: Replace the bolt assembly if the firing pin hole is found to be enlarged. (Check by gage .081 inch Col .30) (.084 inch Col .50)

Preventive Maintenance. Thorough inspection of bolt prior to initial use.

40. **Malfunction:** Failure to lock.

Stoppage: 2nd.

Caused By: Insufficient headspace.

Barrel is screwed into the barrel extension too far so that the front of the bolt strikes the breech end of the barrel before the bolt can get far enough forward to allow the breech lock to come up into the locking recess in the bottom of the bolt.

Corrective Action: Readjust the headspace using the gage provided.

Preventive Maintenance: Adjust the headspace before use. Check the barrel locking spring and the locking notches on the breech end of the barrel. Make sure the barrel is firmly locked to the barrel extension. See inspection guide.

41. **Malfunction:** Failure to lock.

Stoppage: 2nd.

Caused By: Binding breech lock cam, dirty or burred breech lock cam or breech lock.

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Bent barrel or barrel extension. If the breech lock cam is bolted tight to the bottom plate, it may cause binding between the barrel extension and the breech lock and cam. This breech lock cam should have a clearance of (.001 inch—.008 inch, Col .50) (.004 inch—.012 inch, Cal .30). If the barrel or barrel extension are bent, there may be binding against breech lock cam and the barrel extension.

Corrective Action: Obtain the correct clearance between the bottom plate and the breech lock cam by using the gage provided. Clean and remove all burrs and rough spots. Check involved parts for bends.

Preventive Maintenance: Prevent unauthorized disassembly of the breech lock cam. Check for correct field adjustment. Proper cleaning and lubrication.

42. **Malfunction:** Failure to unlock. (Cal .50)

Stoppage: 2nd.

Caused By: Insufficient recoil.

Could be due to binding of the recoiling parts, incorrect adjustment of the oil buffer, or a weak powder charge.

Corrective Action: Free action if binding, check oil buffer and reset if out of adjustment. Recharge the gun and check for faulty ammunition. Check for bent parts.

Preventive Maintenance: Check for correct field adjustments. Check smoothness of operation prior to initial use.

43. **Malfunction:** Loss of oil from the oil buffer on the first few shots (Cal .50)

Stoppage: None.

Caused By: Oil buffer head nut improperly adjusted.

If the proper clearance is not maintained between the oil buffer valve and the oil buffer head, the piston may expel almost all the oil through the oil buffer relief valve on the counterrecoil stroke. This clearance must be between .045 inch—.055 inch.

Corrective Action: Check this clearance by gage and readjust. Refill the oil buffer using the specified oil.

Preventive Maintenance: Prevent unauthorized disassembly of oil buffer tube assembly.

44. **Malfunction:** Ruptured cartridge cases.

Stoppage: 2nd or 3rd.

Caused By: Excessive headspace.

Worn serrations around chamber end of barrel or barrel locking spring prevents correct headspace adjustment. Barrel locking spring slips forward preventing correct headspace adjustment. Improper headspace adjustment.

Corrective Action: Replacement of defective barrel or barrel locking spring. Check for correct headspace adjustment.

Preventive Maintenance: Stake barrel locking spring. Check for correct headspace adjustment prior to initial firing.

Parts Most Frequently Replaced.

Caliber .30 Machine Gun	Caliber .50 Machine Gun
Belt feed lever cap	Sear spring
Cocking lever	Cocking lever
Barrel packing	Barrel packing
Firing pin	Switch spring
Front barrel bearing plug	Trigger bar
Belt holding pawl spring	Sear stop
Belt feed pawl spring	Firing pin
Trigger	Belt holding pawl spring
Belt feed lever	Belt feed pawl spring
	Oil buffer tube filler screw
	Belt feed lever

Inspection of Machine Guns

Machine gun inspection may be divided into visual and gage inspections. The latter concerns detailed maintenance specifications and instructions not generally within the scope of this text for which the reader is referred to TM 9-1205 for caliber .30 machine guns and TM 9-1225 for caliber .50 machine gun gage inspections data. Before inspection is begun, the materiel should be properly cleaned

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to remove any grease, dirt, or other foreign matter which might interfere with its proper functioning.

Cleaning. Observe the general appearance of the weapon. The bore and chamber of the barrel should be kept thoroughly cleaned to prevent bulges, erosion, corrosion, and pits. Moving parts and metal surfaces must be free from all traces of foreign matter, particular care being taken that all recesses in which springs or plungers operate are cleaned thoroughly. Foreign matter will congeal on the mechanism, causing the gun to fail during mechanical operation.

Headspace. From the standpoint of proper functioning, one of the most important adjustments of the machine gun is headspace adjustment; that is, the adjustment of the space between the rear end of the barrel and the front face of the bolt when the bolt is in the locked position. This is done when screwing the barrel into the barrel extension. If the headspace adjustment is not tight enough (excessive), the explosion of the cartridge powder will blow the rear part of the cartridge case backward and pull the case in two, leaving the front part in the chamber and preventing the entrance of the next cartridge. If the adjustment is too tight (insufficient), the recoiling parts will not go into battery so that the gun can fire, or there may be sufficient interference between the bolt and the breech lock to reduce seriously the operation reserve of the gun. Check proper adjustment with the headspace gages.

Timing. Check proper timing with timing gages, or feeler gage to insure that the gun will not fire too early (.116 inch Cal .50), which may cause a failure to feed, or too late (.020 inch Cal .50), which allows the recoiling parts to pound the trunnion block.

Buffer Adjustments. Check adjusting screw in the back plate for tightness and see that it does not project more than one and one-half threads beyond the buffer tube assembly.

Oil buffer adjustment (cal .50 only). Check oil buffer tube so that the index arrow is two notches to the right from "O" or open position, which will give the maximum speed of firing consistent with proper functioning.

Belt Feed Mechanism. Raise the cover and check the action of the belt feed lever making sure the bolt feed mechanism moves freely in its full travel in both directions. Check the function of the belt feed slide and belt feed pawl. Parts must not be forced into position.

Smoothness of Operation. Test functioning of the gun by manual operation and using dummy rounds. Check smoothness and free movement of the recoiling parts to make certain that the gun will perform the eight cycles of operation.

Multiple Gun Mounts

Multiple gun mounts are relatively recent developments in mobile armament which have enabled combat units to deliver large volumes of effective small and medium caliber weapons' fire upon low-flying and dive-bomber enemy aircraft, and also to engage fixed ground objectives. The multiple gun mounts discussed in this section are basic and will enable a ready comprehension for problems which may confront Ordnance officers in the field. The twin caliber .50 Machine Gun Mount M33 is designated limited standard and hence only mentioned in the text, whereas, detailed data is furnished for the Combination Gun Mount M54 and the M45 Multiple Gun Mount. The Combination Gun Mount M54 is basically the top carriage assembly for the 37mm Carriage M3A1 which in turn is fitted with the 37mm Automatic Gun M1A2. Because of the multitude of uses for the 37mm Automatic Gun M1A2, and its present employment in aircraft armament under the designation 37mm Automatic Gun M4, a detailed functional treatment is presented here as a description of functioning for this gun is not elsewhere given. Except where special preventative maintenance measures are listed, the care, lubrication, and maintenance notes furnished at the end of this chapter are mainly applicable to multiple gun mounts. Detailed information for the correction of malfunctions and adjustments of 37mm antiaircraft gun material are prescribed in the revised TM 9-235.

Mount, Combination Gun, M54

Description. With this mount on the M3 half-track the vehicle is designated the Multiple Gun Motor Carriage M15A1. Basically the mount consists of the top

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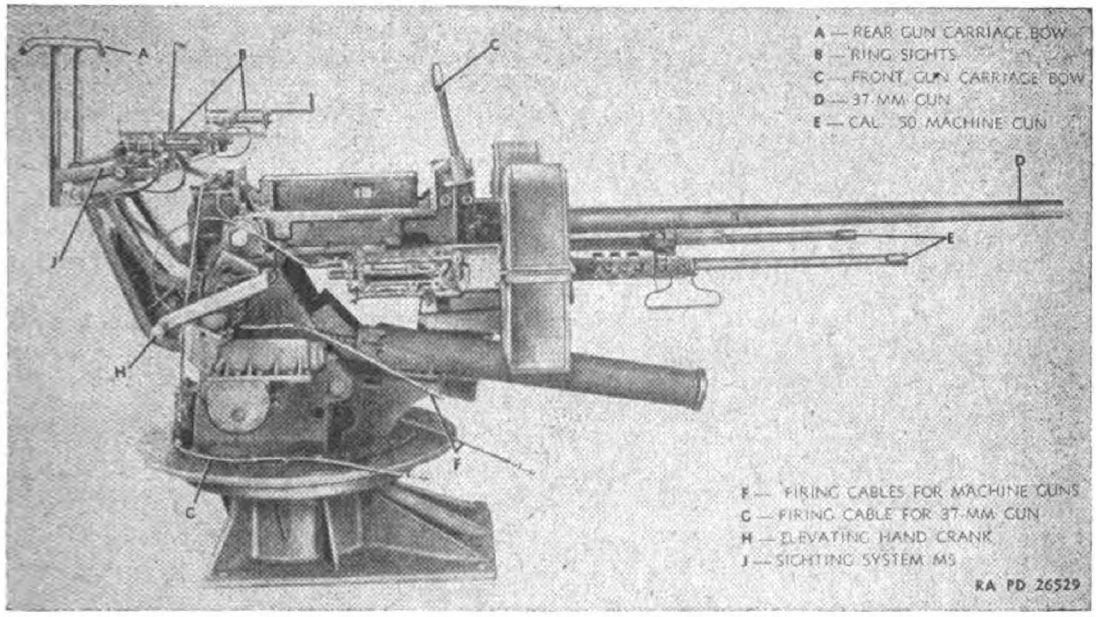
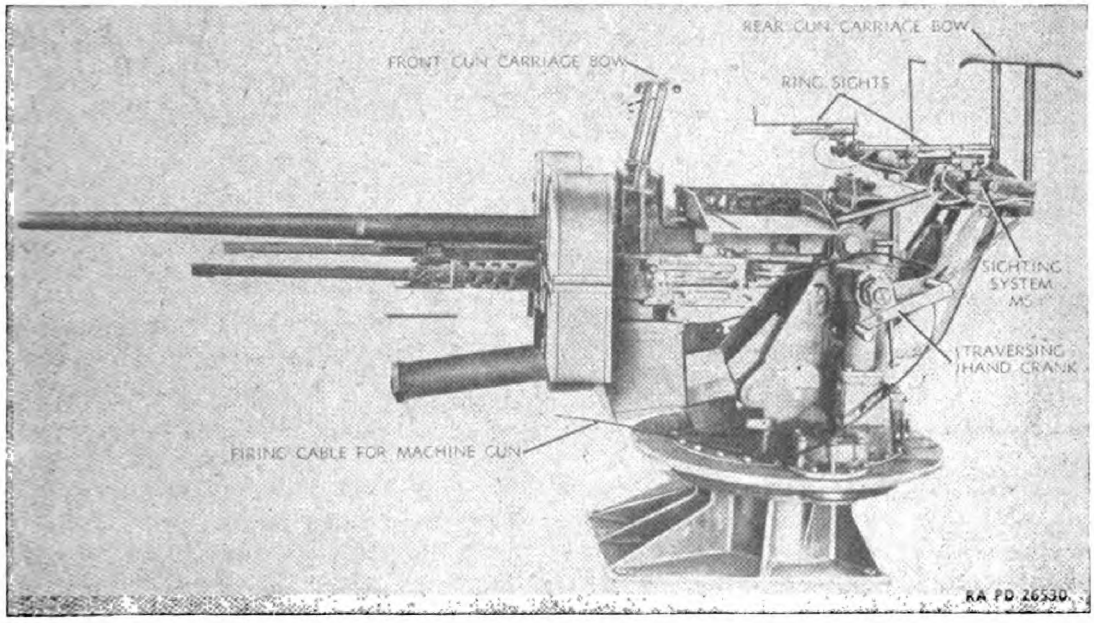
carriage of the 37mm Gun Carriage M3A1 with certain modifications which principally concern the provision of front and rear gun carriage bows, the sighting system M5, two seats for gun operators located on the gun carriage platform, a foot firing mechanism, and two cable firing mechanisms for the machine guns. Armament for this mount consists of one 37mm automatic AA gun M1A2 and



Right View



Left View
Figure 142. Mount, Combination Gun M54.

two cal .50 machine guns M2, heavy barrel. The gun mount is elevated manually through a range of —5° to +90° and traversed manually through 360°.

The equilibrator is connected to the cradle by means of a rod and chain. The firing mechanism consists of a lever and cable arrangement operated by two foot pedals.

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Description and Functioning of 37mm Gun M1A2. The 37mm Antiaircraft Automatic Gun M1A2 is a high-velocity antiaircraft weapon of the long recoil type and uses an ammunition clip carrying 10 rounds. The cartridges are fed into the left side of the feed box, the empty cases ejected through a longitudinal opening below the trunnion block, and the empty clip ejected through an opening in the right side of the feed box. Sustained fire is possible, since a new clip of ammunition may be fed into the mechanism without interruption of the firing.

The entire gun depends for its operation upon the functioning and proper relationship of the following major assemblies:

Trunnion Block
Feed Box.
Tube and Tube Extension.
Lock Frame Assembly.
Driving Spring Assemblies.
Back Plate Assembly.
Recuperator.

A description of the major assemblies listed above will be found in chapter 2, *Artillery and Ballistics.*

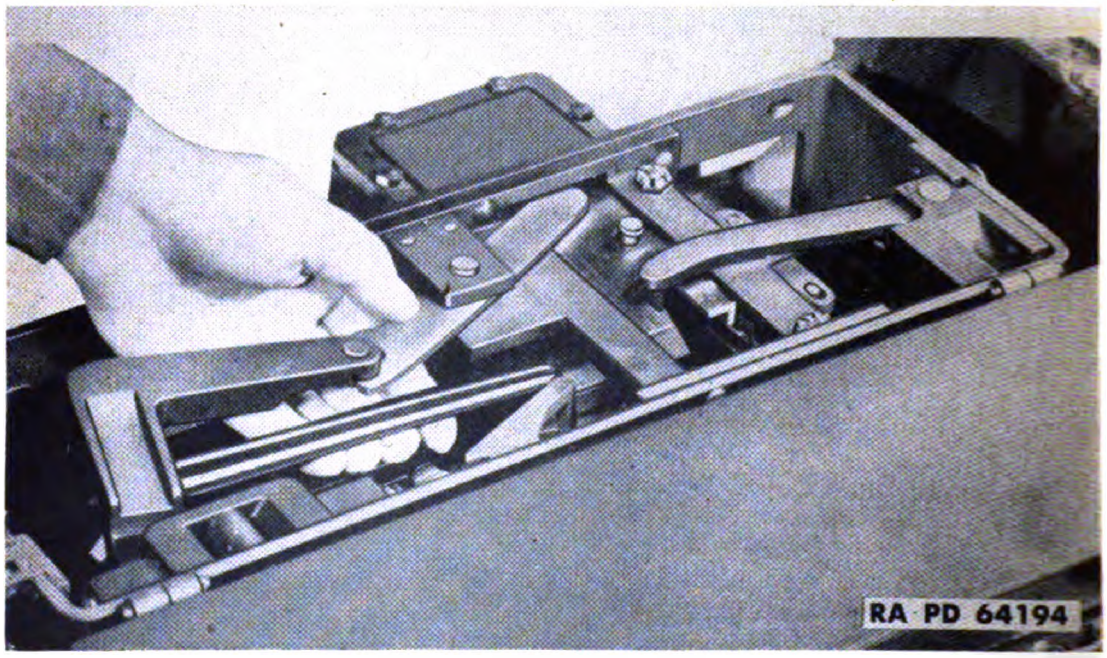

Figure 143. Raising the Carrier.

Functioning of the 37mm AA Automatic Gun M1A2. The series of operations and motions of the various parts of the gun occur in a definite and interrelated manner. Each part receives its motion from some other part, and each functions at a definite moment of the entire cycle. To describe the action and function of the various parts of the gun during one complete cycle of operation, the entire cycle will be broken down into the following motions and each will be discussed in detail, in the order in which they normally occur:

Loading initial round.
Firing initial round.
Recoil.
Counterrecoil of the tube and tube extension.
Counterrecoil of lock frame.
Function of feed mechanism.
Function of recuperator.

Loading Initial Round. Initial cocking is accomplished by manually lifting the carrier until caught by carrier catch and pulling the lock frame to the rear

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until it is caught by carrier dog. The loaded cartridge clip is then manually pushed into the feed box and against the stripper cam until the first cartridge is stripped from the clip. As the cartridge is stripped from the clip it strikes the carrier catch which releases the carrier so that the front end snaps down, pushing the cartridge downward, while the carrier dog pivots upward releasing the lock frame. As the lock frame is driven forward, the charger contacts the base of

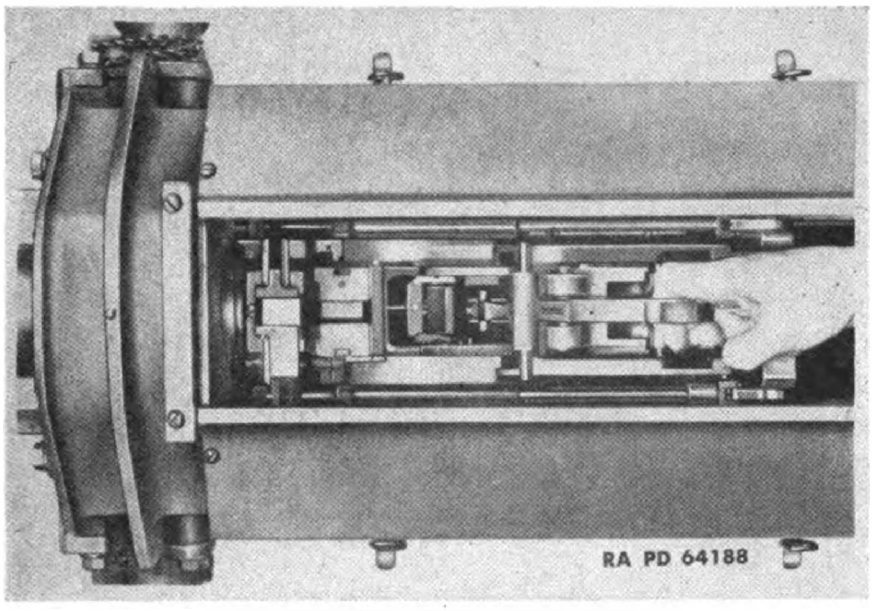

Figure 144. Pulling Lock Frame Back.

the cartridge. The downward movement of the carrier forces the cartridge into the notch of the extractor and the cartridge is carried into the firing chamber. The short guide pins of the operating lever ride the upper groove of each rear operating cam. When the lock frame reaches a point where the T-lug on the

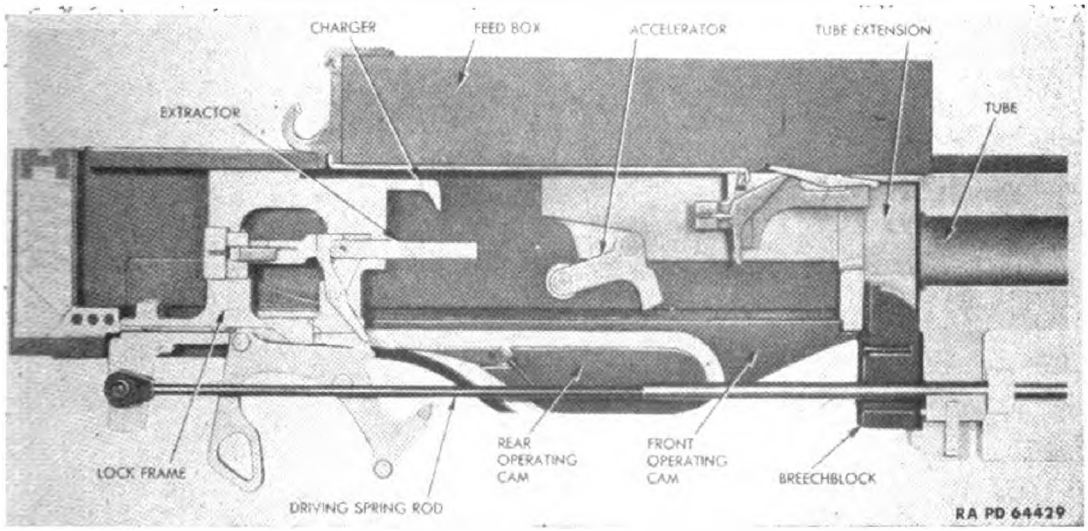

Figure 145. Hand Cocking of Gun-Lock Frame Held to Rear.

front end of the operating lever is about to enter the T-slot of the breechblock, the contour of the cams causes the operating lever to pivot sharply, forcing the breechblock upward. Pressure applied by the operating lever spring through the strut assures positive action of the operating lever and final positioning of the breechblock.

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Firing Initial Round. The final movement of the breechblock into position raises the front end of the trigger trip and lowers the rear end which bears against the trigger lever connector, so that when the trigger is pulled the trigger bar moves the trigger lever and trigger lever connector rearward as an assembly. Rearward pressure of trigger lever and connector assembly against the sear disengages it from the hammer which springs forward striking the firing pin in the breechblock, and the round is fired.

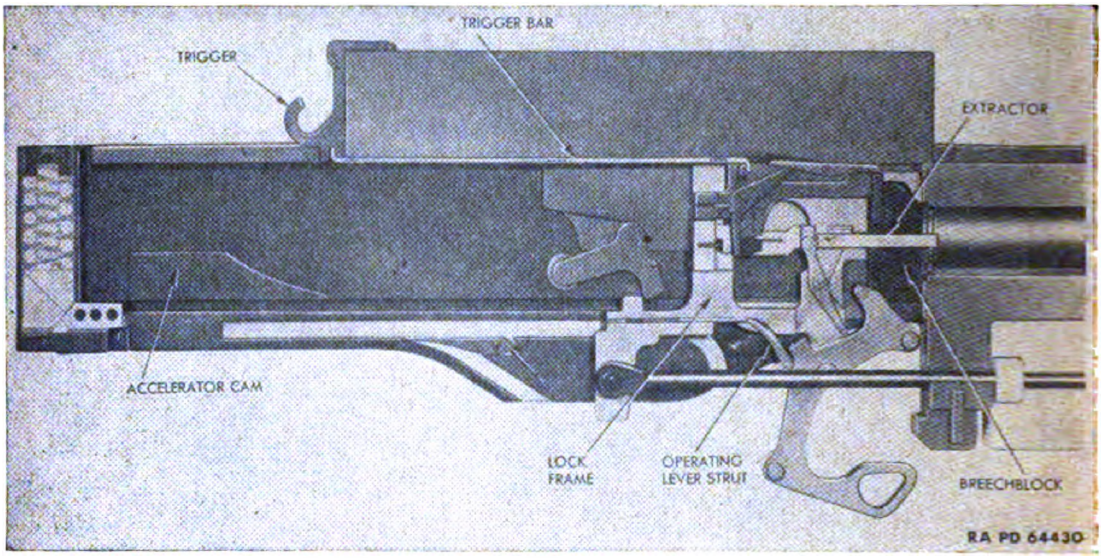

Figure 146. Lock Frame Released—Cartridge, Chambered, Breechblock Raised to Battery Position.

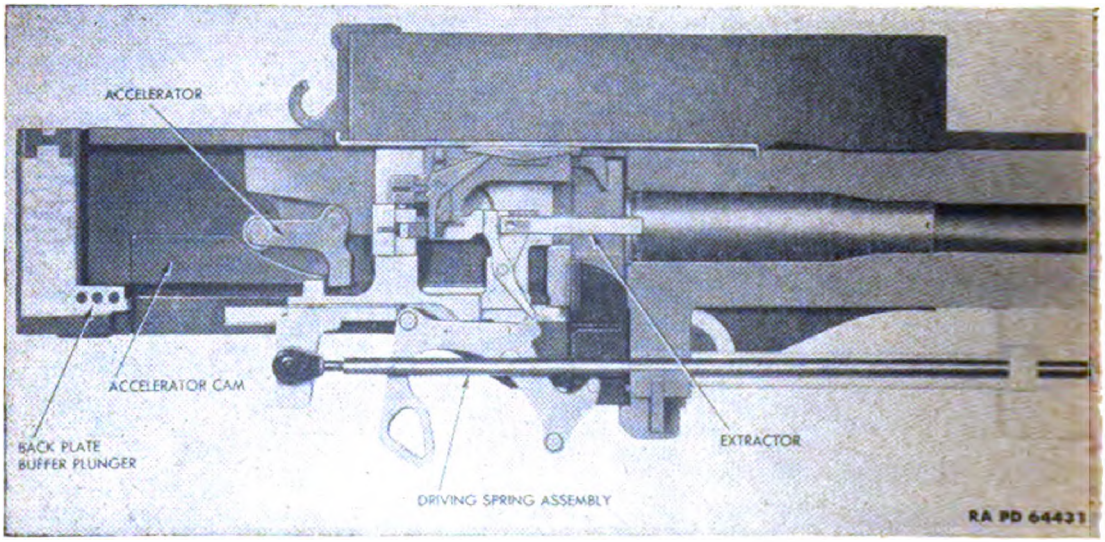

Figure 147. Gun in Recoil—Lock Frame Accelerating Toward Back Plate Buffer.

Recoil. Immediately after the detonation, the tube, tube extension, and lock frame start to recoil together. The carrier cam on top of the tube extension engages the projecting stud of the carrier, which is then pushed up by the cam. The carrier rises until caught in its uppermost position by the carrier catch. As the lock frame recoils, the operating lever starts to revolve due to the action of the operating cams below the right and left side plates of the trunnion block. The operating lever, which is engaged to the breechblock, pulls the latter down until the breechblock rests on its stop at the bottom of the tube extension. Coincident with this motion is that of the cocking of the firing hammer. This is

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accomplished when a projection of the operating lever forces one end of the cocking lever forward, causing the other end to move the firing hammer rearward until caught by the sear. The rotation of the operating lever also forces the strut back against the action of the follower and spring located in the base of the lock frame.

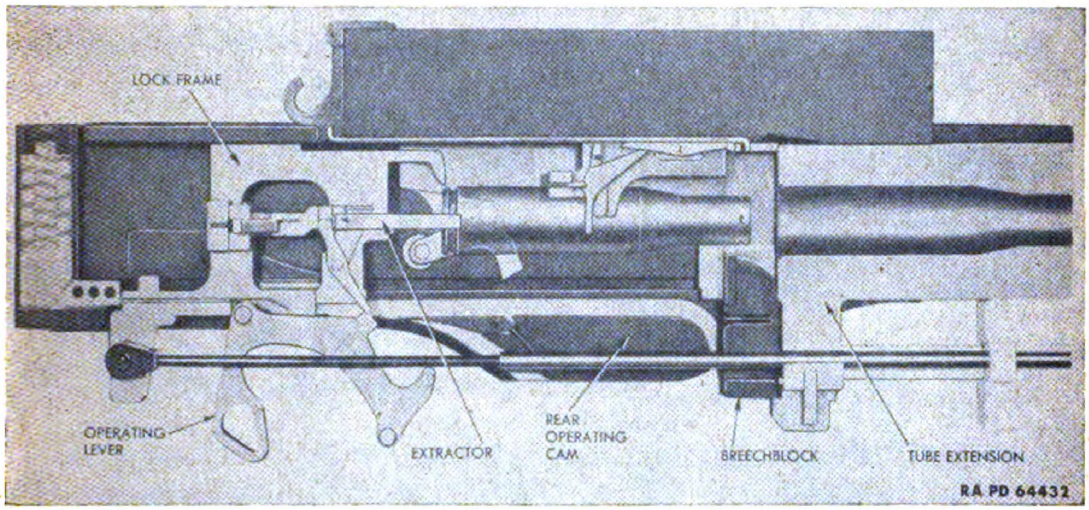

Figure 148. Cartridge Case Extracted as Tube and Tube Extension Counterrecoils—Lock Frame Held to Rear.

Toward the end of the recoil of the tube and tube extension, the accelerator starts to ride up on the accelerator cam. The motion given the accelerator by its cam causes the accelerator to kick the lock frame to the back plate buffer plunger. The tube and tube extension come to the end of recoil and the recuperator spring will immediately draw them back to firing position.

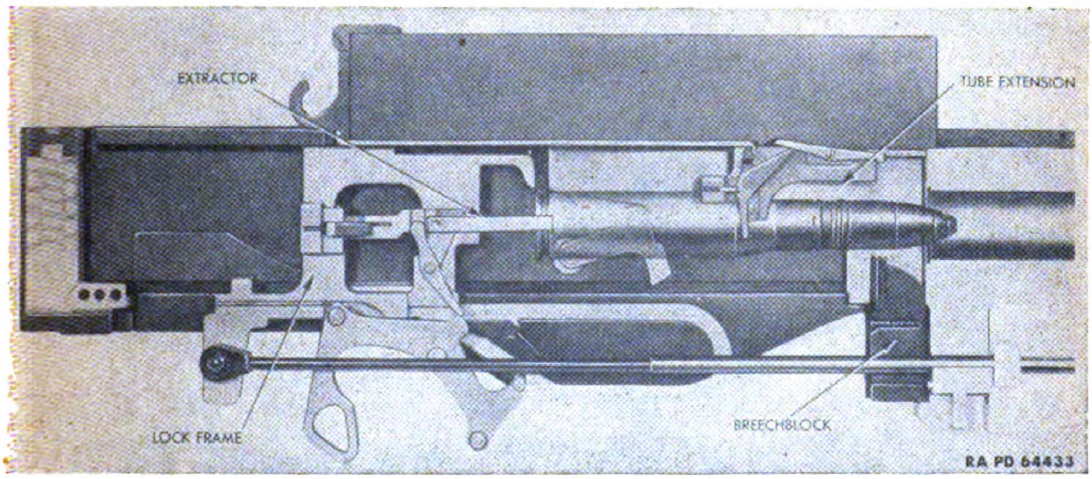

Figure 149. Lock Frame Counterrecoiling—Cartridge Entering Firing Chamber.

Counterrecoil of the Tube and Tube Extension. The extractor, located on the right front side of the lock frame, enters the chamber of the tube and is held away from the rim of the cartridge case until prior to acceleration of lock frame, at which time it hooks into the rim of the cartridge case causing initial extraction. During counterrecoil, the cartridge case is held to the rear by the extractor. As the tube extension nears the end of counterrecoil, the ejector being accuated deflects the empty cartridge case through the opening in the bottom of the trunnion block. During recoil, the lock frame, tube extension and the driving spring assemblies are also moved to the rear. The driving spring piston rod attached to

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the lock frame remains to the rear. The driving spring tube attached to the tube extension returns to battery. This causes the driving springs to be compressed.

On counterrecoil, the feed lever operating stud pushes the feed lever forward, causing this lever to actuate the system of levers and links that carries the next cartridge into the feed box, strips the round from the clip, and feeds the round

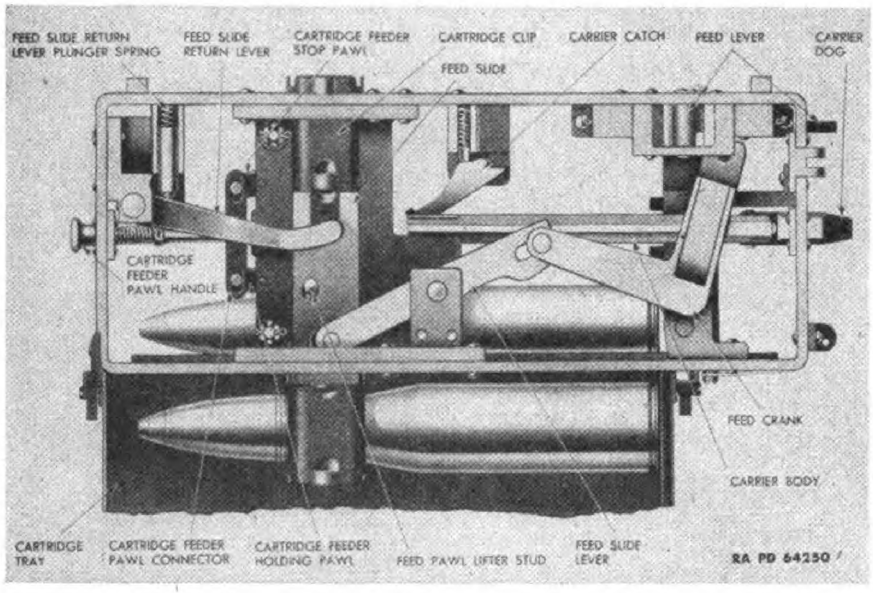

Figure 150. Position of Feed Box Mechanism at Beginning of Feed Stroke.

into the tube extension. The feed lever is then forced back to its initial position by the action of the feed slide return lever, located in the front of the feed box.

Function of Feed Mechanism. Movement imparted to the feed lever by the feed lever operating stud as the tube extension counterrecoils is transmitted through the feed crank and feed slide lever to the feed slide, moving it to the

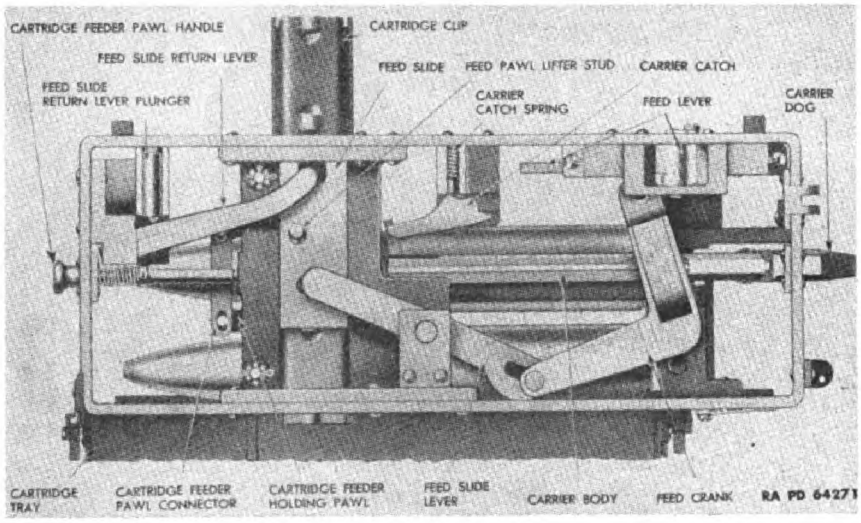

Figure 151. Position of Feed Box Mechanism at End of Feed Stroke.

right. The spring-loaded feed pawl attached to the underside of the feed slide engages a projection on the top surface of the cartridge clip. Near the end of the feed slide movement to the right, the cartridge feeder stop pawl drops into a recess in the front edge of the slide and a notch in the side of the cartridge clip. This stops the clip and prevents it from being moved farther to the right

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than necessary. The holding pawl engages a notch in the cartridge clip body and prevents the clip from being moved to the left as the feed slide moves to the left in preparation for bringing in another round. As the tube extension nears battery position, the feed slide return lever causes the feed slide to move to the left. This movement of the feed slide disengages the stop pawl from the notch in the cartridge clip and the recess in the feed slide. Since the holding pawl engages only the notch in the cartridge clip, it will prevent the clip from moving to the left during the return of the feed slide, but it will become disengaged from the notch in the cartridge clip as the clip is moved to the right. Both pawls are pressed into engagement by the cartridge feeder pawl spring.

Function of Recuperator. The recuperator cylinder fits in the lower front opening of the trunnion block and houses the recoil piston rod, piston, recuperator springs, and the recoil oil. The piston rod is fastened to the lower part of the front section of the tube extension by means of the recuperator piston rod nut. As the tube and tube extension recoil, the piston moves backward, compressing

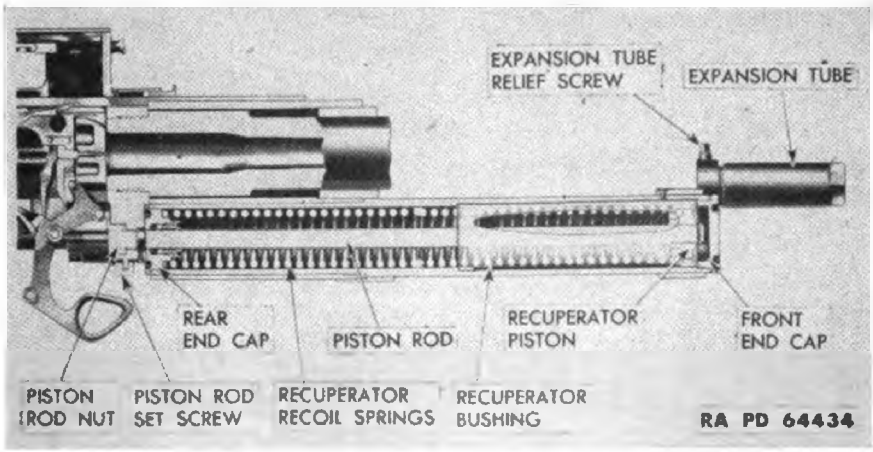

Figure 152. Recuperator Assembly—Cutaway View.

the recuperator spring and forcing the recoil oil through the openings of the recuperator bushing. The expansion of the compressed recuperator spring returns the piston, piston rod, and recoil oil to their initial positions, thereby causing counterrecoil. The tube and tube extension are carried back to battery by the recuperator piston rod. The expansion tube is the small cylinder screwed to the upper front end of the recuperator. This cylinder is a hollow body used to compensate for expansion and contraction of the recoil oil in the recuperator.

Description and Functioning of Machine Gun, Cal .50 M2, HB. Reference is made to coverage of Browning machine guns in a preceding section of this chapter.

Description and Functioning of the Mount

The 37mm Automatic Gun M1A2 is mounted on carriage M3A1; but in the Combination Mount M54, the mounting is essentially the top carriage.

Top Carriage. The top carriage consists of welded steel sections which form a circular base and two upright sections. It is supported by a long circular bearing resting on top of the pedestal. Through the medium of the traversing rack bolted to the leveling mechanism and the connecting gearing bolted to the traversing mechanism, the top carriage can be turned, or traversed, about a vertical axis through 360°. The platform is bolted to and swings with the top carriage. Mounted on the top carriage are all operating mechanisms essential to the functioning of the gun. The upright members support the cradle in which the gun is mounted.

For a detailed description and functioning of the carriage components listed below the reader is referred to chapter 2, Artillery.

Elevating Mechanism. Rack and pinion type, providing a range from —5° (depression below the horizontal except where gun is pointed directly to the vehicle front in which case the minimum elevation is +20°) to +90°.

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Traversing Mechanism. Ring and racer type, affording a continuous traverse of 360°.

Equilibrator. Spring-puller type. Adjustment of the equilibrator mechanism is possible by means of two adjusting units made accessible by removing the front cap of the equilibrator.

Pedestal. The pedestal is provided for mounting the gun mount, guns, and armor shields on the multiple gun motor carriage M15A1. The pedestal consists of the upper pedestal and lower pedestal and two heavy castings bolted together by 8 bolts, nuts, and lock washers. The lower pedestal is screwed to the vehicle by means of 12 bolts, nuts, and lock washers.

Care and Preservation

The principles of preventive maintenance outlined at the close of this chapter may be applied to the Combination Mount M54 particularly for the .50 caliber machine guns. Generally, special care should be given to disassembly and assembly of the various components following technical data contained in TM 9-235 and TB 9-235-8. The gun, carriage, and sighting equipment covers should be used when service of the mount is not current or contemplated. Similarly, proper steps for storage should be taken when the materiel will be inactive for a temporary period.

Cleaning. Unless otherwise specified, use dry-cleaning solvent or diesel fuel oil, to clean or wash all metal parts, whenever partial or total disassembly is undertaken. Gear cases and bearing housing must be disassembled for cleaning and all trace of cleaning solvent removed from various component parts prior to lubrication and reassembly. Ideally, clean, dry conditions are best suited for cleaning operations, but as a minimum requirement, dirt, residue, and sediment are thoroughly removed from lubricating compartments before reassembly. When high pressure water is used to clean the gun, care should be taken water does not enter into and damage the trunnion bearings. Normally the gun tube is cleaned while still hot from firing and daily for three successive days thereafter, using a solution of ¼ pound of soda ash to 3 gallons of warm water. When not being fired, the gun bore is cleaned with solvent, dried, and oiled once every 5 days and swabbed clean and oiled daily.

Lubrication. Instructions for lubrication of this materiel are prescribed and furnished the using arm in War Department Lubrication Order No. 158.

Mount, Machine Gun, Multiple Cal .50 M45

The early mount, designated officially as the M33, had a pair of .50 caliber machine guns mounted to it. This mount has been superseded in production by the Mount, Multiple Machine Gun, Cal .50 M45. The M45 mounts four .50 caliber machine guns. In our discussion no distinction will be made between the M33 and the M45, since the mechanical features of the mounts are identical in many respects and the differences between them are concerned only with adapting the M45 to hold four .50 caliber machine guns. The machine guns on both mounts are the heavy barrel turret types.

Description. The Multiple caliber .50 Machine Gun Mount M45, is a power driven armored gun mount with a self contained power unit. It may be mounted on a vehicle, on any suitable fixed base, or on the ground. Normally it is mounted on a half track or a generator trailer M7. It can be elevated through an arc of 10°, below the horizontal, to 90°, above the horizontal, and it can be traversed continuously through 360°. The mount movement and gun fire are controlled from a pair of hand grips placed directly in front of a centrally located gunner's seat within the mount. The mount is operated by one man. Additional members of the crew keep the machine guns loaded and charged.

The four machine guns are mounted to the trunnion and have no movement independent of the trunnions. When one desires to elevate the guns, the trunnions are rotated until the guns are placed at the desired angle of elevation. The trunnions in turn are rigidly mounted to a turntable. In order to move the guns in azimuth the turntable must be rotated through the desired angle. The trunnions are moved in elevation and the turntable must be rotated through the desired angle. The trunnions are moved in elevation and the turntable is slewed

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in traverse, through the locomotion of an electric motor suspended from the bottom of the turntable. The electric motor receives its operating current from two six-volt wet cell batteries connected in series and fastened to the top of the turntable. The batteries are charged by a gasoline generator which is also mounted on top of the turntable.

Since the generator is incapable of replacing the charge in the batteries as rapidly as the electric motor removes it, the generator, as well as being run while the electric motor is operating, must be run approximately three times as long as the period during which the electric motor was operated, in order to keep the batteries fully charged.

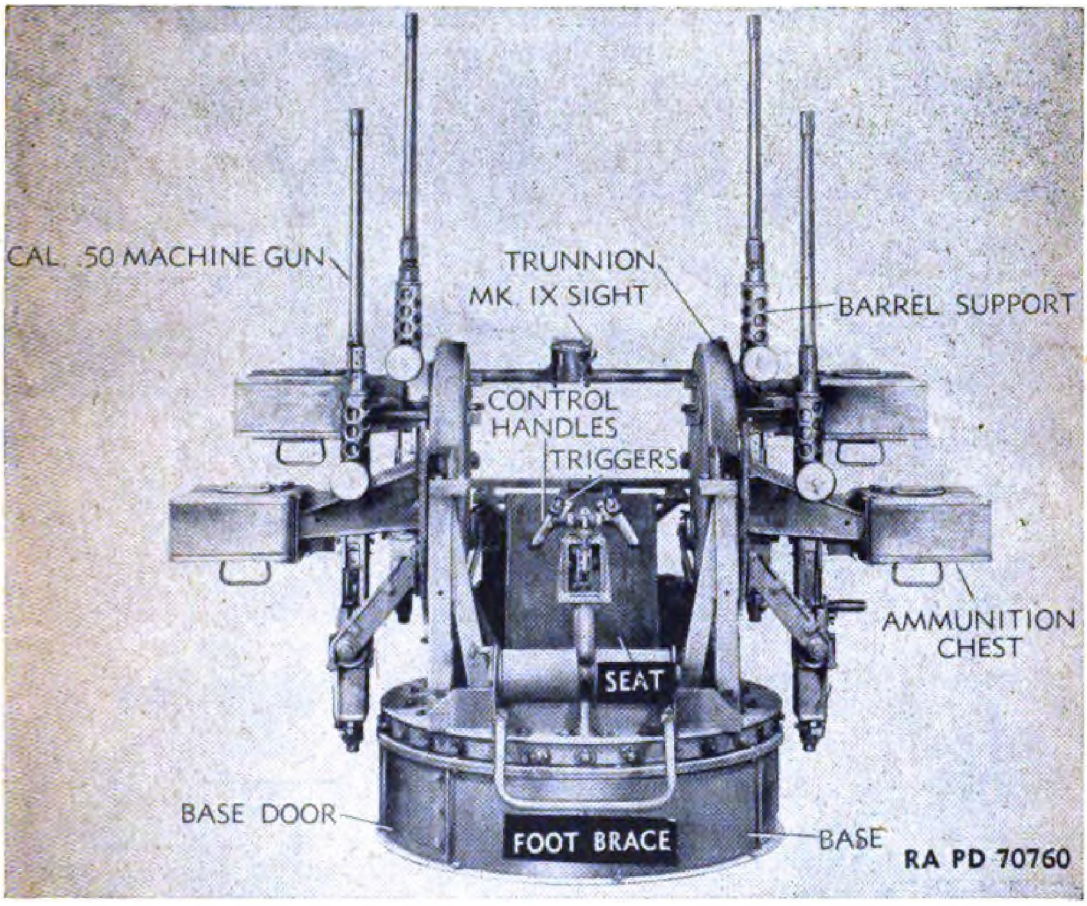

Figure 153. Mount, Machine Gun, Multiple Cal .50 M45—Front View, Guns at 90° Elevation.

Variable Speed Drive Unit. The electric motor which drives the unit in elevation and in traverse is a one-horsepower, compound wound, twelve-volt, one hundred ampere motor, which makes approximately 5,400 revolutions per minute. The electric motor has, through construction, been incorporated in the driving unit which is known as the variable speed drive or power unit. The electric motor may be operated for a maximum period of five minutes. Should the operator fail to shut the motor off after five minutes of operation, a circuit breaker will automatically do so. The motor must then be allowed to cool for five minutes before being started again.

The armature of the electric motor is supported by ball bearings and has an extension on either end to which are mounted driving gears. One of these driving gears faces the front of the mount and the other driving gear faces the rear of the mount. The driving gear facing the front of the mount revolves clockwise and meshes with two large power pulley gears, which are fastened to the power pulleys. These two gears revolve counterclockwise and the pulleys to which they are attached also rotate counterclockwise. The rear driving gear meshes

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with two idler gears. Since the drive gear is rotating clockwise the two idler gears, which also mesh with the small power pulley gears, will rotate counterclockwise. The small power pulley gears will rotate clockwise, causing the power pulleys to which they are fastened to also rotate clockwise.

Each of the power pulleys is connected by means of a belt to one of the differ-

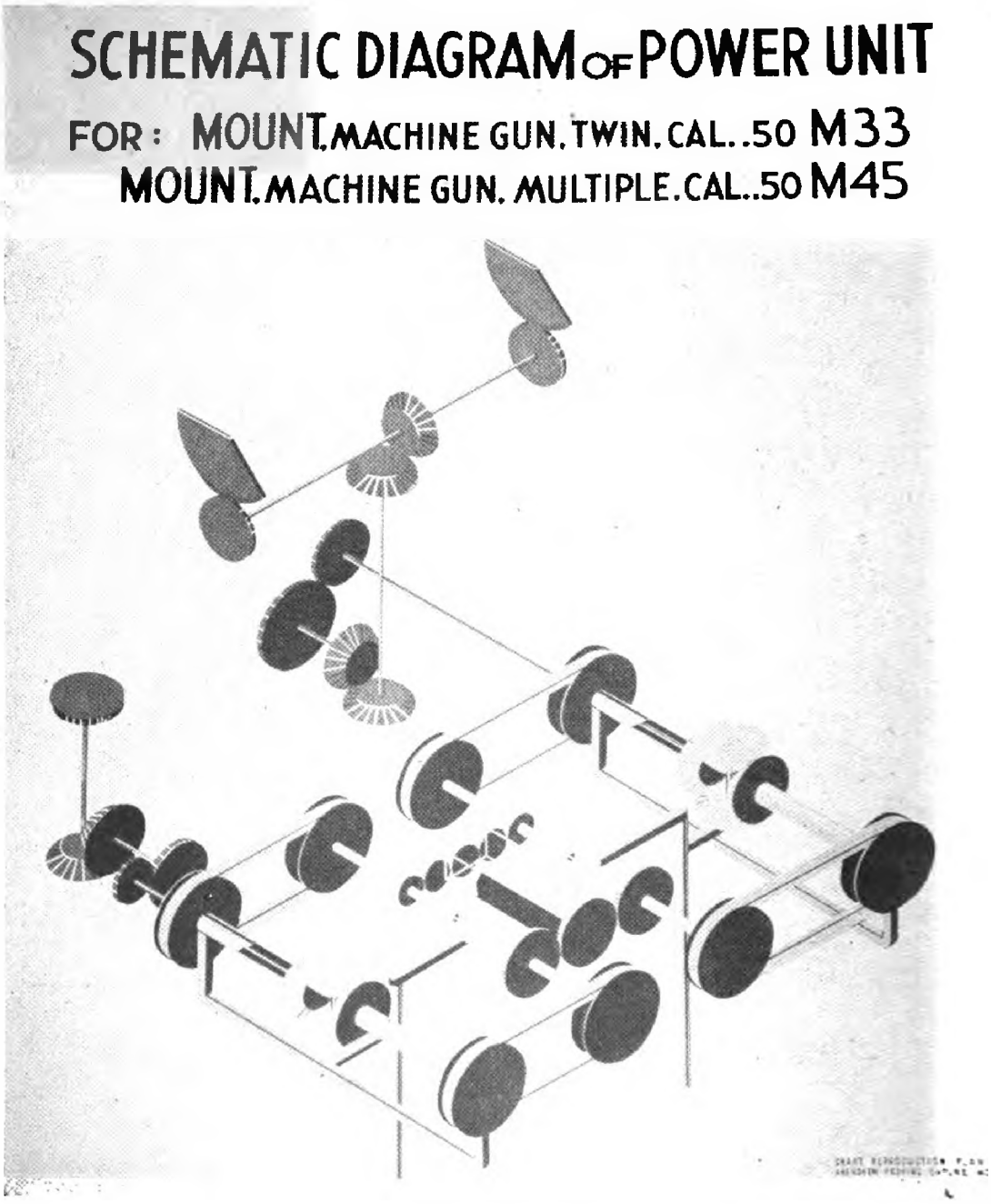

Figure 154. Variable Speed Drive Unit.

ential pulleys. Each differential pulley has affixed to it a gear which meshes with the spider gears of the differential.

The power pulleys on the right hand side of the drive unit are connected to the azimuth differential. One pulley rotates clockwise and the other pulley rotates counterclockwise. The azimuth differential, upon receiving the motions, will output shaft, to the azimuth gears. The azimuth gears will cause the turntable

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to revolve either to the right or to the left depending upon which of the differential pulleys is rotating at the faster speed.

The power pulleys on the left-hand side of the drive unit are connected to the elevation differential. One pulley rotates clockwise and the other pulley rotates counterclockwise. The elevation differential, upon receiving the motions, will transmit the motion of the faster pulley through the spider gears and the elevation output shaft to the elevation gears. The elevation gears will cause the trunnions to rotate, either elevating or depressing the guns, depending upon which of the differential pulleys is the faster.

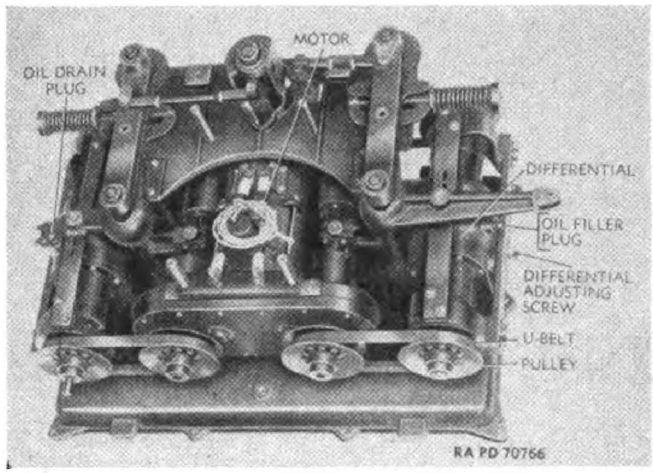

Figure 154A. Variable Speed Drive Unit.

The speed of the pulleys is governed by the positioning of the control handle. The control handle is located on the top of and in the front of the turntable. As the operator moves the control handle in azimuth, all pulleys which form a part of the azimuth power train change their diameters and by changing diameters determine which of the differential pulleys will rotate at the greater speed. Each pulley of the mount is split in two halves and the belts travel between the two halves of the pulleys. The inner half of a pulley is immovable while the outer half may be moved away from or toward the inner. By moving the outer half away from the inner half the belt is allowed to move closer to the hub of the pulley. Since the belt moves closer to the hub of the pulley, in effect, the diameter of the pulley is decreased. If the halves are moved closer together the diameter of the pulley, in effect, is increased.

If the control handle is rotated clockwise all pulley diameters in the azimuth power train will change. The front power pulley will increase in diameter while the front azimuth differential pulley will decrease in diameter, resulting in an increase in the speed of the front azimuth differential pulley; the rear power pulley will decrease in diameter and the rear azimuth differential pulley will increase in diameter, resulting in a decrease in the speed of the rear azimuth differential pulley. The difference in the speeds of the pulleys will be transmitted through the spider gears and the output shaft and cause the mount to move in traverse to the right.

If the control handle were moved in the opposite direction, the shifting in diameters of the pulleys would be reversed and the mount would move in azimuth to the left.

If the control handle is placed in the neutral position, the diameter of all pulleys is the same and the output shaft of the differential will remain stationary.

The amount the control handle is moved determines the amount the pulley diameters will be changed and consequently the variation in speed.

As examples of the extent speed may be varied, the mount must pass the following field test: For rapid speed it must be able to move, in elevation or azimuth only, through 60° in one second. For slow speed it must be able to move

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so slowly that eight seconds are required for movement of the mount through 12°. This varied speed is necessary so that the gunner may engage all types of targets.

The action of the elevation power train is exactly the same as the action of the azimuth power train. Pushing the bottom of the control handle forward will elevate the guns. Pushing the top of the control handle forward will depress the guns.

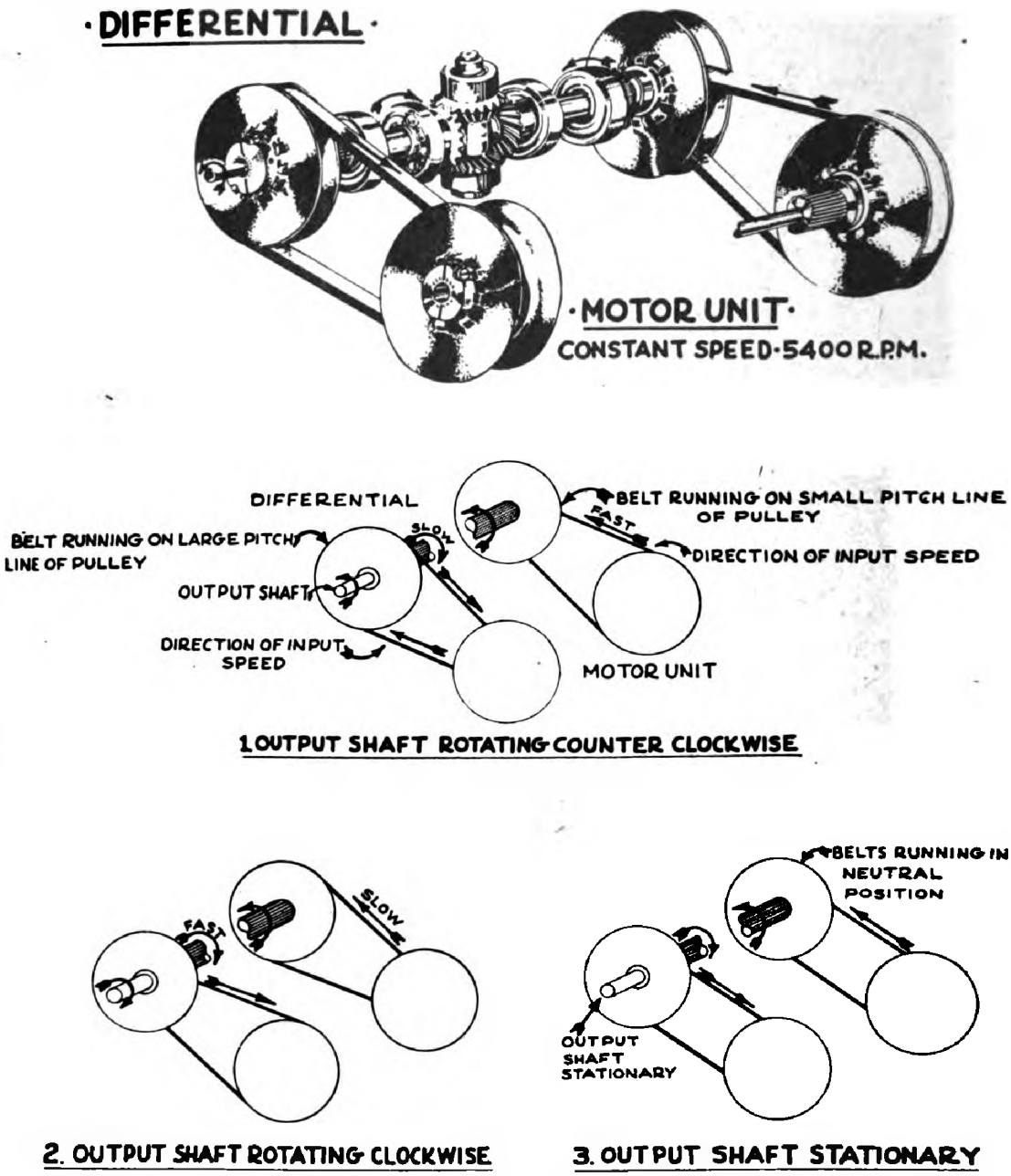

Figure 155. Differential Action.

Operation. To fire the guns one of two trigger switches are pressed. Pressing either switch will actuate a solenoid on each of the guns, and if the guns are loaded and charged all four guns will fire. One gun cannot be fired independently except in the case of malfunctions of weapons or normal operation of the interrupter switches. Before any firing can be done, however, a firing circuit must

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be closed. The firing circuit switch is employed as a safety device. It is clearly marked and located on the column supporting the control handles.

Interrupter switches which operate on a cam break the firing circuits when the guns approach a danger area such as where the mount is placed in a position where damage to either personnel or equipment might result from firing. There are two interrupter switches for each gun. One switch will break a circuit when the gun reaches a predetermined angle of elevation. The other switch will break a circuit when the gun reaches the predetermined angle in azimuth. The guns will cease firing when the predetermined angle of elevation and angle of azimuth are reached, because at that time both interrupter switches will have operated. Both interrupter switches must operate to enable an unbroken current flow from the battery to the solenoids. After the guns have been elevated or traversed beyond the danger area, the interrupter switches will close completing the circuit, and then firing will be resumed.

Sighting Equipment. The guns are aimed by use of an illuminated reflector sight of Navy Bureau of Ordnance design. It is called the Mark IX Reflector Sight. The sight reticle is composed of a dot surrounded by concentric circles. The dot and the circles are used to 'lead' the target. Both the dot and the circles are illuminated and glow resembling in color the orange-red colored neon lights. The intensity of illumination is varied by means of a rheostat to suit the different lighting conditions.

Care and Preservation of the Mount. Lubrication of this mount is most important since all parts operate at relatively high speeds. Technical Manuals which specify the proper lubricants and the intervals of lubrication must be followed closely if maximum service is to be expected. The many precisely made bearings introduced into construction will fail if improperly lubricated, and such bearing failures may result in unserviceability of the mount.

The gasoline generator requires servicing and will present the same problems generally encountered in most types of small gasoline engine driven generators.

The variable speed drive unit will usually require unit replacement when serviced. The various gears mesh with only very small specified backlash tolerance and endplay is held to a minimum movement.

The belts of the power drive are adjusted tightly, and one-half inch displacement is permitted. If at any time one belt should become unserviceable through stretching or wear, that belt, as well as the belt opposite it, must be replaced in order to keep the power train working properly.

The mount as a whole will require unit replacements and an occasional tightening of all the nuts, bolts, and screws. These parts will become loosened from the vibration caused by the firing of the four guns.

Ground Machine Gun Mounts

Units equipped with ground machine guns know little about the mounts used in conjunction with them and care less. The mount has no automatic function, so parts are not kept clean, free from burrs, and oiled. They see the mounts only as something to be thrown about and treated very roughly; yet they expect them to perform their function properly, instantly, and when needed.

This is a serious mistake. A mount is essential for firing machine guns. A machine gun functioning perfectly is of little value with a malfunctioning mount.

To care for mounts properly, first be familiar with them. In this chapter are covered the standard ground machine gun mounts.

Mount, Tripod, Machine Gun, Cal .30 M1917A1

Description. The machine gun tripod mount, cal .30, M1917A1, may be used with all Browning machine guns, cal .30, and with the US trainer machine gun cal .22. The two front legs and the rear leg can be adjusted independently of one another on sloping or uneven ground, so that the traversing dial will be level. The machine gun is secured to the mount by the elevating screw joint pin in the rear, and by the pintle and pintle bolt, and pintle bolt nut in front. The pintle lock group assembly provides for locking the pintle into the pintle support. (See Figure 99).

Fixed Ground Targets. Before firing at ground targets, zero the elevating

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knobs, so that the elevating and traversing screws are centered. This allows traverse of fifty mils right and fifty mils left, and an elevation of fifty mils plus or minus. Partly unscrew the cradle pintle clamping screw. Lay the gun on the target, and then clamp the cradle to a fixed position by tightening the cradle pintle clamping screw.

Moving Ground Targets. For firing at moving ground targets, keep the cradle pintle clamping screw partly unscrewed to permit 360° traverse of the gun. A slowly moving ground target can be followed by use of the elevating and traversing mechanism.

Antiaircraft Fire. To prepare for firing at aircraft, place the gun elevator in the pintle socket and clamp it tight. Put the cradle into the pintle socket of the gun elevator and mount the gun. Keep the cradle pintle clamping screw of the gun elevator partly unscrewed.

Cleaning. After firing, machine gun drill, marches, etc., the mount must be thoroughly cleaned. Special attention should be given the elevating and traversing mechanism and the traversing dial. The traversing dial seat should always be kept clean and dry. Mounts received from storage should be thoroughly cleaned with solvent, dry-cleaning. Use of solvent must always be followed by an application of a lubricating or preservative film. If dry-cleaning solvent is not available, kerosene may be used.

Lubrication. Proper lubrication of all parts is necessary for smooth functioning and operation. However, oil should be used sparingly. Excessive oiling is a waste of oil and results in collection of dirt, which causes friction and wear. Lubricate all bearing surfaces and moving parts with Oil, lubricating, preservative, light.

General Instructions for Inspections. Inspections are for determining the condition of the materiel, with especial emphasis on whether repairs or adjustments are required to insure serviceability. The materiel should be thoroughly cleaned before inspection.

Visual Inspection. Observe general appearance. The cradle pintle, pintle socket, tripod legs and the elevating and traversing mechanism body should have a good coat of paint. No split cotter pins or straight pins should be missing. The leg heads and shoes must be firmly welded to the leg tubes.

To test smoothness of operation, slowly rotate the traversing knob. The mil-click should be felt and heard distinctly. The elevating and traversing mechanism body should move with each mil-click. If it does not, it indicates that the traversing screw is too loosely adjusted or is worn or that the threaded portion of the elevating and traversing mechanism body may be worn. Both screw and body may be worn. If the traversing knob cannot be rotated easily, look for a bent or burred traversing screw, hexagon head cap screws too tight, safety nuts on right and left of the traversing screw too tight, or a bent or burred elevating and traversing mechanism body. The pintle or pintle support may also be burred.

To test the elevating mechanism, hold the upper square part of the elevating screw with the fingers of the left hand and with the right hand slowly turn the elevating knob. The mil-click should be distinctly heard and felt, the elevating screw should move up or down with each mil-click, depending upon which way the elevating knob is rotated. The elevating screw sleeve and the elevating screw sleeve bushing should rotate in unison with the elevating knob. There must be a moderately tight fit of all parts on the elevating and traversing mechanism, with the elevating and traversing knobs turning with ease. If binding in the elevating mechanism is encountered, it indicates either that the parts are rusty, bent, or burred, or that the elevating screw sleeve bushing is screwed too far into the elevating screw sleeve. The elevating and traversing mechanism scale nut may be partly unscrewed from the elevating knob.

Check the pintle lock group assembly for proper locking and unlocking of the pintle in the pintle support.

With the front leg jamming and rear leg jamming handles tight, the tripod should stay in a mounted position when the gun is mounted and with a man's weight on it. If it does not stay mounted, the front leg clutch plates, or rear leg clutch plates or the serrated leg heads may be worn or dirty.

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To inspect the cradle pintle clamping screw assembly with the pintle clamping block attached to it, proceed as follows: Screw the cradle pintle clamping screw tight into the pintle socket. Now the cradle should be clamped to a fixed position in traverse. Partly unscrew the cradle pintle clamping screw. This should allow an easy, all-around traverse of the cradle with the latter still locked in the pintle socket. Then unscrew the cradle pintle clamping screw until resistance other that that caused by unscrewing it is felt. At this point, the rear of the pintle clamping block is up against the inside of the cradle pintle clamping screw nut, and its rounded front end clears the inside of the pintle socket. This permits removal of the cradle from the pintle socket. If the cradle cannot be removed now, it indicates that the pintle clamping block has been sheared off the cradle pintle clamping screw, because the latter has been forcefully unscrewed all the way from the pintle socket. This causes the pintle clamping block to remain against the cradle pintle, preventing removal of the latter.

If the cradle can be rotated after the cradle pintle clamping screw is screwed tight into the pintle socket, the pintle clamping block is not properly positioned. This is caused by the missing straight pin that normally keeps the pintle clamping block positioned so that all of its rounded portion engages the correspondingly shaped annular groove on the pintle socket. If this is the case, replace the straight pin and replace the pintle clamping block properly by guiding its slot over the straight pin.

A bent or burred cradle pintle clamping screw causes binding in screwing or unscrewing. If it is bent or burred, unscrew it only a turn or two at a time, trying to lift the cradle from the pintle socket each time until the cradle can be lifted out. This procedure prevents shearing the pintle clamping block off the cradle pintle clamping screw if the latter is bent or burred.

Check the traversing dial. It should be rotated with ease by means of the four traversing dial knobs and with the dial locking knob partly unscrewed from the traversing dial clamping screw. The dial locking knob stop should be screwed tight to the traversing dial clamping screw, thus preventing accidental loss of the dial locking knob.

All zero marks must be distinct. The ones on the traversing click plate and elevating and traversing mechanism guide should be toward the rear.

The name plate must be securely riveted to the rear leg. This plate secures the tripod strap to the rear leg. Check cradle for ease of elevation with the cradle clamping handle partly unscrewed.

Mount, Tripod, Machine Gun, Cal .30 M2

Description. This mount was originally designed for use by the cavalry, but it is now in general use by practically all of the using arms. It was made primarily to mount the Browning machine gun, cal .30 M1919A4; however, all types of cal .30 machine guns can be and are occasionally used on this mount. It is carried as an auxiliary mount on armored vehicles such as scout cars, tanks, weapons carriers, and practically all types of armored vehicles carrying or mounting the cal .30 machine guns. The M2 mount is used on ground targets only.

The machine gun is secured to this mount by a pintle, pintle bolt, pintle bolt nut, and pintle lock assembly in front. In the rear, the elevating screw joint pin connects the gun with the upper elevating screw, which is part of the elevating mechanism, the latter being connected with the traversing bar by the traversing slide lock lever. With the upper elevating screw scale plate zeroed, the elevating mechanism provides for an elevation of two hundred mils plus and two hundred mils minus. The more recent type elevating mechanism allows traversing fifty mils right and fifty mils left, or one hundred mils in either direction if the upper elevating screw yoke is first moved to its extreme right or left. The traversing bar permits traversing four hundred and fifty mils right and four hundred and twenty-five mils left with the traversing slide zeroed, a total of eight hundred and seventy-five mils. The reading in mils is taken from the left of the elevating mechanism sleeve. The traversing dial permits laying off or measuring horizontal angles (azimuth if measured from magnetic, grid, or true north).

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Fixed Ground Targets. To fire at fixed ground targets, tighten the traversing slide lock lever to the traversing bar. For slight changes in elevation, use the elevating handwheel. Minor changes in traverse are obtained by rotating the traversing handwheel (new type elevating mechanism).

Moving Ground Targets. A moving ground target is engaged by keeping the traversing slide lock lever unscrewed for the traversing bar. For an all-around traverse, disconnect the gun from the elevating mechanism.

Cleaning, Lubrication, and Rust Preventive Instructions. Same as for mount, tripod, machine gun, cal .30 M1917A1.

Inspection. Observe the general appearance. Legs and traversing bar should be straight and free from rust and burrs. Shoes should be welded firmly to tubes. The pintle bushing and traversing dial should be free from grease and oil, thus preventing accumulation of sand and dust which would cause wear and would make it difficult to rotate the traversing dial with the dial locking knob partly unscrewed from the dial locking screw. The dial locking knob stop should be screwed tightly to the dial locking screw, thus preventing accidental loss of the dial locking knob (old type E). Check the pintle lock assembly for proper locking and unlocking of the pintle.

Inspect the elevating mechanism for binding and looseness of parts. The upper and lower elevating screws should move with ease by rotating the elevating handwheel. Be sure both elevating screws move with each click. The mil-click should be distinct in feeling and hearing. The elevating mechanism should slide freely on the traversing bar, with the traversing slide lock lever loose. Check the sleeve latch and the sliding sleeves for proper locking and unlocking. The name plate must be secured to the tripod head by two brass machine screws. The zero mark on the pintle must be distinct (old type). Make sure the headless set screw that secures the pintle bushing into the tripod head is not missing.

MOUNT, TRIPOD, MACHINE GUN, CAL .50 M3

Description. The machine gun tripod mount cal .50 M3 was developed for ground targets with the Browning machine gun cal .50 M2 HB. The aircraft Browning machine gun cal .50 M2 may be used also with this mount. It is used by the infantry and cavalry and is carried as an emergency mount on armored vehicles. The machine gun is secured to this mount by a pintle, pintle bolt,

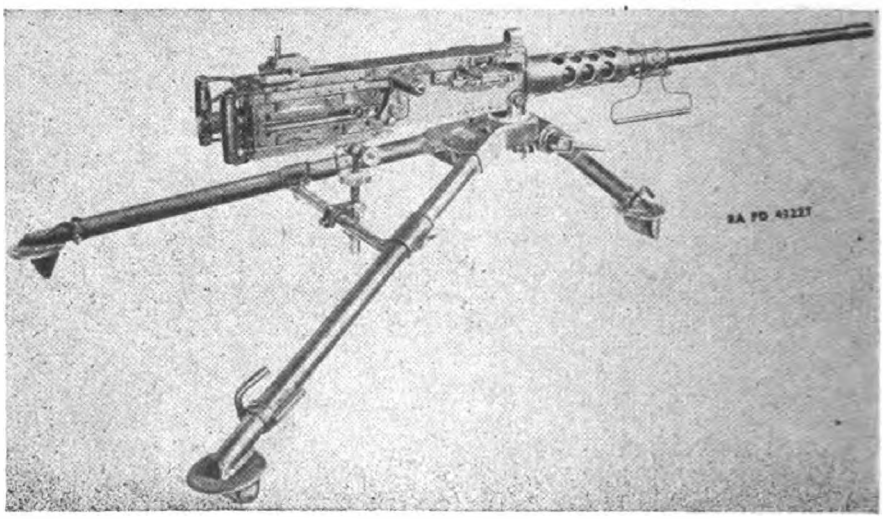

Figure 156. Browning Machine Gun Cal .50 M2 H.B.—Flexible—on Mount Tripod, M3.

pintle bolt nut, split cotter pin, and by the pintle lock assembly in front. In the rear the elevating screw joint pin assembly connects the gun with the elevating mechanism. The elevating mechanism provides for an elevation of one hundred mils plus and two hundred and fifty mils minus, providing the upper elevating screw scale plate is at zero. A traverse of fifty mils right and fifty mils left is

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obtained by means of the traversing mechanism (the newer type elevating mechanism). The traversing bar is graduated from zero in its center to four hundred mils right and four hundred mils left. The traversing dial permits measuring and laying off horizontal angles (or azimuth if measured from any type of North).

Fixed Ground Targets. Tighten the traversing slide lock lever. For minor changes in elevation, rotate the elevating handwheel. (The newer elevating mechanism permits minor changes in traverse.)

Moving Ground Targets. Keep traversing slide lock lever loose. This allows traversing four hundred mils right and four hundred mils left. A free all-around traverse is obtained by disconnecting the elevating mechanism from the rear of the gun.

Cleaning, Lubricating, and Rust Preventive Instructions. This procedure is the same as for the mount, tripod, machine gun, cal .30 M1917A1, as previously discussed in this section.

Inspections. This is the same as for the mount, tripod, machine gun cal .30 M2, except that the leg assemblies require more detailed attention due to their being telescopic. Be sure the front leg clamp screw nut assembly is secured to the front leg clamp screw by a straight pin. Worn, serrated plates, and the worn, serrated portion of the upper front leg assembly causes the tripod not to stay in a mounted position. Make sure shoes are firmly welded to tubes. No leg guiding screws or leg clamping handle stop nuts should be missing. Indexing lever assemblies should properly lock and unlock the lower leg assemblies from the upper leg assemblies. All nuts should be screwed tight to bolts. The pintle bushing should be firmly secured into the tripod head by the headless set screw. There should be a shakeproof lock washer with each leg guiding screw, thus preventing accidental unscrewing of the latter from the leg ring clamps.

ANTIAIRCRAFT MACHINE GUN MOUNT, CAL .50 M2A1

General Description. The antiaircraft M2A1 mount is composed of a pedestal, cradle, and pintle and may be assembled either with three legs or with a pedestal base attached to the lower end of the pedestal. This mount is a modification of the M2 antiaircraft mount, the primary difference being that the sight groups and their support were removed and a combination AA ring-type sight (M1) mounted to the muzzle end of the water jacket. Also, the right-hand side plate is without the mounting lugs used for the sight support of the M2 mount, and the upper buffer recoil shaft nuts are on the counterrecoil spring adjusting plugs instead of on the upper buffer recoil shaft.

The antiaircraft machine gun mount cal .50 M2A1 was designed for antiaircraft fire with the Browning machine gun cal .50 M2 watercooled. It may also be used against ground targets. The recoil mechanism stabilizes the mount in firing the gun by absorbing the shock of recoil and counterrecoil. The hook assembly provides for clamping the mount on a truck or cement base by screwing it into the base ring. By removing the tripod legs and assembling a pedestal base the mount may be mounted on decks of ships or other permanent positions. The tripod pedestal forms the pivot for the cradle in traverse. In elevating the cradle pivots on the cradle pintle trunnion studs. The cradle group is locked into the tripod pedestal assembly by the pintle lock assembly. The gun is fed from the left side only. The accessories for this mount are: ammunition chest M2, capacity 200 rounds, with crank; water chest M3, capacity 8 gal.; two hose assemblies; metallic belt link bag; steel chest M5 with special wrenches; and the cradle cover.

It is possible to elevate the gun with this mount 68.75 degrees and depress it 15 degrees from horizontal. It may be locked in any position by means of the cradle clamping bolt, extending through the pintle and radial slots in the side plates of the cradle and the clamping handle. The pintle is free to rotate through an arc of 360 degrees.

Preparing for Antiaircraft Firing. Secure the side plate trigger assembly to the left side of the gun, being sure the split cotter pin is not missing. Fill water chest and water jacket on the gun with clean water. Before mounting the gun, check recoil mechanism and trigger control mechanism for proper adjustments and engage the recoil mechanism slide with the recoil mechanism slide stop.

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Make sure the gun is properly placed on the mount so as to prevent damage to the trigger control mechanism and the side plate trigger. The leg clamp ring assembly must be screwed tight to the base ring. The leg head bolt nuts also must be screwed tight against their countersunk seats on the projections on the base ring. Keep the water chest at a sufficient distance from the mount so that it will not interfere with the movement of the gunner in firing. For proper functioning of the water chest, rotate the crank at a rate of fifty revolutions per minute, and have the water strainer and cap on top. Keep the cradle clamping handle loose and the pintle lock release cam lowered.

Care and Cleaning. The general care and cleaning of all mounts is similar to all small arms weapons. They must be kept clean, free from foreign matter and rust, and lightly oiled.

Inspections. Inspection is for the purpose of determining the condition of the mount, of finding out what repairs or adjustments, if any, are required, and what remedies must be taken to insure the serviceability of the material. Before inspection the mount should be thoroughly cleaned.

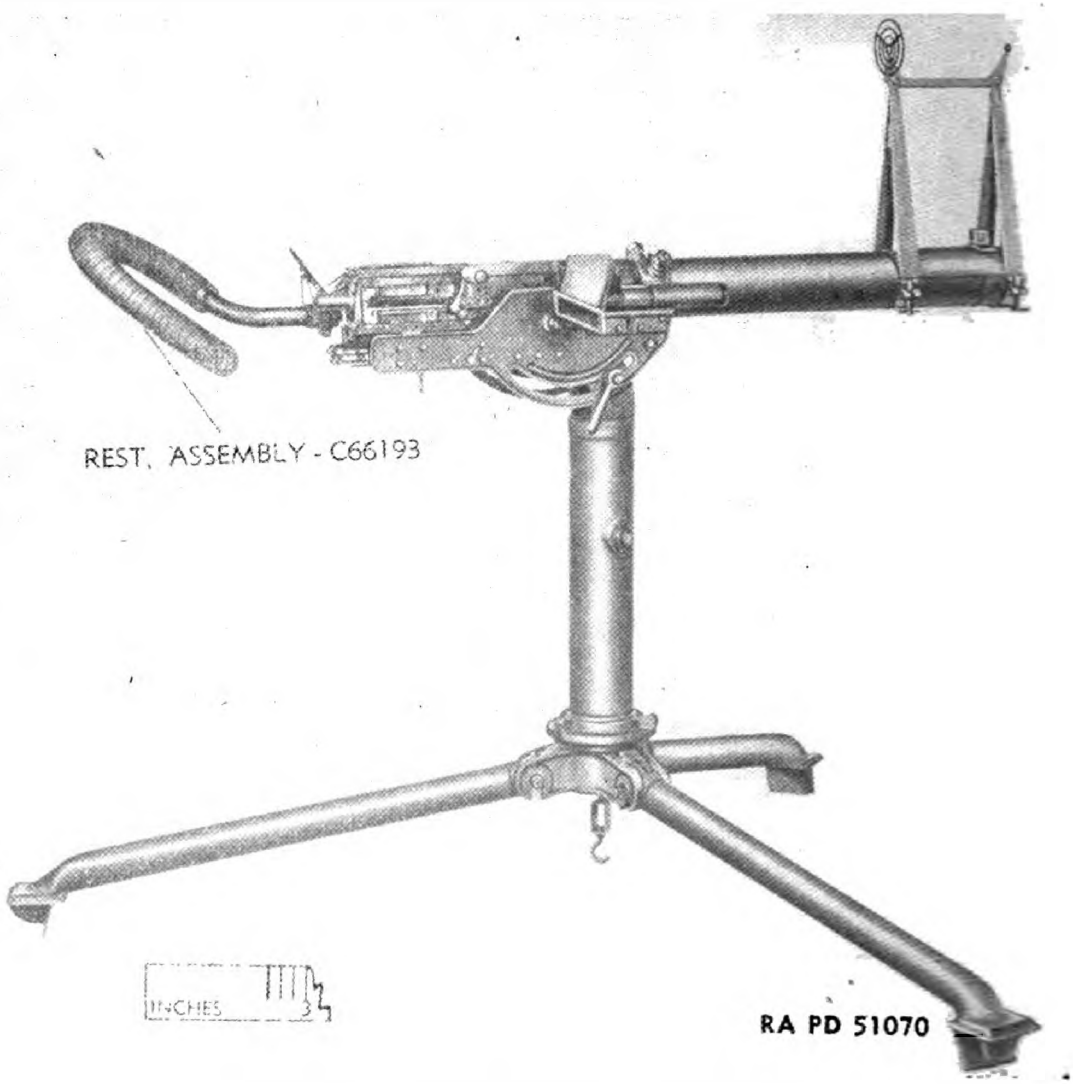

Figure 157. Mount, AA MG Cal .50, M2A1, Right Side.

Cleaning. Observe the general appearance. Tripod pedestal, legs, buffer brackets, recoil mechanism frame, upper portion of the cradle pintle, recoil mechanism slide, and the trunnion slide should have a good coat of paint. All parts must be thoroughly clean. Special attention should be given the

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trigger control mechanism, and the recoil mechanisms, gears, and racks. All parts must be kept free of rust. Rust causes more damage than use and wear.

Lubrication. After cleaning, the mount should be given a light film of protecting lubricating oil. This prevents wear, corrosion, and rust. Lubrication of the recoil mechanism should be more liberal because the recoil mechanism slide wiping washer and the upper buffer recoil shaft washers absorb oil readily. Therefore, keep the recoil mechanism slide, recoil mechanism housing, trunnion slide, long recoil spring guides, and upper buffer recoil shafts well lubricated.

Smoothness of Operation. The cradle should be traversed and elevated with ease, with the cradle clamping handle loose and the pintle lock release cam lowered. With the pintle lock release cam in the horizontal position, the cradle pintle should slide *into* or *from* the tripod pedestal without binding. The trigger control hand lever should return to its non-firing position when released. The alignment marks of the cradle pintle gears, transfer gears, and racks must be aligned. Screwing the safety nuts on the transfer gear studs and the nuts on the cradle pintle trunnion studs too tight against the left and right side plates will cause binding in elevating the cradle. All safety nuts, hexagon head cap screws, and bolts should be tight. No split cotter pins, taper pins, shake proof lock washers, trigger control body washers, and trigger control link washers should be missing. The upper buffer recoil shaft washers and the recoil mechanism slide wiping washer lubricate the recoil mechanism housing. Therefore, make sure that they are in their respective seats on the recoil mechanism slide and trunnion slide. Be sure that the compensating spring adjusting plug washer, the recoil mechanism housing washer, and the trigger control washer are in their proper places. The leg clamp ring nut must be screwed tight to the base ring with the leg clamp ring properly engaging the lugs of the leg heads. In disassembly and assembly, the leg heads, which should be welded firmly to the leg tubes, should slide easily *from* and *into* their seats in the base ring. The shoes should be welded firmly to the leg tubes. Check the side plate trigger assembly for completeness and smooth function. Make sure the recoil mechanism slide stop spring pushes the recoil mechanim slide stop upward when the recoil mechanism slide is retracted after being engaged with the recoil mechanism slide stop.

Inspection for Proper Adjustment of the Recoil Mechanism. *Upper Buffer Counterrecoil Springs.* For proper adjustment of these two springs the counterrecoil spring adjusting plugs are screwed into the buffer brackets until the measurement from the rear of the buffer brackets to the front of the counterrecoil spring adjusting plugs is 6 15/16 inches. The adjustment is locked in place by screwing the upper buffer recoil shaft nuts tight against the front of the buffer brackets.

Lower Buffer Recoil Spring. This spring is properly adjusted by screwing the recoil spring adjusting plug into the recoil mechanism housing until the measurement from the rear of the recoil spring adjusting plug to the rear of the recoil mechanism housing is 4⅞ inches. Care must be taken not to insert the ruler into the wrench slots, because they are 3/16 of an inch deep. This adjustment also prevents metal contact between the rear of the recoil spring adjusting plug and the front of the recoil mechanism adjusting head, at maximum elevation.

Compensating Spring. For proper adjustment of the compensating spring, the compensating spring adjusting plug is screwed into the recoil mechanism slide until it is flush with the compensating spring adjusting plug locking nut. The latter must be screwed tight against the compensating spring adjusting plug washer, thus locking the adjustment in place.

Inspection for Proper Adjustment of the Trigger Control Mechanism. The alignment mark on the trigger control body should be aligned with the mark on the left side plate. The rear of the trigger control clamp should be aligned with the alignment mark on the back rest clamp. This is normal setting. If this normal setting should have to be changed for proper functioning with the side plate trigger assembly, loosen the trigger control body screws and the safety nut that screws onto the hexagon head cap screw, which clamps the trigger control clamp to the backrest clamp. Then move the trigger control body and the trigger control clamp to the front or to the rear of the alignment marks, not to exceed 1/16 of an inch in either direction. Both parts must be moved in the

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same direction and the same distance. (The elongated slots on the trigger control body permit moving the trigger control body in either direction.)

Side Plate Trigger Assembly and Trigger Control Mechanism. *To Secure the Side Plate Trigger Assembly to the Machine Gun Proceed as Follows*: (1) Remove the split cotter pin from the side plate trigger bolt. (2) Unscrew side plate trigger nut about half-way from the side plate trigger bolt. (3) Insert dovetailed lugs on side plate trigger housing and side plate trigger bolt into the two slots on the left side of the casing on the machine gun. (4) Tighten side plate trigger nut. (5) Replace split cotter pin.

To Remove the Side Plate Trigger Assembly From the Machine Guns. (1) Remove split cotter pin from side plate trigger bolt. (2) Unscrew side plate trigger nut about half-way from side plate trigger bolt. (3) Remove side plate trigger assembly from the casing of the gun by pulling it outward.

Trigger Pull. When the trigger control hand lever is pulled down against the back rest body, the lug on the trigger control slide engages a corresponding lug on the side plate trigger slide. This causes the latter to be forced rearward. In turn the side plate trigger cam, which is secured to the side plate trigger housing by the side plate trigger pin, is forced from its seat (slot) in the side plate trigger slide against the sear slide in the gun by the level inner surface of the side plate trigger slide. (This compresses the side plate trigger spring.) The sear slide is forced to the right, pushing the sear down, releasing the shoulder of the firing pin from the sear. Then the firing pin spring forces the firing pin forward to strike the primer.

Recoil. In recoil of the gun the side plate trigger cam is pushed into its seat in the side plate trigger slide by the side plate trigger spring and by the rearward movement of the gun away from the sear slide. This allows the sear to move upward, pushing the sear slide to the left, causing the notch in the sear to engage the shoulder of the firing pin.

Counterrecoil. In counterrecoil the side plate trigger cam is forced out from its slot in the side plate trigger slide by the level inner surface on the latter and by the forward movement of the gun. This causes the side plate trigger cam to force the sear slide to the right, pushing down the sear, releasing the shoulder of the firing pin from the sear.

Adjusting the Trigger Control Mechanism. Align the alignment mark on the trigger control body with the one on the left side plate. Align the rear of the trigger control clamp with the alignment mark on the back rest clamp. This setting should not be changed more than 1/16 inch to front or rear if the adjustment is changed. Move the trigger control clamp the same distance as the trigger control body if the adjustment is changed.

TRUCK MOUNTS, ALL TYPES

Most truck mounts are similar in design, the main difference being in the supports and tracks. Each mount consists essentially of a cradle with a rolling carriage that moves on a circular track. The cradle fits into a pintle socket and can be rotated within this socket. The carriage is held on the track by rollers. There are structural supports holding the circular track to the truck.

The truck mounts M32, M36, M37, M37A1, and the M37A2 have the same carriages, cradles, and circular rails, the only differences being the structural supports such as the posts, braces, and parts used to attach the carriage and rail to the vehicle. The mount ring M49 is basic for these mounts.

These mounts are designed for the Browning machine gun cal .30 M1919A4 or the Browning machine gun cal .50 M2, HB. In an emergency, however, the Browning machine gun cal .30 M1917A1 or the Browning machine gun cal .50 M2, AC may be used.

Mounting. Insert the M1919A4 machine gun in the cradle and aline the front mounting hole of the gun with the hole in the front of the cradle. Then place the machine gun front locking pin through the holes. Move the rear gun spacer forward until the holes line up with the holes in the bottom plate of the machine gun. Then insert the rear machine gun locking pin. To attach the ammunition

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feed tray to the mount, place the two cap screws through the ammunition feed tray and into the hole in the cradle.

The cal .50 M2, HB is mounted on the truck mount in the same way as the cal .30 M1919A4 machine gun, except that the rear gun spacer is pivoted to the rear to aline the holes in the spacer with the holes on the bottom plate of the machine gun. After this is done, insert the rear machine gun locking pin in place.

When in the traveling position, the machine gun is prevented from moving by a gun barrel clamp which secures the front part of the barrel of the gun to the structural supports.

Operation. To elevate the gun, remove the cradle locking pin and place it in the carriage handle. Grasp the gun grips and elevate or depress to the desired position. To traverse, grasp the gun grips and traverse to keep on target. To traverse the gun around the track, raise the brake lever handle until it is released by the brake detent plungers. Move the carriage on the track by grasping the carriage handle and moving the entire gun and mount.

Disassembly and Assembly. To disassemble, loosen the pintle clamping screw, then move the cradle until its rear is outside the track. Remove the cradle by lifting it and the pintle from the carriage. To remove the carriage, loosen the four

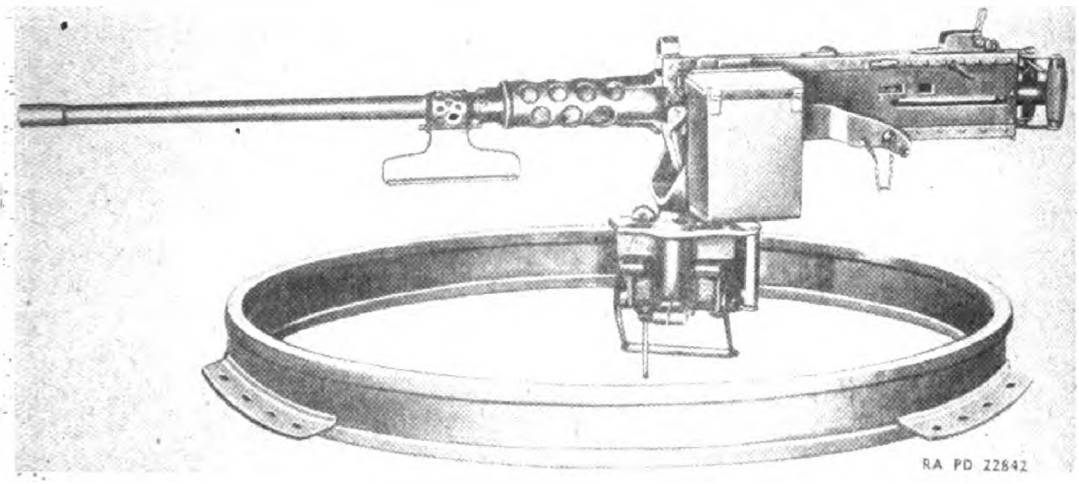

Figure 158. Mount, Ring M49.

bolts holding the four outer carriage rollers, then slide the carriage off the track. CAUTION: *Do not attempt to unscrew the nuts which hold these bolts in place.*

To assemble, put the carriage over the carriage track with the brake lever in the raised position, making sure it is locked by the plungers. This is done to provide slack for the assembly. Be careful not to release the brake lever because it may injure your fingers. Replace the bolts and rollers and tighten them. Replace the cradle with the pintle on the carriage and rotate it until it snaps into position.

Cleaning and Lubrication. Clean in the same way that other machine guns and mounts are cleaned, taking special care on new mounts to get rust-preventive compound out of all recesses and springs. To oil, use an oily rag and wipe surfaces of the pintle and the inside of the pintle socket. Keep all rust from track and keep it lightly oiled. Make sure all unpainted surfaces are clean and oiled.

MOUNT, MACHINE GUN, CAL .50, ANTIAIRCRAFT, M3

U. S. NAVY CAL .50 MOUNT, MARK 30

Description. This mount was designed to meet requirements primarily for an antiaircraft mount employable with ease at all angles from a depression of minus 15° to an elevation of plus 90°. The mount is equipped with armor plate shields

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for the gunner's protection. The M3 can be used either as a tripod or fixed pedestal.

All types of Browning cal .50 M2 guns can be used with this mount; that is, the watercooled, aircraft, or heavy barrel. Conversion parts are needed to convert the mount to fit the three different types. These conversion parts are: counterbalance weight for the heavy barrel and aircraft, front sight for the watercooled guns, ammunition feedway adaptor permitting use of standard Navy cal .50 ammunition box Mark 6.

By use of the pedestal base and base adapter, the mount M3 can be converted from the tripod type to the pedestal type for use on ship decks, movable vehicles, concrete emplacements, floors, or other permanent positions.

The Mounts M3 and Mark 30 are used with machine guns for close range, high angle fire as antiaircraft defense from a fixed position on land or at sea, or as a portable tripod for any land emplacement.

The mounts can be turned by hand through a 360° traverse and from a minus 15° depression to a plus 90° elevation. A gunner of average height can sight the mounts with ease from an almost erect position without the use of steps or platforms of any kind.

To Assemble as a Tripod Mount. Place the pedestal in the approximate center of the desired emplacement position, insert the tripod leg in the leg housing, and tighten the leg clamping handles.

Note: Leg clamping handles must be pulled up completely tight. After a few bursts are fired, the leg clamps should be checked to make sure they are tight. Tighten the cradle clamping handle on the cradle group and the brake shoe clamping handle. Loosen the trunnion bracket clamping bolt assembly several complete turns. Place the cradle group on top of the trunnion bracket socket, lifting the rear of the cradle group until the lug protrusions on the trunnion cradle bracket fit in the fingers of the corresponding lugs on the trunnion bracket socket. Then lower the rear of the cradle group and tighten the trunnion bracket clamping bolt.

To Assemble as a Pedestal Mount. The pedestal base is first secured to a smooth surface in the position wanted. Quick acting clamps, when supplied, are threaded into the three tapped holes in the upper plate of the pedestal base adapter. The chambered or beveled ends of the lower studs of the clamp should protrude through the upper surface of the plate for the purpose of properly locating the holes in the base plate of the pedestal body on the pedestal proper. This is done in order to locate the pedestal in relation with the pedestal base adapter. This prevents rotation of the mount on the pedestal base due to vibration.

The pedestal body is then placed on the pedestal base and the clamps are tightened by forcing them in toward the pedestal body. The quick acting base clamps are adjusted by screwing the upper bolt in the clamp arm down tight against the mount base plate until the base plate is held securely. The jam nut is then tightened securely against the clamp arm. These actions are carried out with the clamps in locked position and with the locking pin chain assembly in place.

Mounting Gun and Proceeding With Adjustment. Place side plate trigger assembly (which has been taken from the side plate trigger container on the left side of the mount) on the left side plate; side plate trigger nut is loosened from the housing and bolt is placed in the smaller of the two rectangular holes in the side plate. The longer cammed portion of the side plate trigger housing is placed in the remaining longer angular hole. The nut is then drawn tight, and the split cotter pin inserted. The gun securing pins, front and rear, are pulled from the gun attaching brackets (front and rear). The gun is placed in the mount from the front, breech end first. When the mounting holes of the gun and the holes of the mount coincide; the securing pins are then replaced. Pins are replaced as far as they will go and are turned down to lock in place. The front sight is then secured to the front end of the water jacket if the watercooled gun is used. If the heavy barrel or aircraft gun is used, the counterbalance weight is assembled to the mount before the gun is mounted. No sight is used with the heavy barrel gun on aircraft.

Adjustments. When the mount is received in the field, adjustments before firing must be made on the link chute, ammunition feed tray, and the trigger

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control mechanism. Other adjustments have been made before the mount reached the field, but they should be checked as at times they require adjustments. This check-up should include the traversing clamp and the distance of recoil.

Link Chute. With the gun in mount and at 0° elevation, the chute is positioned so the lower lip of the entry opening is on the same horizontal plane as the feedway of the gun. Three hexagon head cap screws and lock washers are used in making this adjustment.

Ammunition Feed Tray. The lip of the ammunition feed tray should be on the same horizontal plane as the platform of the gun feedway. With the gun in battery, the ends of the tray coincide with the muzzle end and the breech end of the feedway. Two hexagon head cap screws are used in these adjustments.

Trigger Control Mechanism. Clearance between the firing lug on the trigger control slide and the firing lug on the side plate trigger slide should be a minimum of ¼ inch. This clearance is desirable for the reason that if the gun is being charged and the charging handle is suddenly released, the gun will not travel far enough forward, and the two lugs (described above) will not meet and thus fire the gun accidentally. To make this adjustment remove trigger control rod lever pin and split cotter pin, releasing trigger control rod. By releasing hexagon head cap screws on the trigger control body, the required ¼ inch distance can be made. Screws are then tightened securely. With trigger control grips held in extreme off position, loosen jam nut on trigger control rod and adjust length until the trigger control rod lever pin can be inserted without changing the position of the trigger control grips. The pin is then replaced. At this point adjustment should be tested. Cock gun and try firing grips. If the firing pin is not released, the trigger control rod should be shortened by screwing it farther into the yoke.

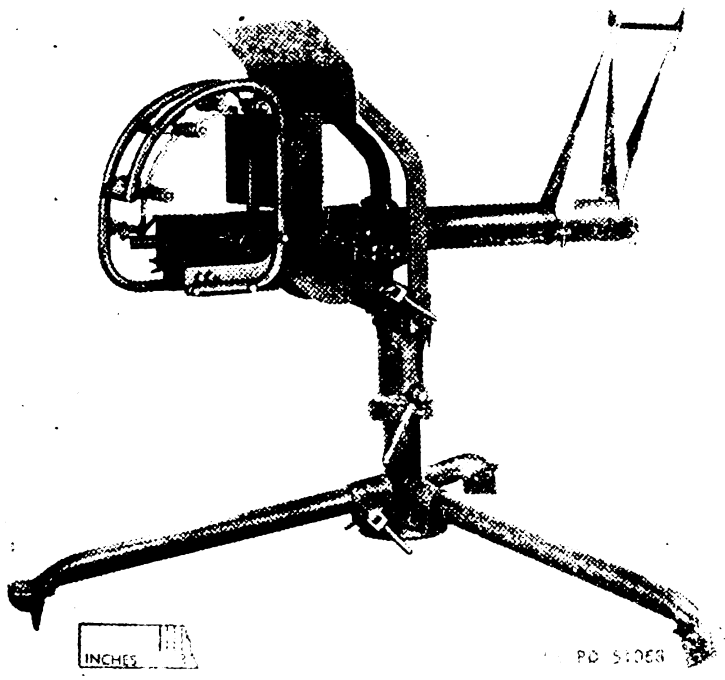

Figure 159. Browning Machine Gun Cal .50 M2 Watercooled on Antiaircraft Machine Gun Mount M3.

Traversing Clamp. The brake shoe clamping handle may be adjusted by removing the brake handle retaining spring that holds the handle to the brake shoe adjusting screw, by removing the handle and repositioning it downward on the serrations, replace brake handle retaining spring.

Recoil. This is one of the most important adjustments. Adjustment of the trigger control mechanism depends on having the following adjustments made

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first: adjustment of the recoil spring and the counterrecoil buffer spring. This will automatically place the gun in one position. After the adjustment is made for the trigger control mechanism in regard to the ¼ inch distance between lugs, the gun is then ready to fire. Should the recoil be more or less than required, changes should then be made. The recoil mechanism is adjusted for the water-cooled gun at the factory.

In using the watercooled M2 cal .50 gun, the distance of recoil should be ⅜ inch, and after recovery to the battery it should travel $\frac{1}{16}$ inch further in counterrecoil. The length of over-all travel should be about $\frac{7}{16}$ inch. A slight overriding in counterrecoil is not an indication of excessive recoil.

If movement of the gun is less than required, tension of the recoil spring (the longer of the two springs which is the one located forward in the recoil mechanism) should be reduced. To accomplish this two set screws set in the recoil spring guide nut are loosened. The nut is then turned counterclockwise until the desired results are obtained. This is tested by firing the gun. If movement of the gun in recoil while firing is too great, tension is increased by rotating the recoil spring guide nut clockwise. Then retighten the set screws.

For the heavy barrel gun the distance of travel should not exceed ⅛ inch in recoil and in counterrecoil about $\frac{1}{16}$ inch; total over-all travel should be about $\frac{3}{16}$ inch.

Note. Adjustment of the recoil mechanism for the heavy barrel gun, as in the foregoing, may necessitate readjustment of the trigger control more closely than the adjustment described for the watercooled gun. The adjustment of counterrecoil buffer spring (rear) ordinarily need not be changed.

If for any reason the recoil mechanism is disassembled and requires reassembly, approximate tension of the counterrecoil buffer spring (rear, smaller spring) may be obtained by screwing the recoil spring guide nut (rear nut) onto the recoil spring guide until about 1/6 of the guide extends beyond the rear face of the nut.

To mount the aircraft gun, the counterbalance is used and proper adjustment of the recoil and counterrecoil mechanism is obtained by the above methods. Total travel for the aircraft gun should not exceed ½ inch.

Pedestal Assembly Adjustments. The trunnion bracket socket houses elements which form an isolation joint, the purpose of which is to separate metal from metal contact and to prevent the transmission of vibration shock between the socket and the pedestal body and the leg assemblies. These isolation joints are *not* to be disassembled in the field.

A four-way thrust ball bearing race housing is situated between the trunnion bracket socket and the pedestal body. The ball bearing group assembly is so situated in an insulation material that vibration shock is absorbed by it in low angle fire. In high angle or vertical fire the vibration isolation cups, cones, and insulation parts come into play. This prevents excessive pounding on the mount as the gun is elevated in the high angle vertical positions. The adjustments are extremely delicate and the assembly should never be disassembled in the field. Grease should be forced into the grease fitting and into the bearing housing at least once every six months.

Lubrication. Edges between the cradle side plate clamping blocks and the side plates should be well greased at all times.

A good grade of grease and oil such as is used on the M2A1 mount should be used. This will allow for a wide variation of temperatures and climates.

The mount is equipped with alimite grease fittings at seven points.

Recoil Mechanism Front and Rear. Two front and two rear fittings supply lubrication to the recoil mechanism and attaching bracket bushings. These bearings or bushings are bronze and do not require too frequent lubrication. However, grease injected under pressure will force any foreign matter such as dust, sand, and other particles out of bearing range.

Trunnion Bearings. On each side of the trunnion cradle bracket in the cradle bracket in the cradle bolt pivot, there is a grease fitting that should be lubricated in much the same way as the recoil mechanism.

Main Pintle Bearing Group. The main pintle bearing group should be lubricated at least every six months, or more, if needed, depending a great deal on the ease of the cradle group action in traverse.

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Trigger Control Mechanism and Trigger Frame Group. An occasional drop of oil on the trigger control mechanism and the trigger frame group is all that is needed. These are bushed with oilite bronze and require almost no attention.

APPROXIMATE LENGTH OF SPRINGS

	Free	*Assembled*
Counterrecoil buffer spring	2.687 inches	2.375 inches
Recoil spring (front spring)	3.100 inches	2.687 inches

The safety is the trigger control locking plunger located on the lower left hand side of the trigger frame group. It should be engaged when the gun is not in actual firing.

FUNDAMENTAL PRINCIPLES OF PREVENTIVE MAINTENANCE FOR SMALL ARMS

Modern war is mechanical war. Never before in the history of the world have the lives of individuals, the success of armies, and the existence of nations been so dependent on the proper functioning of mechanical equipment. Every member of the military forces has a definite responsibility. These maintenance responsibilities vary from the actual preventive maintenance operations and highly specialized repairs and reconditioning techniques to the general supervision and inspections necessary to insure that equipment is ready for use when needed.

Observations of various tactical and service organizations during recent maneuvers and other ordnance inspection trips in various theaters of operation during their training program and when in an alerted status have indicated a lack of first echelon maintenance of all small arms. Many of these weapons were out of action due to normal loss or breakage of parts, but a large percentage of the weapons were unserviceable because of neglect or abuse.

Certain preventive procedures in proper cleaning, lubrication, and care will reduce the maintenance and repairs to the limits of normal wear for all small arms, while certain other specific points are only applicable to a single weapon.

Preventive Maintenance Applicable to all Current Small Arms

Cleaning. The importance of a thorough knowledge of how to clean small arms cannot be overemphasized. The kind of attention given to a weapon determines whether the weapon will shoot accurately and function properly when needed. The bore and chamber must be kept in perfect condition for accurate shooting, and the receiver and all moving parts must be kept clean for reliable operation. After firing, the weapon should be thoroughly cleaned not later than the evening of the day fired, preferably immediately after firing—and inspected and cleaned each day for three days following the cessation of firing.

The purpose of compulsory, intelligent cleaning is to eliminate corrosion. Rusting of parts causes more damage to, and shortens the life of, small arms more rapidly than does the actual wear due to firing. When the weapon is fired, the projectile deposits in the bore the combustive products of powder and primer together with platings or smears of metal from the jacket of the bullet. Combustion of the powder being nearly complete usually leaves a fouling of an almost harmless ash. Combustion of the primer mixture, however, deposits a salt known as potassium chloride, which is a part of the primer mixture of all small arms ammunition. The bore of the weapon, under the action of pressure and heat of the burning powder gases, is hardened in a manner similar to that which forms the case hardened surface of steel. Under the further action of heat, pressure, and abrasion, the hardened surface becomes covered with minute cracks. These minute cracks normally follow the tool marks and extend from the surface of the bore to a depth of approximately 0.0015 inch. They accumulate the potassium chloride or salt which has been deposited over the surface of the bore and in the tool marks, thus making the salts difficult to remove. When the salt is first deposited it is harmless; but being a salt, it quickly absorbs the moisture from the air, and corrosion is spread by the alkaline solution thus formed. This solution is not removed by merely wiping the bore with dry clean patches, neither is it dissolved by oil or by any solution or solvent containing oil. A barrel on superficial cleaning might appear to be in perfect condition, but

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subsequently it will rust from the action of the salt and moisture remaining in the minute cracks. The proper procedure of cleaning is to dissolve all the salt solution from the bore surfaces, minute cracks, and tool marks with which the salt solution comes in contact by using water or solutions containing water; then to dry these parts thoroughly and finally to protect these parts and surfaces with a film of lubricant.

Bore Care. After firing, the bore and chamber of the barrel should be thoroughly cleaned with rifle bore cleaner. It is a combination solvent and preservative, and is especially designed to remove deposits of primer salts which are deposited throughout the bore during firing. To use rifle bore cleaner, insert a clean dry patch in the slot in the cleaning rod and saturate the patch with cleaner. Push the patch back and forth through the bore several times, taking special care that all surfaces of the bore are cleaned from muzzle to chamber. The cleaning operation is to be continued until several successive patches go through the bore without being soiled. While the bore is wet with rifle bore cleaner, a cleaning brush (brass or bronze), if available, should be used to remove any rust spots, hardened particles, or foreign matter which may not have been removed by the cleaner. Remove the cleaning brush and run several patches saturated with cleaner entirely through the bore, removing the patch from the opposite end; then wipe the cleaning rod dry, and using clean dry patches thoroughly swab the bore until it is perfectly dry. Clean the chamber thoroughly in the same general manner, using a patch wrapped around a stick if necessary or a chamber cleaning brush. Inspect the bore and chamber carefully for cleanliness. Although rifle bore cleaner possesses rust preventive properties and will provide temporary protection againsts rust after a bore has been cleaned with the cleaner, the best practice is to wipe the bore dry immediately after cleaning, and coat the metal lightly with oil-lubricating, preservative, special.

In the event that rifle bore cleaner is not available, the bore should be cleaned with hot water and issue soap solution, hot water and soda ash solution, plain hot water, or in the absence of these, cold water. The use of rifle bore cleaner is preferred because of its greater effectiveness due to a faster and easier application.

Metal Surfaces and Moving Parts. All moving parts and metal surfaces except the bore or any assemblies which contain fibre disks, packing, or rubber should be cleaned with dry-cleaning solvent after firing. Dry cleaning solvent is a noncorrosive petroleum distillate of low inflammability and is used for degreasing materiel. It will remove all oily films from metal parts, and its use should therefore always be followed by an application of a lubricating or preserving film. It is generally applied with rag swabs to large parts; small parts are immersed in it. Particular care should be taken to wipe all surfaces completely dry of solvent after use and to apply a thin film of oil immediately. In an emergency, diesel fuel oil may be used but in the event that the above is not available, the parts should be wiped clean with lubricating oil. They should be cleaned at every opportunity and at least once each day.

Special Precautions to be Observed When Cleaning.

1. Extreme care must be used in the choice and application of cleaners. It must be definitely understood that unless a satisfactory cleaning method is selected and properly carried out, more harm than good may result.
2. The choice of a method of cleaning will depend upon the following points:
   Composition of the part to be cleaned.
   Nature of surfaces of the parts.
   Complexity of construction.
   Nature of contaminants to be removed.
   Degree of cleanliness required.
   Availability of cleaning materials and equipment, and hazards involved.
   When cleaning can be done.
3. All surfaces must be kept free from rust, dirt, grease, primer salt, powder fouling, metal fouling, and perspiration from hands.
4. Thoroughly clean the bore and chamber with prescribed cleaning solution or authorized substitutes:
   Rifle bore cleaner.

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Hot water and issue soap solution.
Hot water and soda solution.

5. Clean weapons promptly and thoroughly for three successive days after each firing, using the prescribed methods and materials.
6. Thoroughly clean metal surfaces and moving parts with authorized cleaning solvents, either dry cleaning solvent or diesel fuel oil.
7. Never use carbon tetrachloride, trichlorethylene or perchlorethylene, except in commercial degreasers, as these solvents may cause rust. Gasoline and benzine are not recommended as they are fire hazards.
8. Alkaline cleaning solutions such as those containing soda ash, soap, or borax should not be used on phosphate surfaces (distinguished by a velvety black appearance), because of the difficulty of removing all traces of the alkali after cleaning.
9. After thoroughly cleaning, dry thoroughly, and apply a film of preservative lubricating oil.
10. Examine the bore and chamber carefully for cleanliness. If rust spots or foreign matter are not removed, scrub the lands and grooves of the bore with the cleaning brush and the chamber with the chamber cleaning brush.
11. When using a cleaning brush make certain to run the brush completely through the bore.
12. Dry thoroughly with dry clean lintless rags or patches.
13. When cleaning the bore, make sure the patch goes all the way through the bore before the direction is reversed. This will prevent the patch and rod from becoming stuck in the bore.
14. Only use cleaning rods specified in the S.N.L. pertaining to each weapon.
15. Do not use a ferrous (steel) brush for cleaning the bore and chamber. Only use non-ferrous (brass or bronze) cleaning brushes.
16. All gun components must be thoroughly dry and lubricated immediately after cleaning.
17. Never immerse the assemblies which contain fibre disks, packing, or rubber in solvent or boiling water. To do so will remove the oil and cause them to deteriorate quickly.
18. Particular care must be taken that the coils of all springs, holes, guideways and recesses in which springs and plungers operate are cleaned thoroughly.
19. Rust spots can easily be removed with crocus cloth and light oil. If light rust appears on the blued exterior surfaces, use light oil and rub with a stick of wood to prevent damage to the bluing.
20. It is essential that all traces of rust preventive compound are removed from all surfaces of the weapon. Rust preventive compound is not a lubricant.
21. Buffer disks, packings, and rubber should not be cleaned with commercial degreasers.
22. Never use a solution of water and lye or any other caustic to clean gun parts.
23. Never use an acid.
24. Never use any type of abrasive for cleaning.
25. Remove all obstructions from the bore before firing.
26. To avoid leaving finger marks, which are ordinarily acid and induce corrosion, gloves should be worn by persons handling parts after cleaning.
27. The bore should always be cleaned from the breech end whenever possible.
28. Use rifle bore cleaner on the front face of the bolt and all gun components which have been exposed to the powder gases.
29. Hard carbon which gradually accumulates on gun components should be carefully removed with a scraper or crocus cloth, and the parts oiled immediately.
30. The bores having a phosphate finish, which is similar in appearance to the outside of the receiver, will cut and discolor cleaning patches. This porous coating absorbs oil and affords excellent protection against rust. No special effort should be made to remove the phosphate coating.
31. When dry cleaning solvent is used, the parts should not be touched with bare hands until oiled, as the solvent removes every trace of oil or grease and thereby promotes rusting.
32. All accessories and equipment used with each weapon should be kept in perfect order, cleaned thoroughly, and lubricated immediately.
33. If issue patches are not available, use cut patches 2½ inches square.

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Large cleaning patches may cause the cleaning rod to bend while being pushed through bore.

34. For instructions as to use of and the specifications pertaining to cleaning, refer to TM 9-850, S.N.L. K-1, TB 9-2835-7, and the technical manuals pertaining to each weapon.

LUBRICATING

Proper lubrication is second in importance only to intelligent cleaning. It is a vital necessity for working parts, but oil should be used sparingly.

Oil, lubricating, preservative, special, should be used for lubricating all moving parts and bearing surfaces and for protection against rust of all metal parts of small arms fired on the ground. This oil has rust-preventive as well as lubricating properties, but should not be depended upon to provide protection from rust for long periods. Frequent inspections must be made to insure maintenance of an adequate oil film. The thickness of the film of oil to be applied must necessarily depend upon climatic conditions.

Oil, lubricating, preservative, medium, is a heavier oil than oil, lubricating, preservative, special, and possesses much better preservative characteristicss for short-term storage. It is also effective in the presence of salt spray and in atmosphere such as prevails in a territory adjacent to salt waters. It contains rust inhibitors and forms a relatively heavy film which protects against the direct washing action of spray. These characteristics make it useful for coating all parts during landing and wading operations. When used for temporary storage, frequent inspections should be made to insure maintenance of an adequate protective oil film.

Grease, rifle, is a specially designed lubricant and preservative for use in the mechanism of the US rifle, cal .30, M1 when exposed to rain or sea water spray. It has been found that the US rifle, cal .30, M1 when exposed to severe conditions of rain or spray from sea water, may occasionally fail to unlock. To assure the operation of the rifle under such conditions, it is essential that the cam surfaces in the hump of the operating rod, the locking recesses in the receiver, the bolt camming lug on the face of the hammer, the circular surface under the lid of the rear of the receiver and above the bolt, be coated with rifle grease, which has excellent resistance to the action of water. This grease is issued in small plastic containers to be carried in the rifle butt recess and is a 'MUST ITEM.'

Special Precautions to be Observed When Lubricating.

1. All lubricant containers must be kept closed so as to prevent the possibility of grit, dirt, lint, moisture, and other foreign materials getting into the lubricants. Rapid wearing and even immediate destruction of parts may result from the use of lubricants which contain abrasives or other foreign matter.
2. The containers should be kept closed when the lubricant is not actually being removed. They should not be opened when it is possible that sand and grit might be blown into them.
3. Always clean and dry all parts thoroughly before lubricant or preservative is applied.
4. Use only the following prescribed lubricants or authorized substitutes:
   Oil, lubricating, preservative, special.
   Oil, lubricating, preservative, medium.
   Oil, lubricating, preservative, light (until no longer available).
5. Lubricate with dry, clean, lintless rags or patches.
6. Never apply lubricant with patches or rags that have been previously used for cleaning.
7. Do not overlubricate. A light film of lubricant is sufficient. Excessive oiling results in a collection of foreign matter which causes friction and wear.
8. Bore and chamber should be wiped dry of oil before firing.
9. The thickness of the film of oil to be applied must necessarily depend upon climatic conditions.
10. Lubricate all bearing surfaces.
11. Authorized lubricants have rust-preventive as well as lubricating properties, but should not be depended upon to provide protection from rust for long periods of time.

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12. Frequent inspections must be made to insure maintenance of an adequate oil film.

13. Never squirt oil from an oiler while applying. Use an applicator.

14. Specifications of oils and greases used for lubrication are subject to revision from time to time; therefore, always refer to the latest revision of the specification for the item in question, as listed in the latest War Department publication on the matter.

15. For instructions as to use of and specifications pertaining to lubricating and preserving materials, refer to TM 9-850, S.N.L. K-1, TB 9-2835-7, and to the Technical Manuals pertaining to each weapon.

Cleaning and Lubricating Under Unusual Conditions. When working under unusual conditions, where extremes of temperature and humidity occur, special care should be observed with regard to the cleaning, oiling, and lubricating of weapons.

Cold Climate. 1. Clean weapons promptly and thoroughly for three successive days after each firing, using the prescribed methods and materials.

2. At temperatures below freezing, antifreeze materials such as alcohol, glycerine, and antifreeze compound (ethylene glycol type) must be added to the authorized cleaning solutions. Refer to OFSB 6-5 for proper proportions.

3. After cleaning, dry thoroughly and lubricate lightly using only the lubricant specified. Cf. TB 9-2835-7.

4. Always keep a careful check on the bore and chamber for ice.

5. Do not fire a weapon and let it stand for any great length of time without removing the moisture left from powder residue.

6. Only use cleaning rods. Pull-through cords are not effective enough to remove ice.

7. Keep wire brushes and cleaning patches clean, warm, and dry.

8. Be sure that the weapon is clean and free from all traces of rust-preventive compound and old oil.

9. Oiling is best performed by wiping with a clean cloth, dampened with oil and well wrung out.

10. Lubricants should be used sparingly.

11. Dry thoroughly with dry, clean, lintless patches or rags.

12. Great care should be used to remove excess oil from the piece, with special attention to guideways and springs. Excess oil will congeal at low temperatures and cause sluggish action or even malfunction of the piece.

13. Remove every trace of the cleaning agent from the smallest groove and recess. Remember that a small amount of grease or other foreign matter left within the mechanism may cause the weapon to malfunction.

14. If possible, condensation should be avoided.

15. The working surfaces and parts which show signs of wear may be lightly lubricated but only with the lubricants specified.

16. For instructions as to use of and specifications pertaining to cleaning, lubricating, and preservative materials used in cold climates, refer to TM 9-850, TB 9-2835-7, and to the technical manuals pertaining to each weapon.

Tropical Climates. 1. Clean weapons promptly and thoroughly for three successive days after each firing, using the prescribed methods and materials.

2. The weapon should be thoroughly inspected daily and kept lightly oiled when not in use.

3. The weapon should be field stripped at regular intervals, and, if necessary, disassembled sufficiently to enable the drying and oiling of parts.

4. Unexposed parts and surfaces are to be kept cleaned and oiled, such as the underside of barrels, springs, recesses, guideways, housings and plungers.

5. After cleaning, dry thoroughly and lubricate immediately with only the lubricants specified.

6. Wooden parts should be inspected daily to see that swelling due to moisture does not bind the working parts.

7. Screws and pins should be inspected frequently to prevent rust attacking them and freezing them in place.

8. For instructions as to use of and specifications pertaining to cleaning, lubri-

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cating, and preserving materials used in tropical climates, refer to TM 9-850, TB 9-2835-7, and to the technical manuals pertaining to each weapon.

Hot, Dry Climates. 1. Clean weapons promptly and thoroughly for three successive days after each firing, using the prescribed methods and materials.

2. The weapons should be cleaned daily, or more often, if necessary.

3. Lubrication should be kept at a minimum.

4. The weapon should be disassembled as far as necessary to facilitate proper cleaning. Lubricate only interior parts.

5. Perspiration from the hands is a contributing factor to rust because it contains acid; therefore, metal parts should be wiped dry frequently.

6. Immediately upon leaving sandy terrain, the weapon should be thoroughly wiped clean of dust and then lubricated with only the lubricants specified.

7. During sand or dust storms weapons should be kept covered, if possible.

8. Inspect daily the wooden parts which are apt to dry out and shrink.

9. For instructions as to use of and specifications pertaining to cleaning, lubricating, and preserving materials used in hot, dry climates, refer to TM 9-850, TB 9-2835-7, and technical manuals pertaining to each weapon.

PREPARING MATERIEL FOR STORAGE AND SHIPMENT

The best preservative is practically worthless when applied over a dirty surface. To obtain the maximum or even reasonable benefits from the various preservative coatings, there should be no dirt residues under the coatings which could cause corrosion.

To obtain maximum benefits from careful cleaning and processing before preservation, the selection and application of the preservative coating must be as careful as the choice and application of the cleaning method. In some cases the use of a wrong preservative may actually ruin materiel.

Temporary Storage Not Exceeding 30 Days. At all atmospheric temperatures use oil, lubricating, preservative, medium, as a rust preventive for temporary storage of small arms not exceeding 30 days, depending on climatic conditions.

Shipping or Permanent Storage. At all atmospheric temperatures, use compound, rust preventive, light, as a rust preventive for small arms in permanent storage or shipment. Before applying compound, rust preventive, light, all unprotected metal surfaces should be thoroughly cleaned and dried before application of the preservative. The rust preventive compound should preferably be applied by dipping the parts in the heated compound. Do not heat the compound over a flame because of the danger of the preservative's catching fire. Use some indirect method such as steam or hot water. If heating facilities are not available, compound, rust preventive, light, can be brushed on at temperatures as low as 60° F. plus.

Special Precautions to be Observed When Preparing Materiel for Storage or Shipment.

1. Corrosion preventive must be carefully selected and properly applied.

2. The choice of a preservative will depend on the following points:

Composition of the part to be preserved.

Nature and function of the surfaces of the parts.

Complexity of construction.

Type of exposure and degree of preservation required.

Nature of packing to be used over the preservative.

Ease of removal or the necessity for quick removal of preservative from parts at a later date.

Availability of preservative material.

Difficulties of application.

3. Any ordinary lubricating oil or grease should not be used as a preservative.

4. Thoroughly clean the weapon for three successive days before applying a preservative film.

5. Only use the prescribed rust preventive compound or authorized substitutes:

Compound, rust preventive, light.

Oil, lubricating, preservative, medium.

6. All unprotected metal surfaces shall be treated with rust preventive compound whether the weapon is to be shipped, boxed or unboxed.

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7. All unprotected metal surfaces shall be thoroughly cleaned and dried before application of the preservative.

8. Apply solvent, dry cleaning when available, and immerse the unit in a cleaning tank, brushing or scrubbing it sufficiently to remove all traces of dirt, grease, perspiration, and other foreign matter. Cf. TM 38-305.

9. If a cleaning tank is not available or is impracticable due to the size of the unit, cleaning can be accomplished by hand brushing or wiping.

10. Where solvent is not available, units may be cleaned with a soap solution by vigorously brushing or scrubbing until all traces of contamination have been removed.

11. After a soap solution has been used, the surfaces must be thoroughly rinsed with clean, hot water and thoroughly dried.

12. Avoid contact of bare hands with the cleansed surfaces.

13. Application of the preservative should be made immediately after cleansing.

14. Any painted surface that has become scratched, marred, etc., shall be repainted or touched up before packing.

15. The rust preventive compound should preferably be applied by dipping the parts in the heated compound.

16. The best way to apply rust preventive compound to the bore is by dipping the metal cleaning brush in the rust preventive compound and passing it through the bore several times. The cleaning brush should be clean when used for this purpose.

17. Do not wrap small arms coated with rust preventive compound in cloth of any kind before placing in boxes for storage or shipment.

18. Weapons being boxed for shipment shall be wrapped or bagged in greaseproof, acid free wrapping paper.

19. Coat the support cleats in boxes and supporting straps with rust preventive compound before the weapon is placed in the box.

20. The waterproof paper used for lining boxes should have enough strength and elasticity to resist rupture.

21. All seams, closures, and joints should be made in such a manner as to provide protection equal to the expected weight, shape, and type of body material. Where ordinary protection against the passage of water is desired, the joints shall be cemented with asphaltum or any suitable adhesive.

22. For instructions as to use of and specifications pertaining to rust preventive compounds, refer to TM 9-850, S.N.L. K-1, TB 9-2835-7, SB 9-OSSC-B, and to the technical manuals pertaining to each weapon.

WATERPROOFING INSTRUCTIONS FOR WADING OPERATIONS

The instructions in this paragraph must be followed in order to protect small arms against complete immersion during deep water fording operations or surf landings, and still to permit immediate use of the materiel after landing.

1. The weapon should be cleaned thoroughly and properly lubricated.

2. The weapon should be lubricated with oil, lubricating, preservative, medium (landing operations).

3. The weapon should be placed in the specified cover, waterproof, small arms (film type) specification No. P.Q.D. (No. 377), which can be obtained at Quartermaster overseas supply points.

4. The waterproof covers must be securely tied with tape, adhesive, nonhygroscopic.

5. As soon as possible after landing operations are completed, the waterproofing material should be removed.

6. Parts subjected to salt water should be washed with fresh water.

7. For instructions as to use of and specifications pertaining to waterproof covers, refer to TM 9-2835.

Care of Rifle Stocks. The stock and hand guards should be inspected to see that swelling due to moisture does not bind the working parts. (In such cases shave off the wood only enough to relieve binding.) About once a month apply oil, linseed, raw to wooden parts and rub the oil well into the wood with the heel of the hand. Allow the linseed oil to soak in for a few hours and then

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wipe off the surplus oil and polish the wood with a dry clean rag or the palm of the hand. Care must be taken not to allow the linseed oil to get into the mechanism of the rifle or on metal surfaces as it will harden (gum up) when dry. The stock and hand guards or barrel guard should be removed from the barrel and receiver when linseed oil is applied. When stocks are treated with china oil or tung oil at the arsenal, linseed oil is not required.

Care of Leather. The gun sling should be washed with water and castile or saddle soap, rinsed with clean water, and dried. When dry, neat's-foot oil may be applied (if the leather is hard) with a piece of cloth or sponge. Rub the oil well into the leather. Do not use an excessive amount of oil as it will take a long time to dry and may mark clothing. After the oil is dry, the sling may be polished with dressing, russet leather. If leather is pliable and in good condition it may be treated with a thick lather of saddle soap, rinsed with clear water, and when thoroughly dry, rubbed briskly with clean dry wiping cloth.

Special Care of the Weapon. The following are some of the important points to be observed in caring for the weapon.

1. Never lay a weapon down where it may fall.
2. Use only proper tools when disassembling and assembling weapons. Improper tools will burr and score the parts.
3. Select the proper tool to perform the correct job.
4. Issue only authorized tools listed in the latest applicable S.N.L.
5. Using units should only make such repairs as they are authorized to make.
6. Weapons should not be altered without proper authorization.
7. Except as a last resort, never alter a part or assembly in such a way as to make that part or assembly non-interchangeable. Try other parts or assemblies, if available, before making any alterations to the part in question.
8. Using units should not disassemble weapons beyond authorized field stripping.
9. Stoppages must be reduced in the proper manner. The improper method may result in aggravating the stoppage still further.
10. The parts should never be forced together. If properly assembled, the parts go together easily. If force is required, it is an indication of improper assembly.
11. Never leave springs under tension, especially firing pin springs and driving springs.
12. Use the weapon only for the purpose intended.
13. Check all adjustments frequently to be sure they are proper, also make certain that all screws are tight.
14. Know the capabilities of each weapon.
15. All spare parts should be cleaned, treated with a preservative, and wrapped in grease proof paper for protection.
16. Smaller spare parts should be kept in a fabric envelope or container to prevent loss.
17. Tools, spare parts, and accessories should never be mixed within a tool chest or elsewhere because of possible damage to both.
18. Keep weapons out of leather holsters when not in use.

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SMALL ARMS REFERENCES

U. S. Rifles Cal .30 M1903, M1903A1, M1903A3 and M1903A4

TM 9-270	U. S. Rifle cal .30 M1903A4 (Snipers)
TM 9-1270	U. S. Rifles cal .30 M1903, A1, A3, A4
FM 23-10	U. S. Rifle cal .30 M1903
SNL B-3	Rifles, U. S. cal .30 M1903, A1, A3 and A4
	Book of the Springfield, Capt. C. E. Crossman
SB 9-2	

U. S. Rifle Cal .30 M1917

TM 9-2200	Small Arms, Light field mortars and 20mm antiaircraft guns
FM 23-6	U. S. Rifle cal .30 M1917
SNL B-4	U. S. Rifle cal .30 M1917
	Description and rules for the management of the U. S. Rifle cal. .30 M1917. Government Printing Office—1918.
SB 9-2	

U. S. Rifle Cal .30 M1

TM 9-1275	U. S. Rifle cal .30 M1
FM 23-5	U. S. Rifle cal .30 M1
SNL B-21	Rifle, U. S. cal .30 M1
TB 23-5-6	
SB 9-2	

U. S. Carbine Cal .30 M1 and M1A1

TM 9-1276	Carbine cal .30 M1 and M1A1
FM 23-7	U. S. Carbine cal .30 M1
SNL B-28	Carbine cal .30 M1 and M1A1
SB 9-2	

Rocket Launcher 2.36 Inch M1A1 and M9A1

TM 9-294	2.36 inch A.T. Rocket Launcher M1A1
TM 9-294 C1	2.36 inch A.T. Rocket Launcher M9
FM 23-30	Hand and Rifle Grenades—Rocket AT HE 2.36 inch
SNL B-36	Launcher, Rocket A. T. 2.36 inch M1A1
SNL B-41	Launcher, Rocket 2.36 inch M9A1
SB 9-2	

Submachine Guns Cal .45 M1928A1, M1, and M3

TM 9-215	Thompson Submachine Gun cal .45 M1 and M1A1
TM 9-217	Submachine Gun cal .45 M3
TM 9-1215	Thompson Submachine Gun cal .45 M1928A1
FM 23-40	Thompson Submachine Gun cal .45 M1928A1
FM 23-41	Submachine Gun cal .45 M3
SNL A-32	Thompson Submachine Gun cal .45 M1928A1, M1, and M1A1
SNL A-58	Submachine Gun cal .45 M3
SB 9-2	

Automatic Rifles Cal .30

TM 9-1211	Browning Automatic Rifles cal .30—all types
FM 23-15	Browning Automatic Rifle cal .30 M1918A2
FM 23-20	Browning Automatic Rifle cal .30 M1918 without bipod.
SNL A-4	Rifle, Automatic cal .30 Browning M1918, M1918A1, and M1918A2
SB 9-2	

Pistol, Automatic, Cal .45 M1911 and M1911A1

TM 9-1295	Pistols and Revolvers
FM 23-35	Automatic Pistol cal .45 M1911 and M1911A1
SNL B-3	Pistol, Automatic cal .45 M1911 and M1911A1
SB 9-2	

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Revolvers, Smith and Wesson and Colt Cal .45 M1917

FM 23-36	Revolver, Colt cal .45 M1917 and Revolver, Smith and Wesson cal .45 M1917
TM 9-1295	Revolver, Smith and Wesson and Colt cal .45 M1917
SB 9-2	
SNL B-7	

Machine Guns and Their Mounts—.30 and .50 Cal

TM 9-1205	Browning Machine Gun cal .30—all types
TM 9-1225	Browning Machine Gun cal. .50—all types
TM 9-226	Browning Machine Gun cal .50 M2, Watercooled
FM 23-45	Browning Machine Gun cal .30 HB M1919A4, Ground
FM 23-55	Browning Machine Gun cal .30 M1917
FM 23-60	Browning Machine Gun cal .50 HB M2
SNL A-5	Gun, Machine cal .30 Browning M1917A1 and Mount
SNL A-6	Gun, Machine cal .30 Browning M1919A4, Fixed and Flexible and Ground Mounts
SNL A-37	Gun, Machine cal .50 Browning M2 HB and Mounts.
SNL A-39	Gun, Machine cal .50 Browning M2 HB, Fixed and Flexible and Ground Mounts.
SNL A-55	Mounts, Small Arms for Motor Vehicles
SB 9-2	

Multiple Gun Mounts

SNL A-61	Mount, Machine Gun, multiple cal .50 M45

Principles of Preventive Maintenance of Small Arms

TM 9-850	Cleaning, Preserving, Lubricating and Welding Material and Similar items issued by the Ordnance Department.
TB 9-2835-7	General Lubrication Instruction, Small Arms—General Instructions for Care, Preservation and Lubrication.
SB 9-OSSC-B	Ordnance Storage and Equipment Chart Group B, Small Arms
SNL K-1	Cleaning, Preserving and Lubricating Materials, Record Fluids, Special Oils and Miscellaneous Related Items.
SNL K-2	Soldering, Brazing and Welding, Etc.

General References

TM 9-1100	Inspection of Ordnance Materiel
TM 9-1900	Ammunition—General
TM 9-1990	Ammunition—Small Arms
SNL B-8	Bayonets and Their Scabbards
SNL B-20	Tools, Maintenance for Repair, Etc.
SNL G-72	Truck, Small Arms Repair M1
SNL G-138	Truck, 2½-ton 6x6, Small Arms Repair
	Base Shop Data—5th Echelon
	Gun Care and Repair—Charles E. Chapel
	The Modern Gunsmith—James V. Howe
	Textbook of Fire Arms Identification—Gen. J. S. Hatcher
	Encyclopedia of American Hand Arms—Chinn and Hardin
	Automatic Arms—Johnson and Haven
	Notes on U. S. Ordnance—Major J. E. Hicks
	American Rifleman Magazine.

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CHAPTER II

ARTILLERY AND BALLISTICS

HISTORICAL DEVELOPMENT

The simplest appliances for throwing projectiles, such as the sling and the bow and arrow, which were first used many hundreds of years ago, have been claimed as ancestors of modern artillery weapons. But it was not until the 14th century after the discovery of gunpowder that the cannon made its appearance.

The date of the first employment of cannon cannot be established with any exactness. It was certainly in use during the early part of the 14th century and at the battle of Crécy in 1346, the English brought guns onto the battlefield for the first time. But as a field weapon the cannon was ineffective and of little more than a psychological factor in the outcome of a battle. Guns in their early stage of development lacked mobility. Their bores were not uniform in diameter; they fired darts or more usually stones and had no accuracy of aim. The powder, called "serpentine," was mixed on the spot, and it was not always mixed with the same proportion of the various ingredients. Each weapon had to be accompanied by a cumbrous train of supply, baggage, tool wagons, and attendants. These attendants, for well over 300 years after the first employment of ordnance, were civilians—'artists' as they were inappropriately enough called. They formed a heterogeneous crew owing allegiance to no commander, and many were of fairly mellowed age—in Elizabeth's reign there was a complaint that one of the gunners in the Tower of London was over 90 years old. For the dual purpose of protecting these 'artists' and of preventing them from running away, companies of fusiliers came into existence.

It was, however, by its use as a seige weapon, that early artillery gained its importance. Cannon was of inestimable value to kings and princes for keeping rebellious barons in check; in fact, the cannon, more than any other factor, led to the establishment of strong centralized monarchies in the various countries of Europe and to the break-up of the feudal system. At the siege of Constantinople in 1453 the Turks used 'bombardes' cast from bronze. The most famous of these guns weighed 19 tons and threw stones weighing 600 to 700 pounds. About 200 men and 60 oxen were needed to move its enormous weight.

The next step in the development of artillery came with the improvement of the mount. The earliest guns were laid directly on the ground and were fixed in position with wooden stays. By 1376 the Venetians had produced wheeled mounts; by the middle of the 15th century these had become fairly common. But it was not until Gustavus Adolphus, the great warrior king of Sweden, who died in 1632, that artillery gained its true position on the battlefield. Trunnions were now being cast with the guns and wheels and some kind of elevating mechanism had come into use. From being a mere supplementary weapon of doubtful value, Gustavus Adolphus, by cutting down the size of cannon and by increasing the numbers used from 1 per 1,000 men to 6 per 1,000 men, promoted the artillery into a real auxiliary to the infantry, capable of aiding an attack or covering a retreat. This was the first attempt to produce field artillery in the proper sense of the word, *i. e.*, guns of effective fire power, and at the same time, so mounted as to be capable of rapid movement.

After Gustavus Adolphus, for the next 150 years, no radical changes were made to artillery or to its employment. There were various minor improvements made embodying contemporary technical, metallurgical; and chemical advances; and in the employment of artillery Frederick the Great of Prussia organized it into batteries. But, it fell to a French officer, named Gribeauval, to initiate the reforms that paved the way for Napoleon's artillery triumphs. Gribeauval relegated all guns heavier than 12-pounders to siege, garrison, and coast service. For field artillery he insisted on mobility and, therefore, limited this type of cannon to 12-pounders at the heaviest. He reduced the number and variety of the pieces and started a system of uniformity among gun parts; he improved

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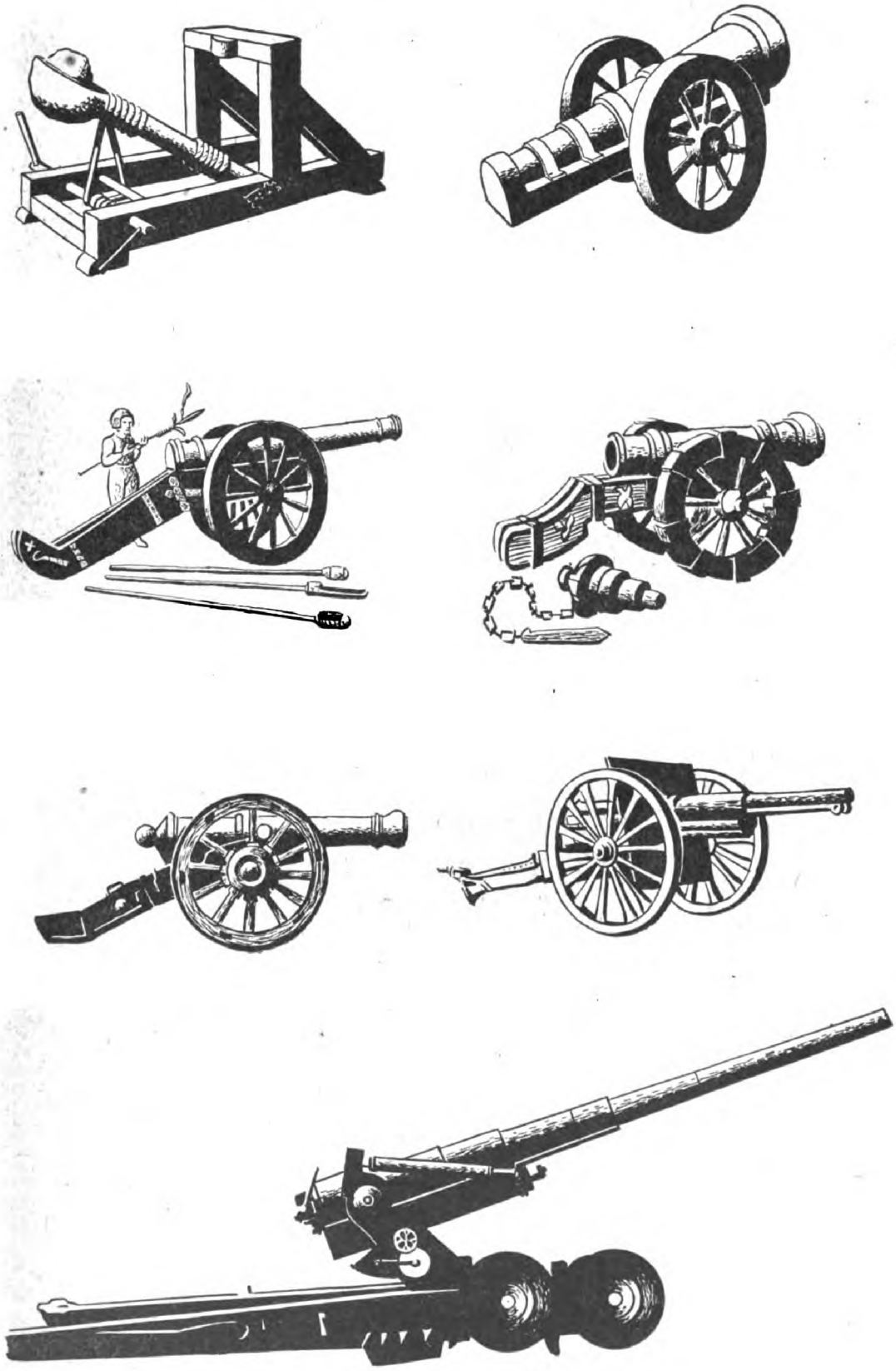

The Development of Artillery.

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ammunition and evolved a new system of transportation and supply which included the caisson; he hitched horses in pairs instead of in file, organized artillery personnel, and formed the guns into batteries and brigades. In 1785 he introduced the howitzer, an 18-inch smooth bore weapon.

During the 19th century artillery development can be divided into two parts. The first fifty years showing very little progress, and the last fifty years showing the most rapid progress yet recorded in this subject.

The progress during the latter half of the 19th century was made possible by the flood of discoveries in almost all branches of science. Great strides forward were made, and the science of guncraft was no exception.

With the development of alloy steels, the perfection of the breechblock was made possible, and in 1891 the modern breech mechanism was introduced. It was the result of continuous experiments to overcome the backward pressure of the gases in the gun which had invariably led to the bursting of the breechblock.

The next great improvement in guns was the invention of a satisfactory recoil mechanism, which gave steadiness to the piece and permitted the cannoneers to be protected by shields. The introduction of smokeless powder in about 1895 further facilitated the gunner's task.

Earlier in the century rifling had been introduced into guns. At the beginning of the Civil War smooth bores were used almost exclusively, but rifled cannon had made its appearance on both sides prior to the battle of Gettysburg. This made possible the elongated shell; and by 1890, armor piercing projectiles, filled with picric acid, were made by the Navy.

As to gun carriages, by the Franco-Prussian war (1870) iron had taken the place of wooden construction.

It was these improvements that made possible the quick-firing field gun. The new breechblock and the recoil mechanism claim the major share in this achievement. The absorption of recoil in itself permitted a higher rate of fire as the gun did not require to be run up and relaid after each shot, and with the introduction of smokeless powder this advantage was able to be turned to practical use, since no longer did rapid fire produce a thick band of smoke which impeded aiming.

The first gun to incorporate these new devices successfully was the French 75mm gun—the triumph of rapid-fire field pieces. With this gun the rate of fire for field guns jumped from one or two rounds a minute to twenty or even forty rounds a minute. The gun had a secret hydropneumatic recoil mechanism, called a recuperator.

With the advent of this famous gun the modern era in field artillery started. All other nations redesigned their artillery in an effort to match to its standards. In World War I all guns were fundamentally varitaions of the French 75mm, though none was as good as its French prototype. Air and spring recuperators were developed and many refinements came in which continually improved the range and efficiency of artillery fire.

The following pictures of modern artillery are presented to assist the reader in physically locating on the gun or carriage many of the assemblies discussed in this chapter.

This chapter deals with the fundamental principles of artillery without regard to any particular weapon. Basic construction and operation of the various components of weapons are discussed, but mechanical details are not described, except when necessary to illustrate principles. A complete chart of weapons (standard at the time of publication) at the end of the chapter gives detailed information on individual weapons.

Artillery is a general term referring to three main types of weapons, namely: *Guns, Howitzers,* and *Mortars* whose bore diameters are over 0.60 inch. All other weapons whose bore diameter is under 0.60 inch are classified as small arms.

Classification. Artillery may be classified under such broad headings as Field Artillery, Coast Artillery, Seacoast Artillery, Anti-aircraft Artillery, etc. It may be further classified as fixed or mobile. The classification, mobile, can be further subdivided into the degrees of mobility.

Fixed Artillery is artillery of position and is designed for permanent emplacement inland or on sea frontiers for defense.

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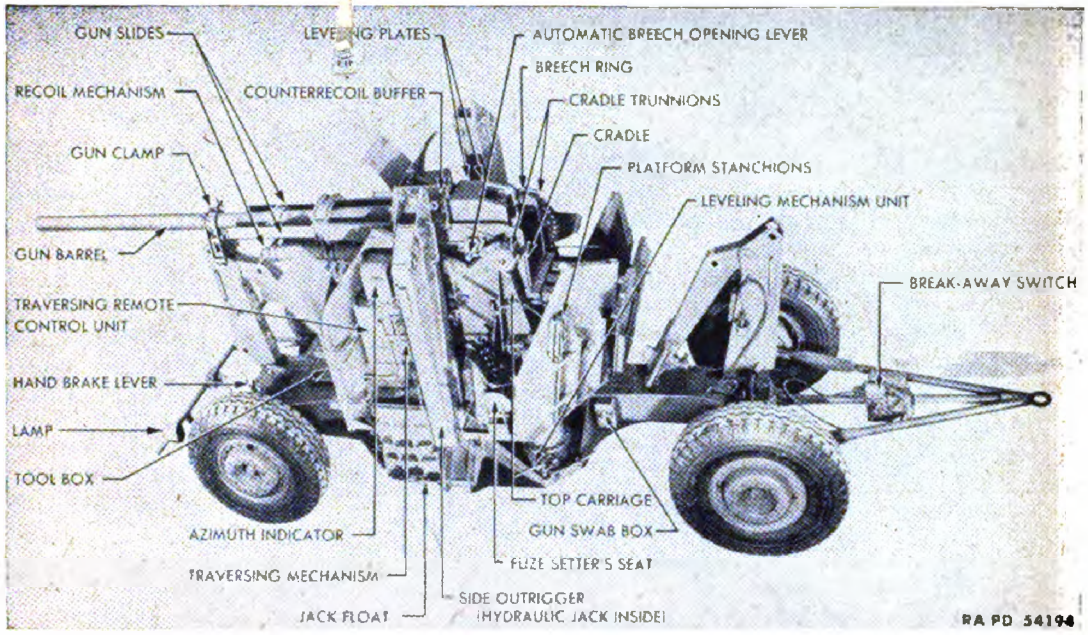
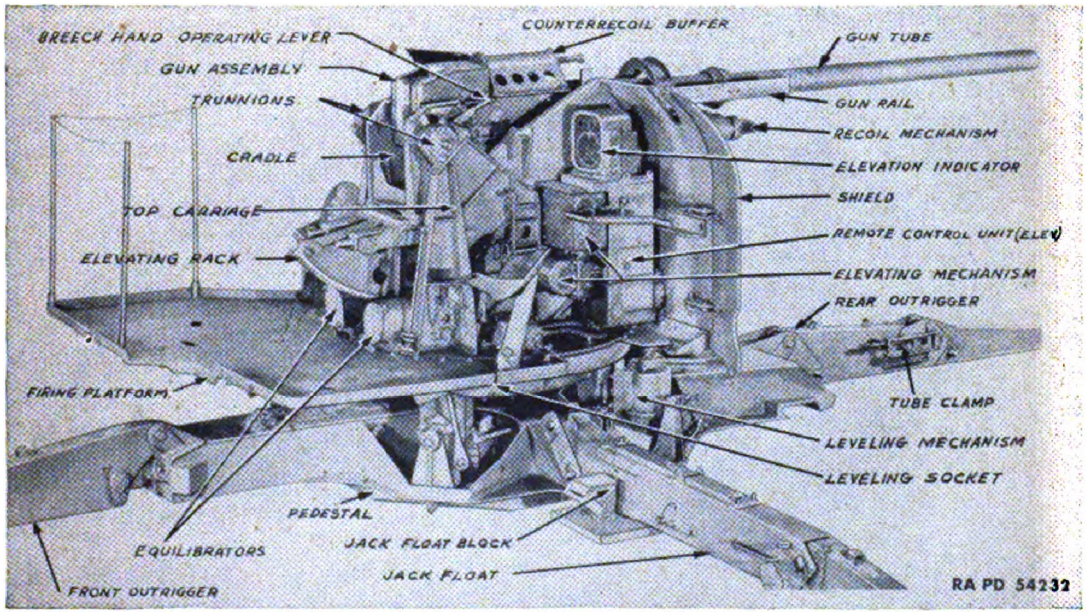


90mm Gun M1 and Mount T2E1—Travelling Position—Left Side.



90mm Gun M1 and Mount T2E1—Firing Position—Left Side.

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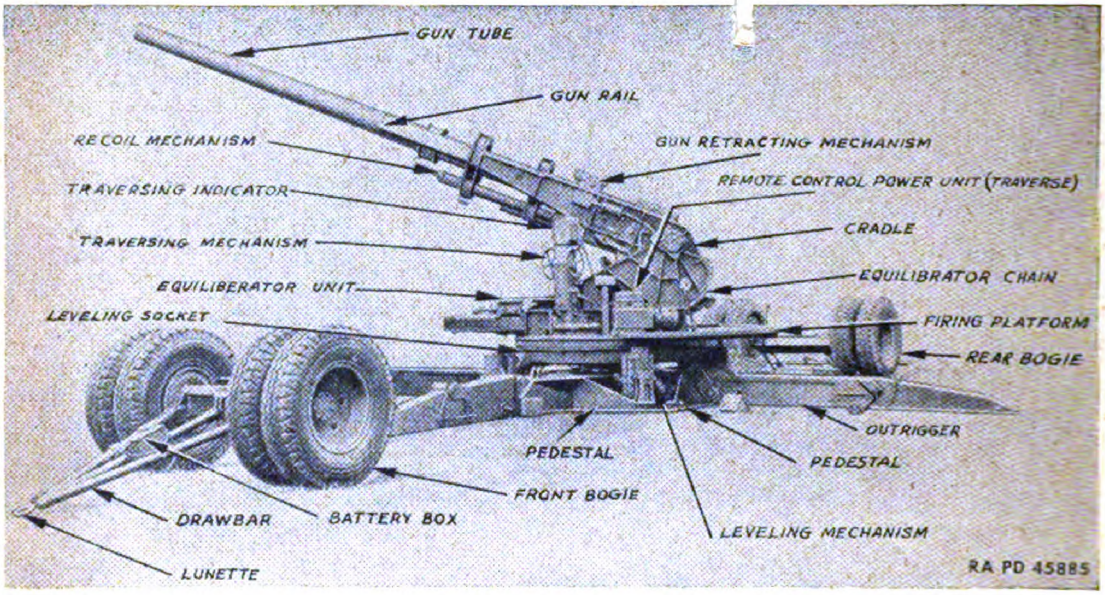
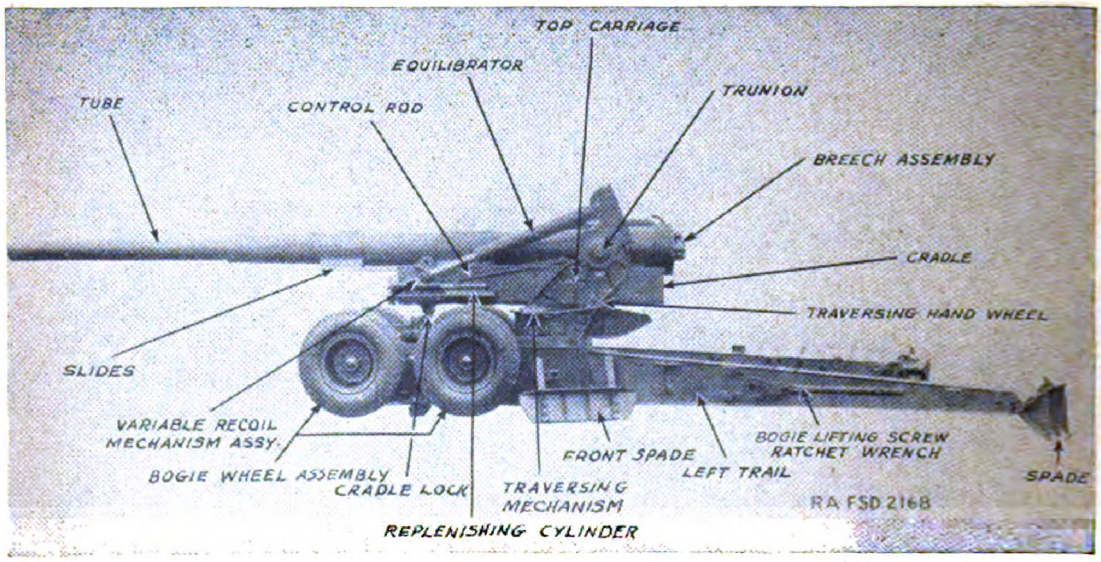


120mm Gun M1 and Mount, AA, Firing Position.



155mm Gun M1, Firing Position.

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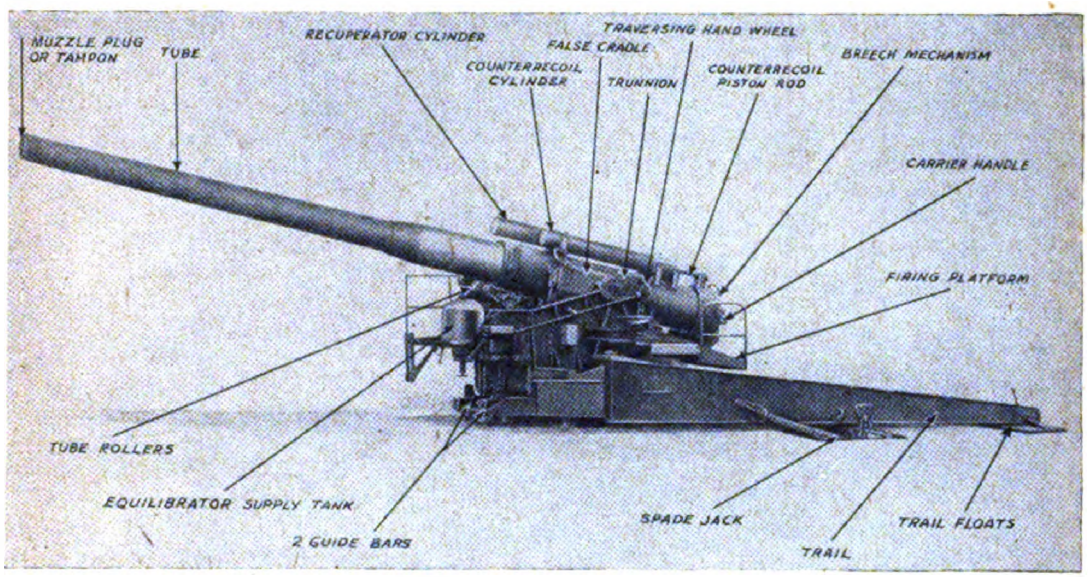
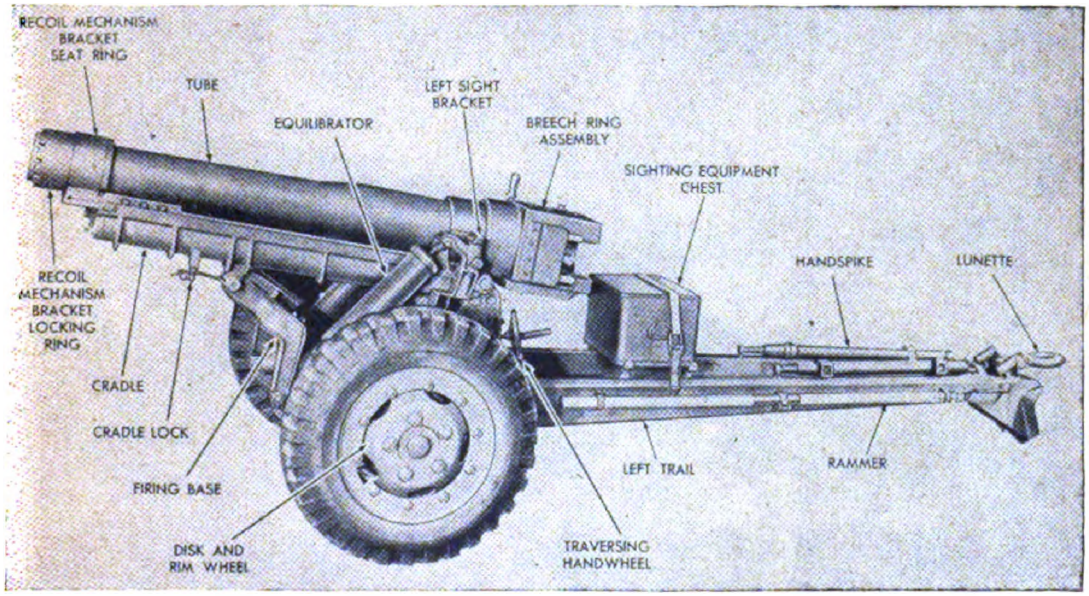


8-in. Gun, Firing Position.



105mm Howitzer M3 and Carriage M3A1, Travelling Position.

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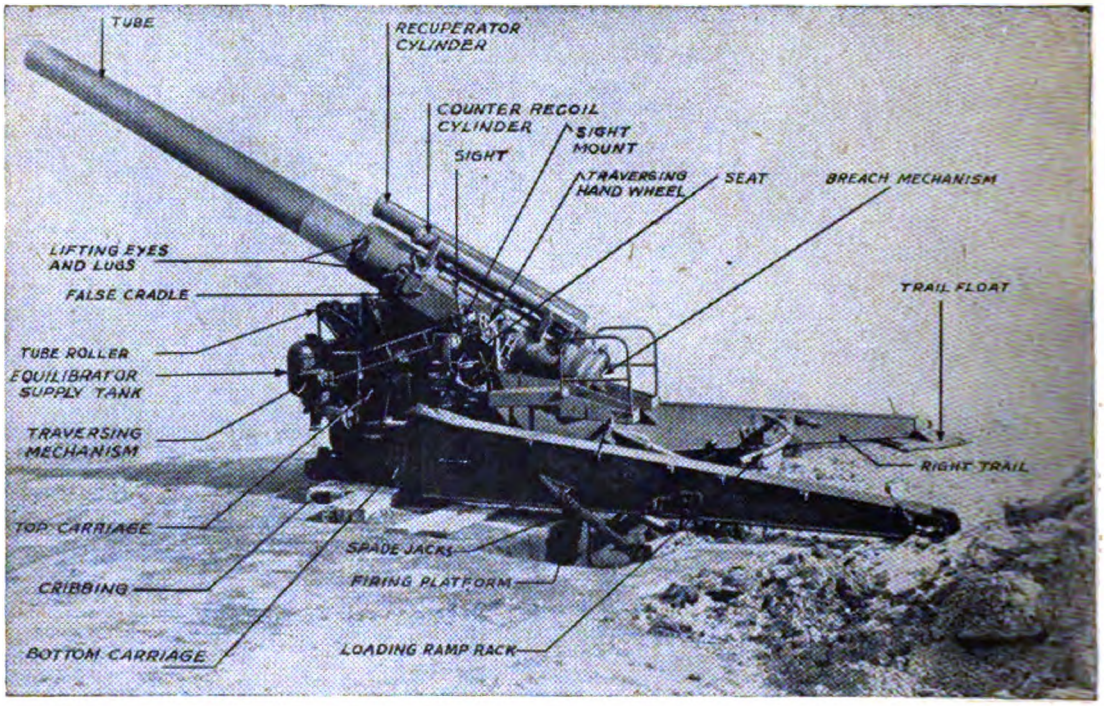
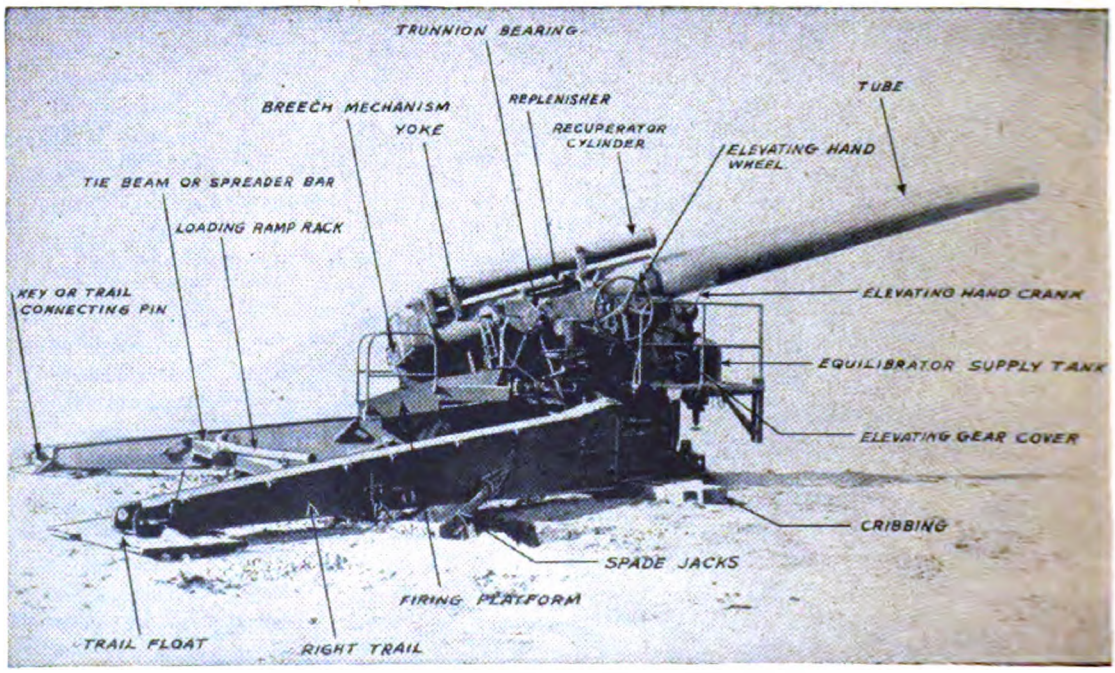


240mm Howitzer, Left Side.



240mm Howitzer, Firing Position, Right Side.

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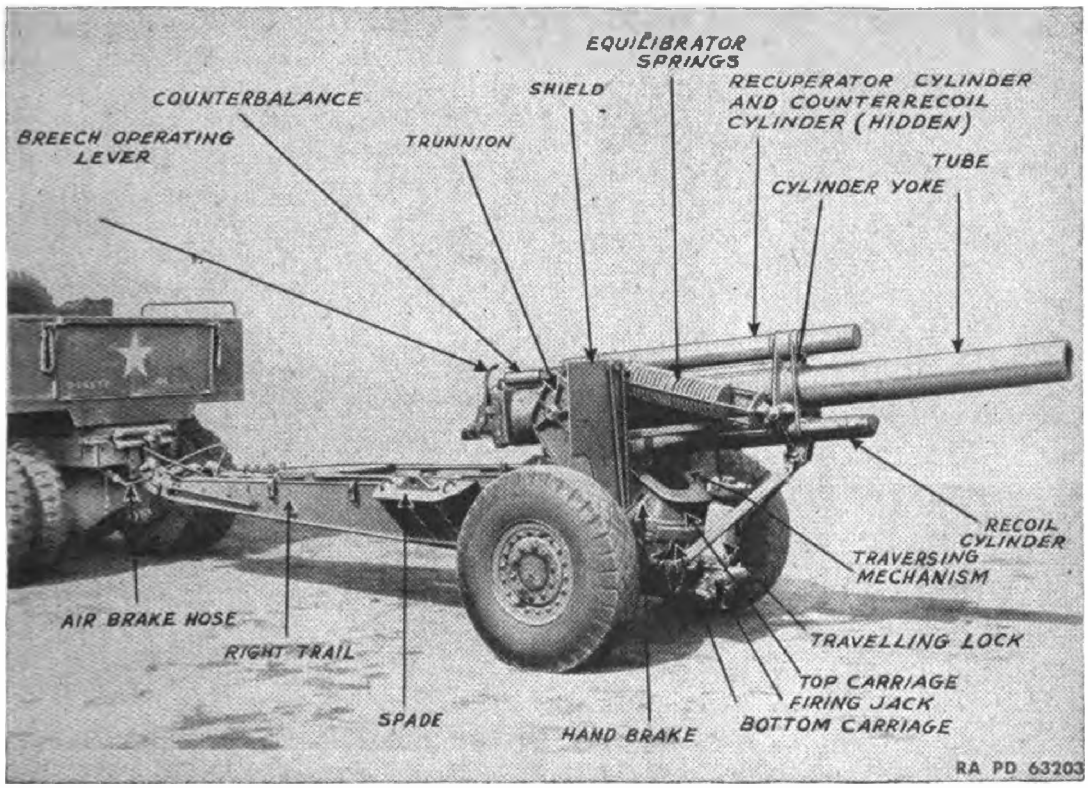

155mm Howitzer M1 and Carriage M1A1, Limbered to Prime Mover.

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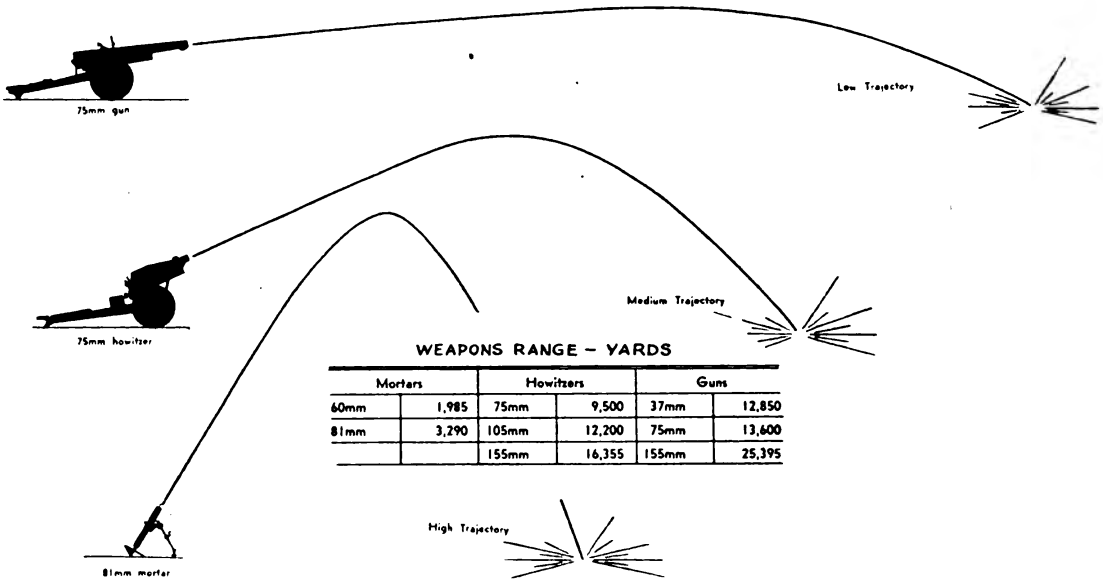
Mobile Artillery is designed to follow field forces and is capable of moving from one position to another. Heavy, Medium, and Light are terms used in classifying degrees of mobility. Light artillery is the most mobile, and heavy artillery is the least mobile. The three main types of mobile artillery are: Railway Artillery, Self-Propelled Artillery, and Towed Artillery.

Railway Artillery is usually designed to be transported on, and fired from, specially designed railway cars. Some types of railway artillery may be transported on railway cars and fired from prepared ground positions.

Self-Propelled Artillery combines the weapon and the motive power into a single unit. A good example of this is one of the latest tank destroyer weapons, the M10 Motor Carriage which mounts a 3-inch gun.

Towed Artillery depends upon outside power (a prime mover) for its mobility. It may be truck-drawn, tractor-drawn, horse-drawn, transported in cargo aircraft, or disassembled into major components and packed on the backs of animals or packed in parachutes to be dropped by parachute (paratroop artillery).



WEAPONS RANGE – YARDS

Mortars		Howitzers		Guns	
60mm	1,985	75mm	9,500	37mm	12,850
81mm	3,290	105mm	12,200	75mm	13,600
		155mm	16,355	155mm	25,395

Figure 1. Trajectories.

The classification of gun, howitzer, or mortar no longer conveys the meaning it once did. As formerly defined, a *gun* was a long high muzzle velocity[1] weapon fired at elevations not exceeding twenty degrees. A *howitzer* of equal caliber[2] was a shorter, lighter weapon, firing at higher elevations than the gun, with a lower muzzle velocity. Howitzers were designed to engage targets that were, by virtue of their position behind hills, inaccessible to the flat trajectory[3] of a gun. A mortar was a still shorter weapon firing at even higher elevations and used to reach highly defiladed[4] targets with plunging fire. The distinction between gun and howitzer is now less marked. The modern gun carriage, with very few exceptions, permits firing at elevations formerly used only by howitzers. On the other hand, increased ranges demanded of howitzers necessitated longer barreled, heavier weapons to produce the desired velocities.

The factors of weight and mobility, however, still justify distinguishing between gun, howitzer, and mortar types of mobile artillery. If a gun and howitzer of equal caliber are compared, the gun will have the higher muzzle velocity, longer range, and will be the less mobile. Of a gun and howitzer of equal mobility, the howitzer will be of considerably larger caliber, will fire a projectile approximately twice as heavy as that fired by the gun, but will have a lower muzzle velocity and a shorter range. The old large caliber coast artillery mortars were

[1] Muzzle Velocity: The speed of a projectile a short distance after it leaves the muzzle.
[2] Caliber: The diameter of the bore. (see page 208).
[3] Trajectory: The path described by a projectile in flight.
[4] Defiladed: Shielded from hostile observation and direct fire.

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designed to place high angle fire on the relatively thin deck armor of enemy battleships. Highly mobile mortars of smaller caliber are finding great usefulness today where terrain will not permit employment of heavier wheeled weapons and where extreme ranges are not a primary requirement.

Components of an Artillery Weapon. Essentially, an artillery weapon consists of a tube assembly, a breech mechanism, and a carriage or mount. These components are described in that order in the succeeding sections of this chapter.

The tube of a weapon refers to the cannon less the breech mechanism. The term may also be used to denote the inner cylinder of a tube assembly such as exists in built-up, wire-wrapped, or removable-liner type assemblies.

CANNONS

A cannon is a machine which uses the force of expanding gas to propel a projectile in a definite direction. It consists of a metal tube, closed at one end, which is sufficiently strong to resist the pressure of the expanding gases when the piece is fired. When the charge is ignited, the rapidly burning propellant gives off a large volume of gas, which exerts pressure against the base of the projectile and forces it from the barrel.

Considered as a machine, the cannon is far from one hundred percent efficient. Part of the energy from the burning gases is expended in the recoil mechanism and in overcoming the friction of the projectile as it travels up through the rifling of the bore, while yet another part of the energy is expended as heat either to the gun, the projectile, or the unburned gases.

As the projectile moves forward, the volume that may be occupied by the expanding gases is increasing; hence, the resultant pressure in a gun tube upon firing rises sharply on ignition and gradually diminishes as the projectile moves out. Obviously a gun tube is subjected to very high pressures and high stresses which tend to split the tube and pull it apart. These stresses must be counterbalanced by compression stresses, which are directly opposed to the firing stresses.

Merely increasing the thickness of the sidewalls, as was done at first, not only failed to strengthen the tube sufficiently, but also decreased mobility. More efficient methods of reenforcement were developed with increased knowledge of metals and better engineering methods.

The *Built-Up Tube* is constructed of concentric cylinders, called 'jackets' or 'hoops', which are heated and then shrunk around the central main tube. Contraction upon cooling places the desired stresses on the inner layers of the tube.

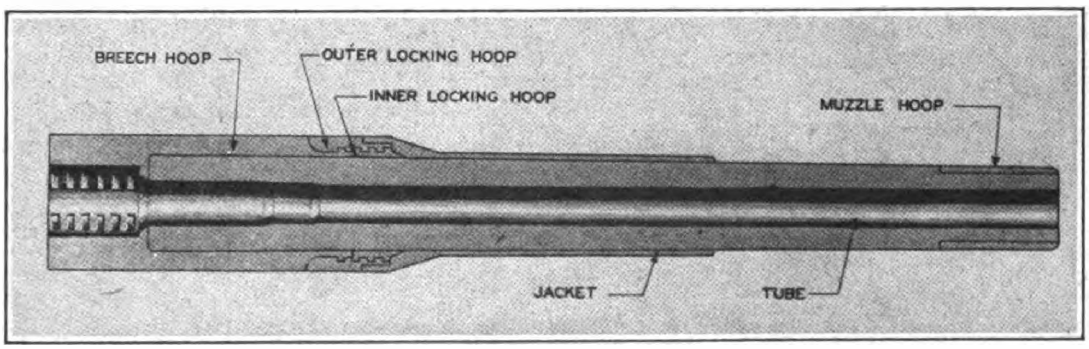

Figure 2. Built-Up Tube.

In a *Wire-Wrapped Tube* the same result is accomplished by wrapping the central tube with wire under tension. As the wire wrappings add nothing to the longitudinal strength an enveloping jacket or hoop must be added to give longitudinal strength and also to protect the wrappings. Many large seacoast guns in service today have this type of construction.

Monobloc Tubes are one-piece and are made from a forging or a casting.

The more modern tubes are centrifugally cast. In making a centrifugal casting,

[1] Cannon: As used in this chapter, this term refers to the parts of a weapon necessary to fire one round, i. e., a tube and a breech mechanism with a firing mechanism.

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the molten metal is poured into a cylindrical mold (chill mold), which is rotating at high speed. The quantity of metal poured in is regulated so that a small opening is left at the center of the casting. Due to centrifugal force, the heavier metals are forced away from the center while the lighter impurities are left near

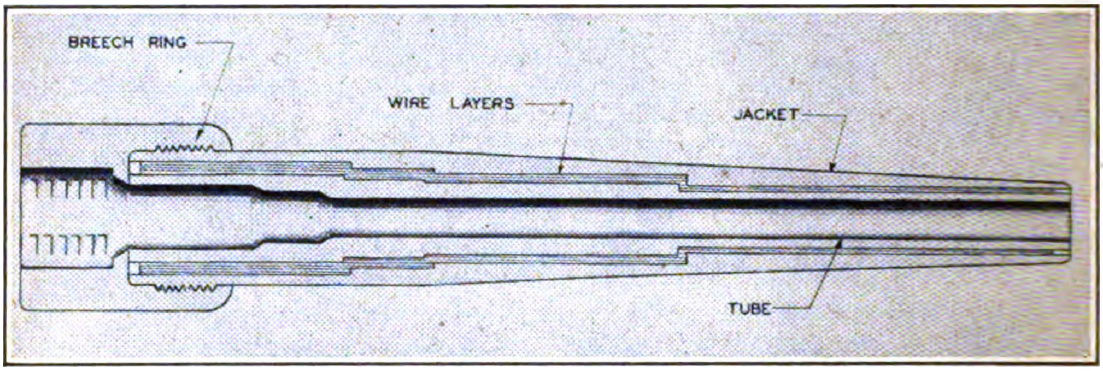

Figure 3. Wire-Wrapped Tube.

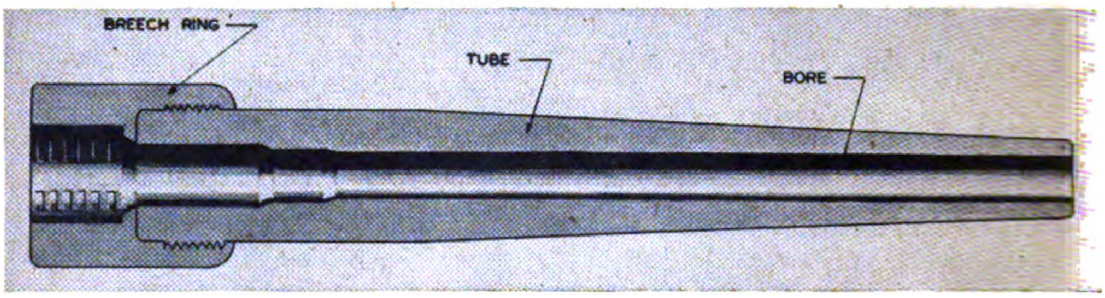

Figure 4. Monobloc Tube.

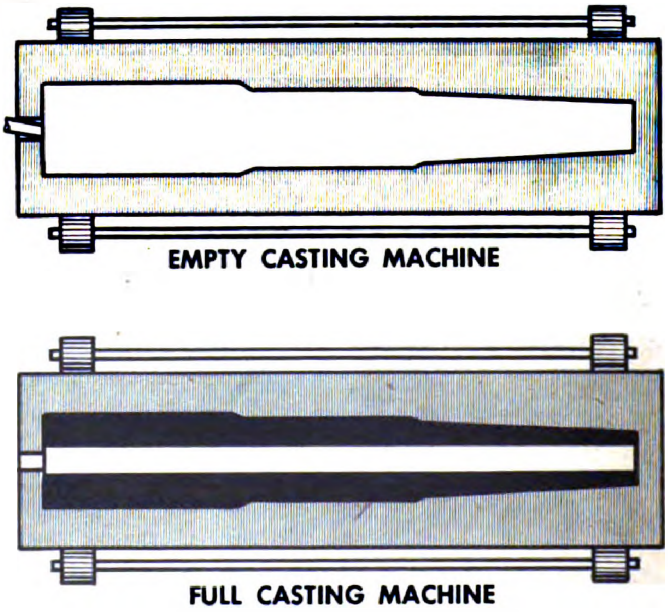

Figure 5. Centrifugal Casting.

the center, where they are removed by boring. The casting is then heat treated to obtain the desired metallurgical qualities and then is usually cold worked. Some of the latest manufacturing methods, however, employ a more intensive heat treatment to give desirable stresses, thus eliminating the necessity for cold working.

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Cold Worked Tubes are made by a process which is more modern than built-up and wire-wrapped methods. This method is employed widely in the construction of the more common types of artillery. In manufacture, the tube is machined to closely computed dimensions, which after cold working will leave sufficient metal for final machining. An accurately machined tube is placed in a heavy steel container, which has an interior surface corresponding in shape to the exterior of the tube but slightly larger. The ends of the tube are securely closed and extreme hydraulic pressure is applied. This forces the tube tightly against the container. The pressure thus introduced to the inside of the bore causes the inside layers to be stretched beyond their elastic limits[1] and to receive a permanent 'set'. The outside layers, however, being stopped in their expansion by the container walls, are not stretched beyond their elastic limit; hence, when the pressure is released they tend to return to their normal dimensions. This places the inner layers under compression of the outer layers—the same effect obtained by the previously mentioned methods. This method has an advantage over the other methods in that any hidden flaws in the metal will show up when the hydraulic pressure is applied. Also, the pressures applied in the process greatly exceed any pressures to which the gun will be subjected during normal usage; hence, it may be considered a partial proofing of the gun tube. The tube is now ready for final processing.

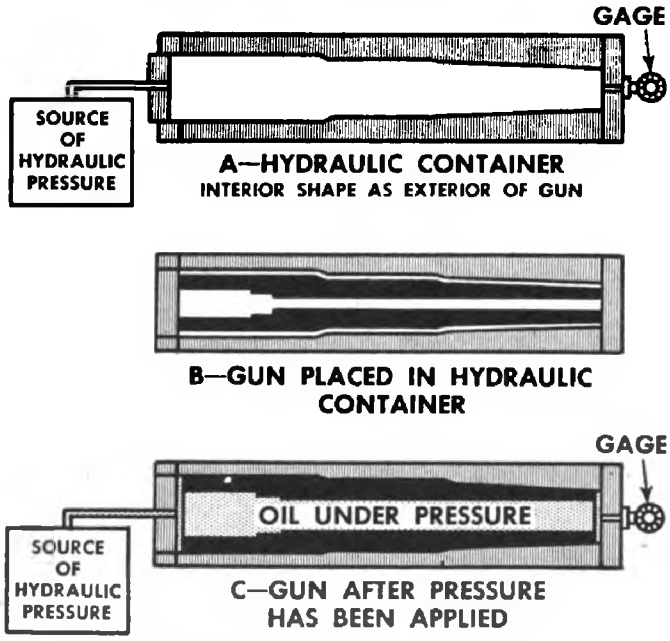

Figure 6. Cold Worked Process.

Combination Cold Worked and Built-Up Tubes. Weapons of large caliber are often constructed by a combination of cold working and built-up methods. This method is used where it is impractical to construct a monobloc tube of great size. In manufacture, the tube proper is cold worked as previously outlined, after which one or more reenforcing hoops are shrunk on it. The famous 155mm 'Long Tom' gun and larger field artillery weapons are good examples of this type of construction.

The Interior of a Tube of a weapon using separate-loading ammunition may be subdivided into several parts. They appear in the following order from breech to muzzle:

The Breech Recess is that space in the rear of the tube assembly which is designed to receive the breechblock.

The Gas-Check Seat is that rear surface of the bore which is tapered and against which the obturator assembly seats forming a gas tight seal.

[1] **Elastic Limit:** The greatest unit stress which a material is capable of withstanding without a permanent deformation remaining upon complete release of the load.

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The Powder Chamber is the cubic space between the rotating band of a projectile when seated and the breech closure where the propellant charge burns.

The Centering Slope is the tapered forward portion of the powder chamber. It is designed to cause the projectile to center itself as it is rammed forward during loading.

The Forcing Cone is the rear portion of the main bore or rifling. It is formed by tapering the rear of the lands. Its function is to receive and properly seat the rotating band of the projectile when it is loaded and to center the projectile in the bore.

The Main Bore includes the forward portion of the tube, that is, the rifled portion.

Muzzle Brake. A short cylindrical device called a muzzle brake is sometimes attached to the muzzle of a tube to help reduce the length of recoil. (See Fig. 31).

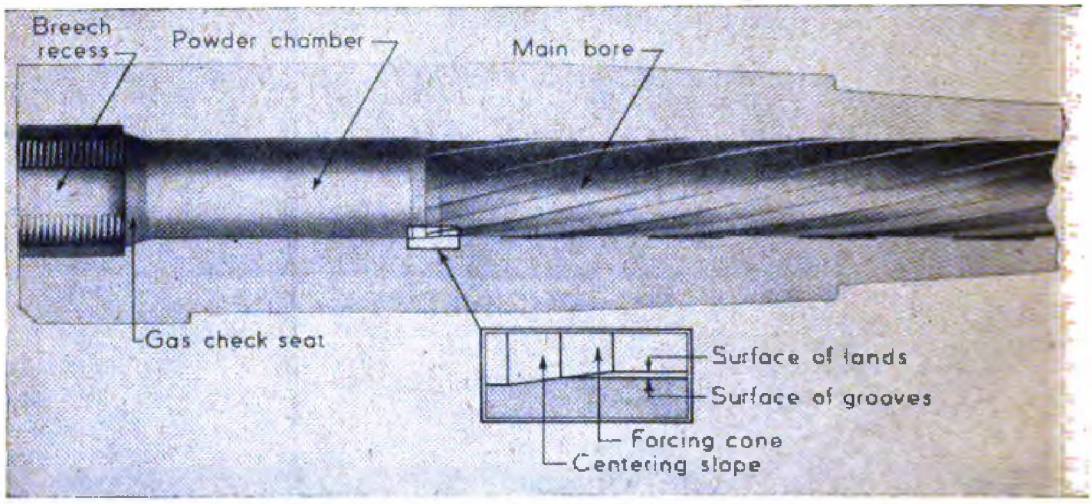

Figure 7. Interior Components of a Tube.

On weapons firing fixed or semi-fixed ammunition, where obturation (page 213) is performed by a cartridge case, there is no tapered gas check seat machined in the rear of the powder chamber.

Rifling consists of a number of helical grooves cut in the surface of the bore. The spaces between the grooves are called "lands." The number and depth of grooves vary in different guns. Usually there are from six to nine grooves per inch of caliber. The soft metal of the rotating band of the projectile is forced into these grooves during the loading operation and as the projectile moves forward the rifling causes the projectile to spin. Proper rotational velocity or spin of the projectile about its longitudinal axis is necessary to assure stability in flight. Underspin will result in tumbling (as a football with insufficient spiral), while in overspin the longitudinal axis of the projectile will tend to retain its same position during its entire flight, not "nosing down" during downward slope of the trajectory. This does not insure head-on impact. When a detonating fuze is used this "nosing down" is especially important.

Caliber. The caliber of a tube is the bore diameter between opposite lands measured either in inches or millimeters. Weapons of 12-inch caliber or more are often referred to as "major-caliber" weapons. Likewise weapons whose bore diameter is 12 inches or less are referred to as "minor-caliber" weapons.

Length In Calibers is the length of the tube from the rear of the powder chamber to the muzzle expressed in units of caliber or diameter. Tubes of same length in calibers, therefore, regardless of bore diameter, are of similar proportions.

Foreign Designation. It is standard practice in many foreign armies to designate a particular weapon by giving both caliber and length in caliber, as for example: "105/30mm cannon." This indicates a piece having a bore diameter of 105mm and having a tube 30 calibers long.

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Twist of rifling is the inclination of the grooves to the axis of the bore, and is expressed in terms of caliber. Thus, a twist of "one turn in 25 calibers" means that the projectile makes one revolution in moving along the bore for a distance of 25 diameters. Twist is designated as right or left hand and as uniform or increasing. Practically all U. S. weapons have uniform right hand twist rifling. Uniform twist is constant throughout the bore, while in the increasing type the twist increases from the breech end toward the muzzle end of the bore.

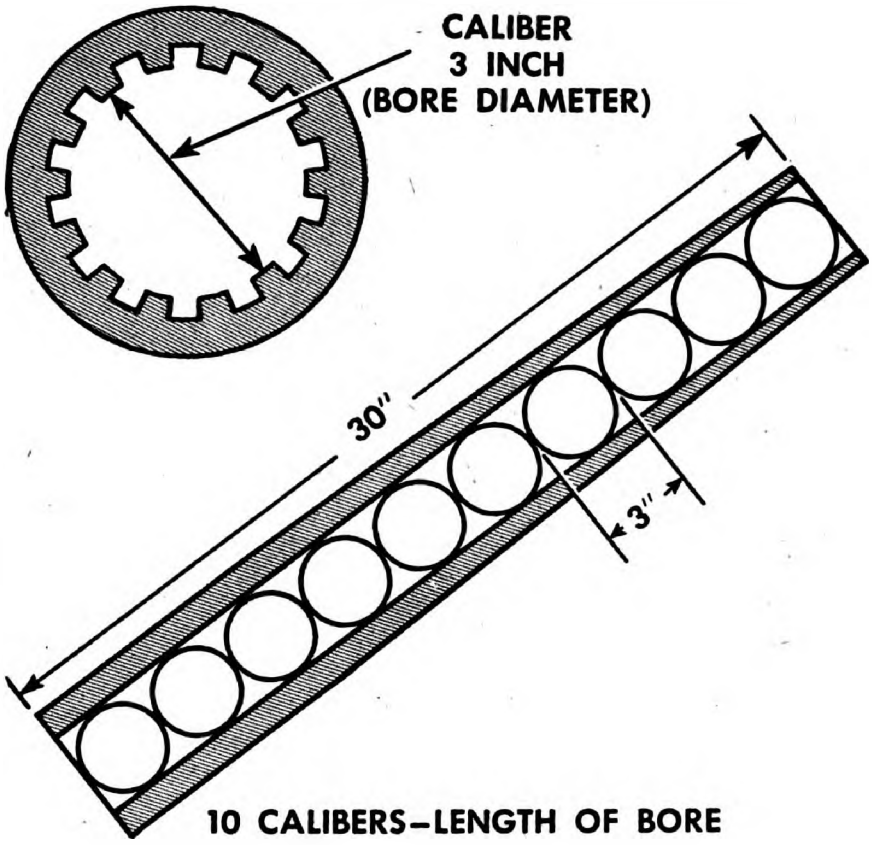

Figure 8. Caliber—Calibers.

BREECH MECHANISMS

A breech mechanism is a mechanical device for closing the rear end of the chamber of a tube for firing. This mechanism affords a means of loading from the rear and houses the firing mechanism. The modern breech mechanism consists of:

1. A breechblock,
2. A breech operating mechanism,
3. An obturator mechanism (if the ammunition is separate loading type),
4. Safety devices,
5. A firing mechanism.

Breechblocks may be classified into three basic types, they are: the sliding wedge type, the eccentric screw type, and the interrupted screw type.

Sliding Wedge Breechblocks are rectangular wedge-shaped and slide perpendicular to the axis of the bore in opening and closing. This motion may be either vertical or horizontal. If the movement is vertical, the block is called a vertical sliding wedge type or a drop block. If the action is horizontal, the block is called a horizontal sliding wedge. This type breechblock is constructed so that as it is closed, the cartridge case is forced home. This is done by inclining the ways in the breech recess and also tapering the breechblock so that as it

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moves to the closed position the face of the breechblock moves forward. This breechblock, since its motion is straight and perpendicular to the axis of the bore, lends itself to rapid fire weapons where automatic or semiautomatic operation is used.

Semiautomatic Breech Mechanism. This mechanism is called semiautomatic since some of the operations of loading are done by hand and some are done mechanically. In counterrecoil, an operating crank is rotated by an operating cam on the top carriage which causes the vertical sliding wedge breechblock to open. It is opened against the pressure of a closing spring assembly. As it is fully opened, the extractors not only remove the cartridge case but also hold the breechblock open.

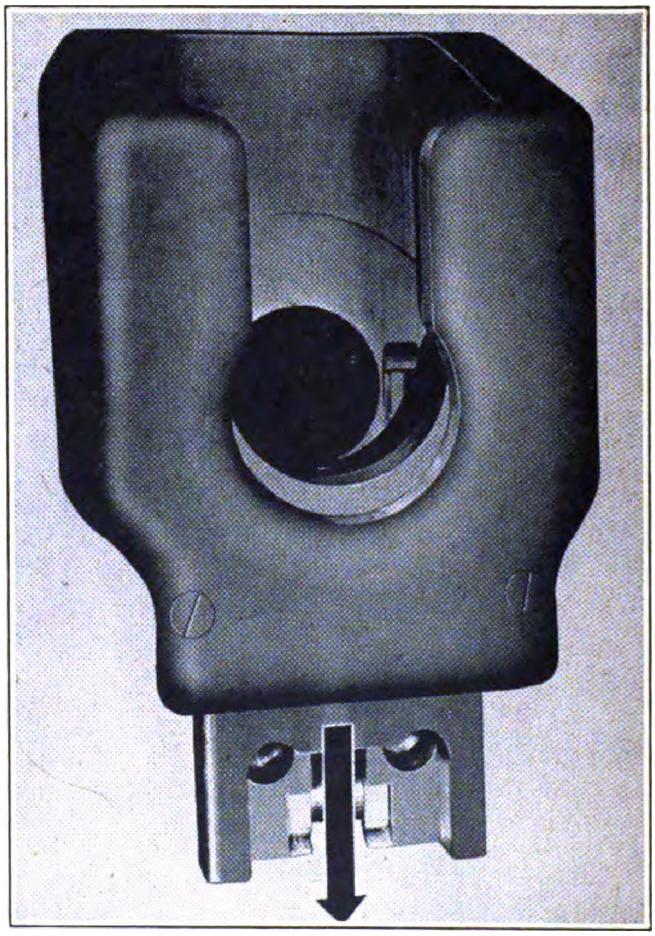

Figure 9. Vertical Sliding Wedge Breechblock.

When the next round is loaded, the rim of the cartridge case pulls the lips of the extractor forward. Now, the bottom end of the extractors which were holding the block open are moved and allow the breechblock to rise and close under the force of the closing spring.

The Eccentric Screw breechblock is cylindrical in shape and is threaded by a continuous thread to the inside of the breech recess. The block is much larger than the chamber of the tube and the axis of the block is below the axis of the bore. The breech is opened by rotating the breechblock slightly less than half a revolution with the operating handle. A U-shaped opening at one side is brought into axial alignment with the bore making it possible to load. The breechblock remains in the breech recess during the opening and closing operations. Final seating of the projectile is accomplished since the lead of the threads by which the block is secured to the breech recess, gives linear movement to the breechblock as it is rotated.

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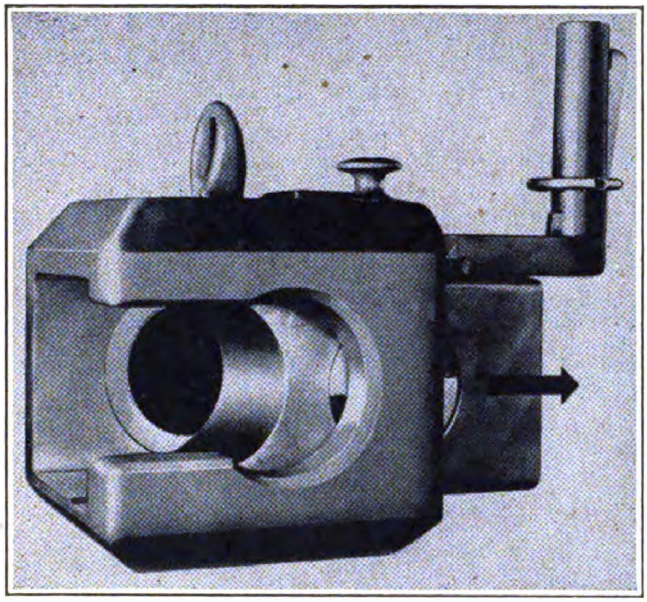

Figure 10. Horizontal Sliding Wedge Breechblock.

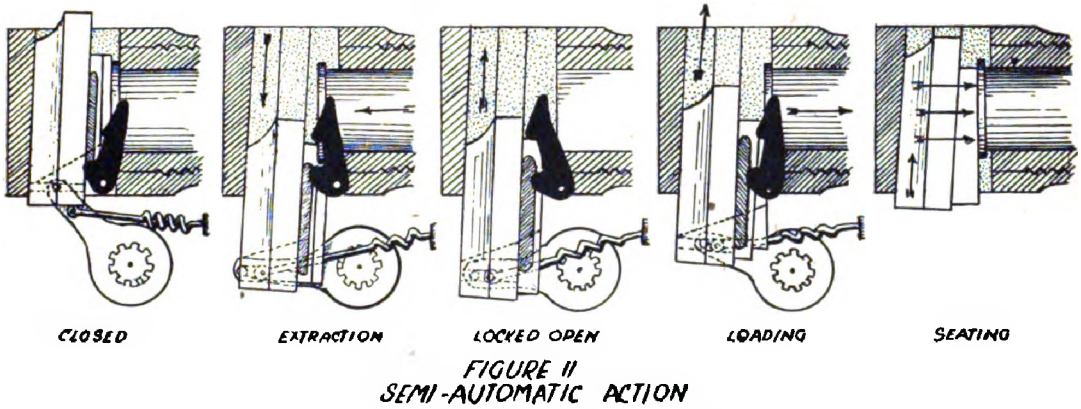

Figure 11. Semiautomatic Operation of Breechblock.

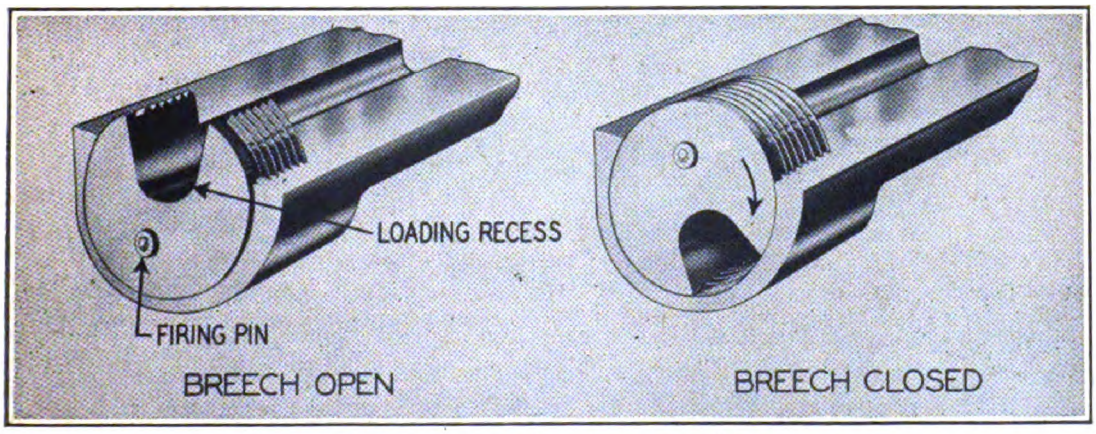

Figure 12. Eccentric Screw Breechblock.

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Extractors are simple mechanical devices used on weapons firing fixed or semifixed ammunition. Extractors pull the cartridge case out of the chamber as the breechblock is opened after a round has been fired.

On some weapons one extractor grips the rim of the cartridge, while on others two extractors opposite each other are used. They are actuated by a camming surface on the breechblock, which causes the extractor to rotate when the breech is opened.

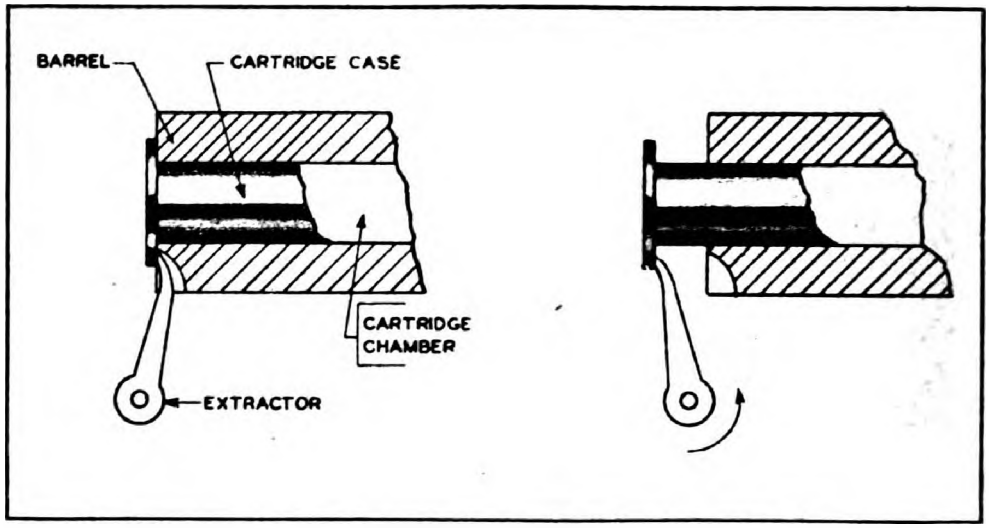

Figure 12A. Extractors.

Interrupted Screw breechblocks are cylindrical in shape and are threaded to the breech recess. To facilitate insertion and withdrawal of the breechblock, the threads of the block have a number of sectors of threads cut away. The threads of the breech recess are likewise cut away. In closing the breech, the threaded

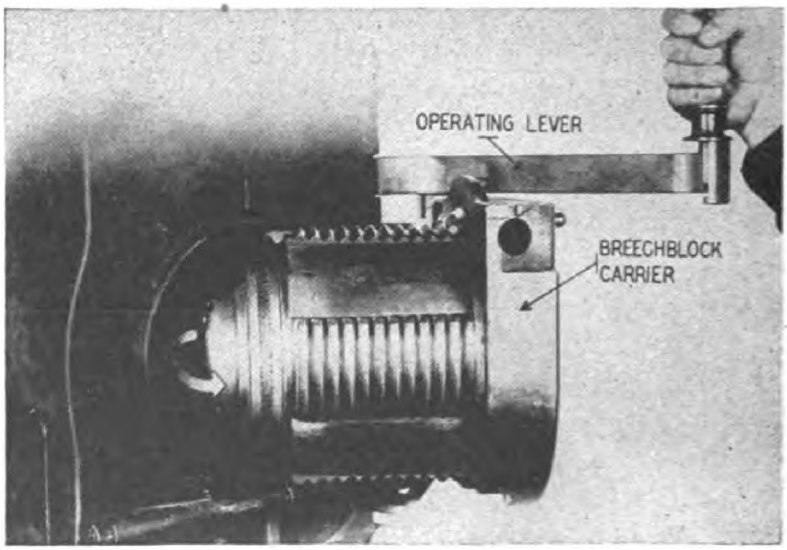

Figure 13. Interrupted Screw Breechblock.

sectors of the block are brought opposite to the blank sectors of the recess and the block is rapidly inserted nearly to its final seat in the breech recess. When the block is rotated a comparatively small amount, the threaded sectors of the block fully engage the threaded sectors of the recess and the breech is closed.

The Breech Operating Mechanism on the interrupted screw type breechblock permits the block to be swung in or out of the recess. It [illegible] provides a means

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of rotating the block to engage or disengage the interrupted threads of the recess. A spring counter-balance is connected to the operating lever on the heavier weapons to assist in closing the heavy breechblock.

The interrupted screw type breechblock in many variations is found on the larger caliber weapons using separate loading ammunition. It is readily adaptable for use with an obturator mechanism.

Stepped Thread Breechblock is a variation of the plain interrupted type mentioned above and permits an increase in the threaded area without increasing the size of the breechblock. In this block, the threaded sectors of the block and of the recess are in steps. With this design, the threaded area may include a much larger portion of the surface of the block, giving additional strength. Closing the breech requires less rotation than other interrupted screw types.

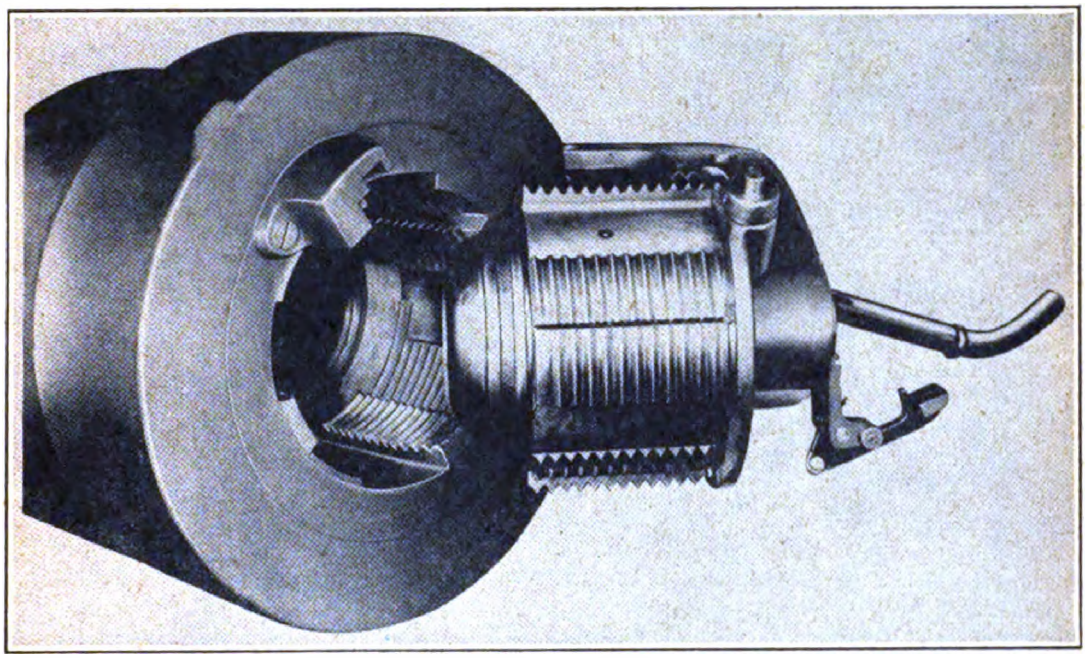

Figure 13a. Stepped Thread Breechblock.

Obturation. Muzzle-loading cannon continued in use for a long time after the advantages of breech-loading were realized, because no effective means of preventing the escape of gases to the rear had been devised. When means were found for accomplishing this seal, muzzle-loaders rapidly became obsolete. Obturation, which is the sealing of the escape of powder gases to the rear, is accomplished on modern artillery weapons either by a cartridge case or by the use of an obturator mechanism. On weapons using fixed and semi-fixed ammunition, the breechblock merely holds the cartridge case firmly in place against the pressure of the powder. On firing, the case is expanded slightly and bears tightly against the walls of the chamber sealing the escape of gases rearward.

When separate loading ammunition is used, since no cartriidge case is present, a device must be incorporated with the breechblock to perform obturation. Hence, the breech mechanisms on large weapons are more complex than those on smaller guns since separate loading ammunition is used.

Obturator assemblies found on our weapons are essentially the same in basic design. The obturator components are assembled around a spindle. This spindle fits into a central hole in the breechblock and has a mushroom shaped head. There is a small vent through the center of this spindle which permits passage of the primer flame from the firing mechanism block to the powder charge. Between the mushroom head and the breechblock face is a pliable, heat-resisting, gas check pad. Two accurately ground steel splint rings encircle the pad and are made to seat in the gas check seat. A third ring fits around the spindle snugly. A filling-in disc acts as a bearing surface between the pad and the face

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of the breechblock since the block rotates when opened, and the obturator assembly does not.

When the gun is fired, the gas pressure forces the mushroom head slightly to the rear. This slight movement to the rear compresses the gas check pad longitudinally, which, in turn, causes it to expand radially forcing the two outer split rings tightly against the gas check seat making a gas tight seal. The smaller inner ring which surrounds the spindle serves to prevent the pad from working between the breechblock and the spindle.

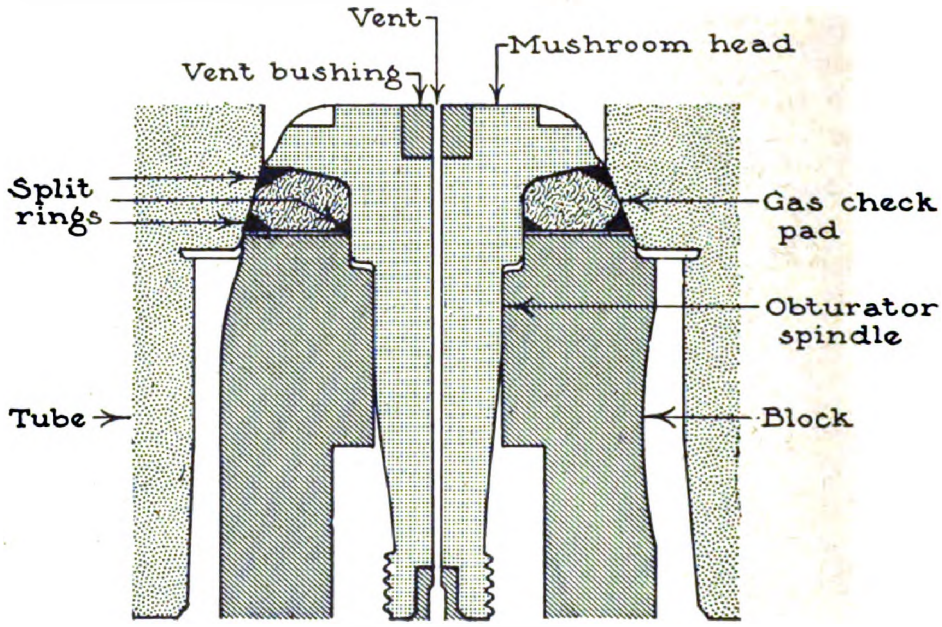

Figure 14. Obturator.

After firing, the pressure on the mushroom head is relieved, the plastic gas check pad contracts to its normal shape, the split rings spring back to their former size and contact the gas check seat only lightly. The breechblock is now ready to be opened.

Safety Devices in the breech mechanisms are incorporated to prevent accidental firing when the breechblock is not fully closed. On sliding wedge and eccentric screw types, there is an inherent safety feature in that the firing pin, which is carried in a recess in the breechblock, will not line up with the primer if the breechblock is slightly open. On the smaller of the interrupted screw types a safety device is provided to prevent the firing mechanism block from being screwed home until the breechblock is rotated to its fully closed position. On major-caliber seacoast artillery weapons using the electric firing mechanism a break in the current is accomplished by a circuit breaker and no electrical impulse can go to the primer until the breechblock is fully closed.

Firing Mechanisms. A firing mechanism is a device incorporated in a breech mechanism of an artillery weapon which, when operated, ignites the primer, which in turn ignites the propelling charge. The burning propellent powder sends the projectile on its way. There are four basic types of firing mechanisms, namely: the Percussion Hammer, Continuous Pull, Inertia, and the Combination Electric-Friction.

Percussion Hammer. This type of firing mechanism is one of the simpler types and it is found on some of the minor-caliber weapons using separate loading ammunition. This mechanism is composed of a firing mechanism block which may be screwed into the breech mechanism, a percussion hammer attached to the breech mechanism, a firing pin, a retracting spring, a firing pin guide, and a primer holder. The primer, which is similar to a small blank cartridge, is placed in the primer holder, and the firing mechanism block is then screwed into the rear of the breech mechanism. With the firing mechanism in this position,

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the primer is seated snugly in the rear of the vent opening in the obturator spindle. When the lanyard is pulled, the hammer is rotated upward, striking against the firing pin. The impact of the hammer forces the firing pin forward against the compression of the retracting spring, igniting the primer and firing the piece. When the pressure of firing develops in the chamber, blowback through the obturator vent is prevented by the primer case which performs obturation exactly the same way the cartridge case will with fixed ammunition.

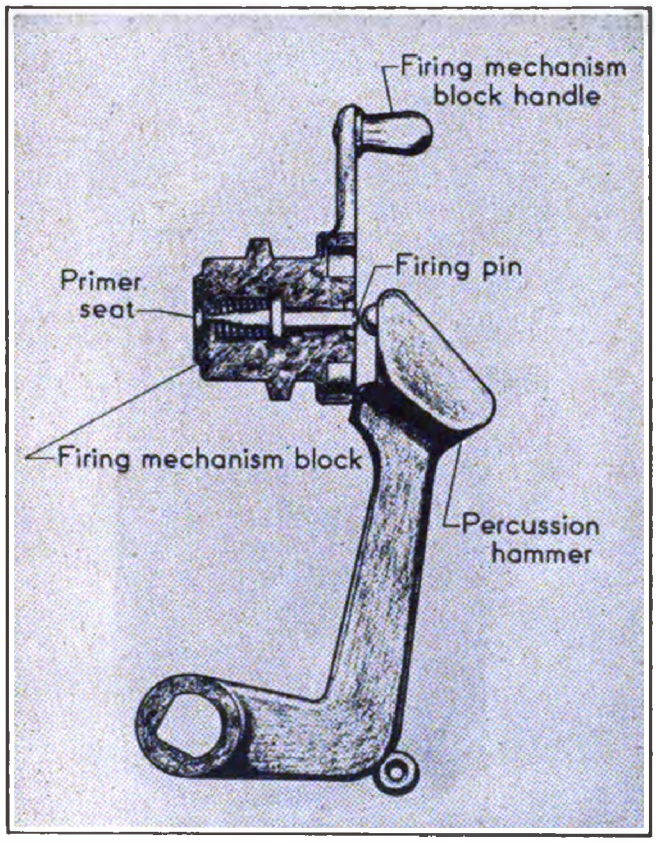

Figure 15. Percussion Hammer Firing Mechanism.

There is another type of percussion hammer firing mechanism which is found on the French 75mm gun, M1897, and its modifications. This mechanism consists of a firing hammer with a gear engaging a firing rack which is held in a down position by the firing rack spring. Pulling the lanyard rotates the firing hammer rearward and through the gearing raises the firing rack and compresses the firing rack spring. On release of the lanyard the firing rack spring furnishes the driving force necessary to rotate the firing hammer up and forward against the firing pin thus igniting the primer and firing the piece. There is no retracting spring provided on this firing pin. It is cammed out of the indentation it makes in the primer when the breechblock is opened. This is possible because the firing pin is rounded and blunt on its forward end.

Continuous Pull Firing Mechanism. This mechanism gets its name from the fact all its functions are initiated by one continuous pull of the lanyard. It is always in the "ready" position in that pulling the lanyard accomplishes cocking and firing of the piece. As the lanyard is released, the firing mechanism automatically retracts to the ready position again. A type of this mechanism which is in general use in this country is the Firing Lock, M13. Its functioning is described below.

The mechanism is assembled into a firing case. The complete assembly is carried in a central hole in the breechblock, being held there by sector lugs on its exterior engaging with lugs in the breechblocks' recess. The case is pre-

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vented from rotating in the breechblock by the trigger shaft, which enters from the side. The components are all contained within the firing case.

As the lanyard is pulled, the trigger fork is rotated forward. This movement forces the holder sleeve forward compressing the firing spring between the holder and the holder sleeve until the holder sleeve rides into the slope of the spring

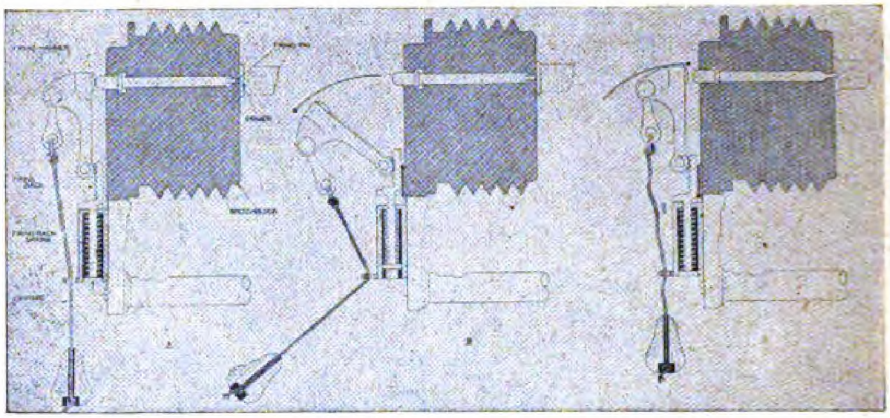

Figure 16. Spring Operated Percussion Hammer Firing Mechanism.

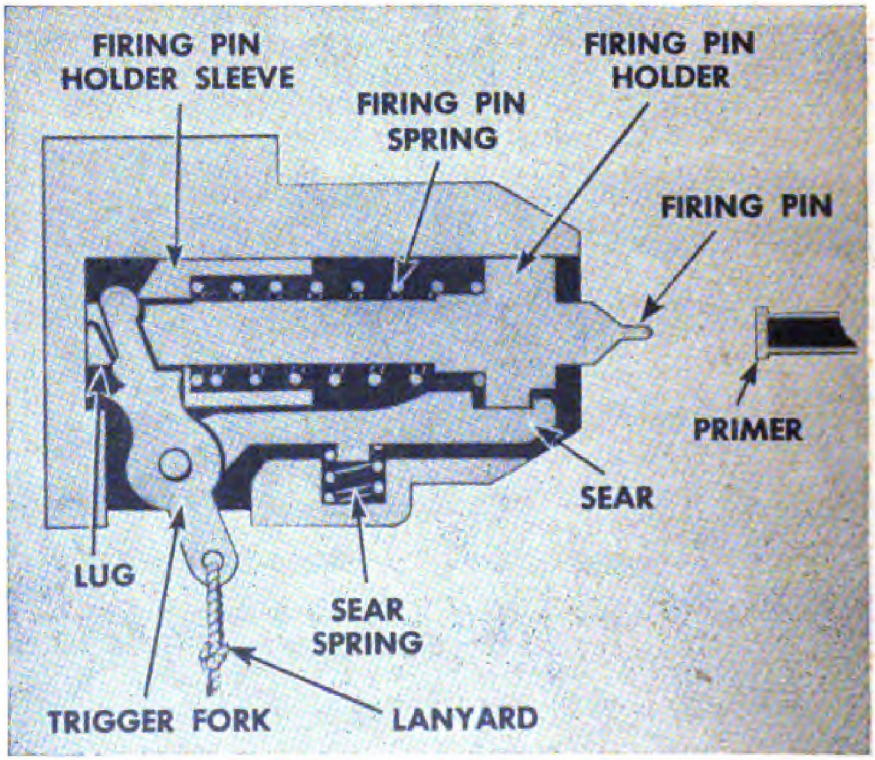

Figure 17. Continuous Pull Firing Mechanism—At Rest.

supported sear and forces it downward. This action disengages the sear from the firing pin holder. The firing pin holder, being under the compression of the firing spring, when released, will drive forward and fire the piece. On release of the lanyard, the firing spring, still partly compressed, forces the holder sleeve backward, against the trigger fork. This same spring exerts an equal pressure forward on the firing pin holder, and this force is transmitted by the lugs on the firing pin holder to the trigger fork, tending to rotate it forward. Since there are

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two equal forces acting in opposite directions on the trigger fork, the one acting on the longer lever arm will rotate the trigger fork. Therefore, since the lever arm from the firing pin holder sleeve to the fulcrum point is longer than the lever arm from the firing pin holder lugs to the fulcrum point, the trigger fork and

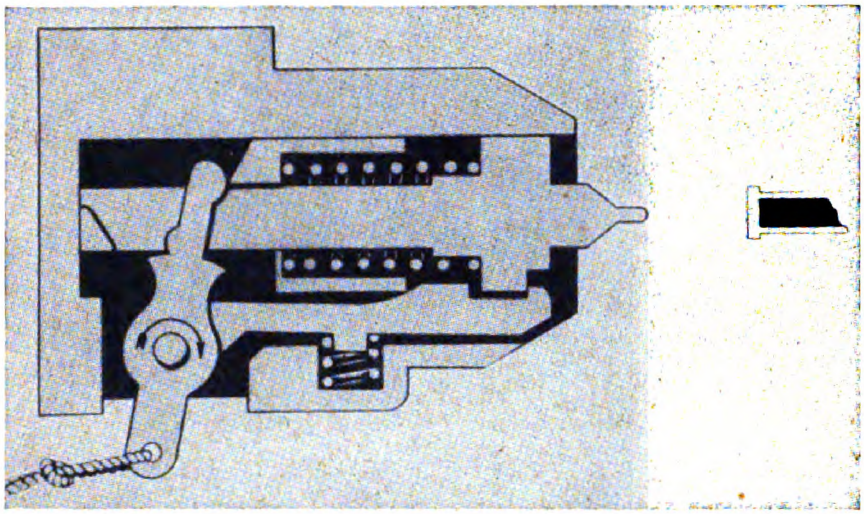

Figure 18. Continuous Pull Firing Mechanism—About to Fire.

firing pin holder will move rearward and return to their original "ready" position. The backward movement of the holder sleeve permits the sear to rise engaging the firing pin holder. The mechanism is now ready to be actuated again.

Inertia Firing Mechanism. This mechanism is often found on semi-automatic weapons. It utilizes the "law of inertia" or the principle of a body in motion tending to remain in motion until acted on by an outside force. There are three separate phases in the operation of this mechanism—cocking, firing, and retracting.

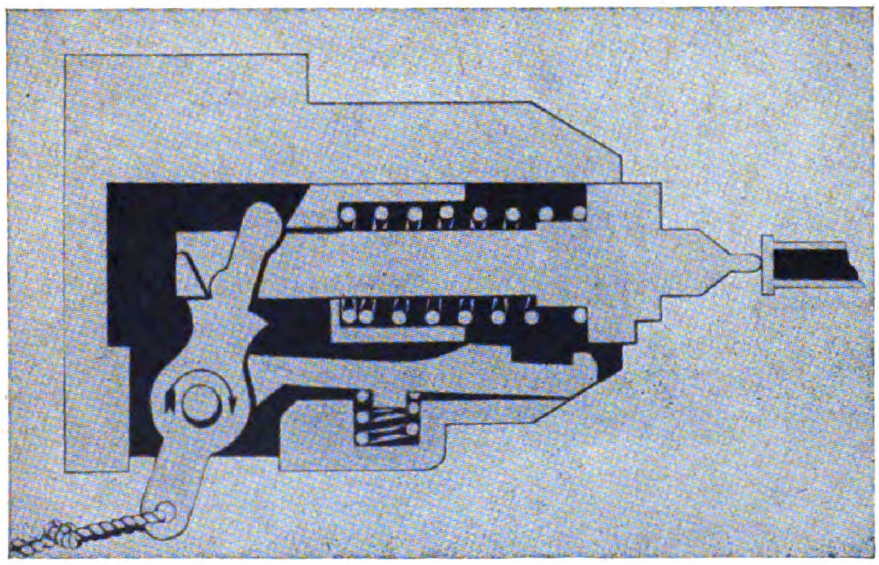

Figure 19. Continuous Pull Firing Mechanism—Fired.

Cocking. In cocking, the cocking lever is rotated clockwise. The lower end of the lever bears against the cocking lever lug, moving the guide rearward and compressing the firing spring until the sear lug cams aside and passes the sear. Under action of the sear spring, the sear moves across the guide in front of the sear lug, after the sear lug passes the sear. The firing spring, now compressed,

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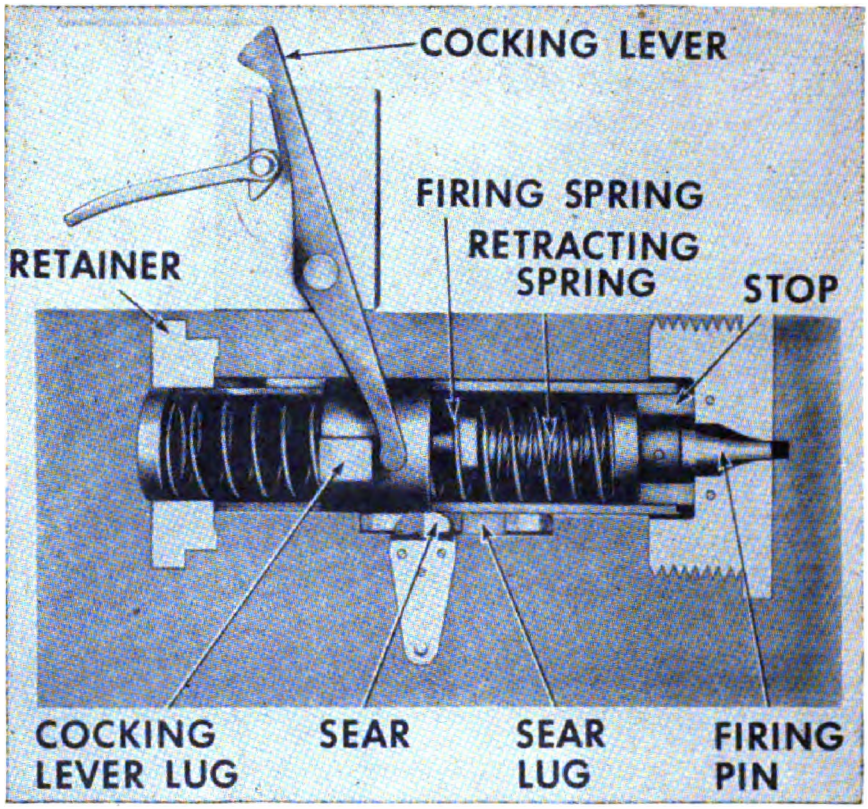

Figure 20. Inertia Firing Mechanism—At Rest.

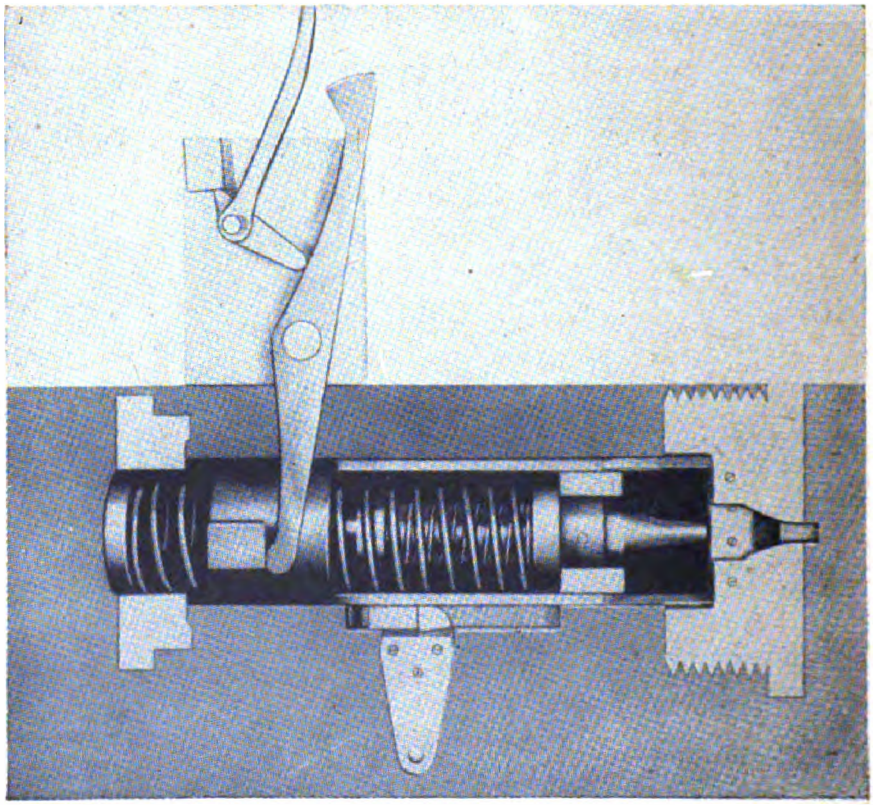

Figure 21. Inertia Firing Mechanism—Cocked.

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tends to shoot the guide and firing pin forward. However, the sear lug bears against the sear which holds the guide from going forward. The system is now cocked and ready for firing.

Firing. To fire the mechanism the sear is depressed. This disengages it from the sear lug. This action releases the guide and allows it to move forward under the pressure of the compressed firing spring. The stop moves forward with the guide and firing pin until it strikes against the breechblock bushing. The pressure of the firing spring is now taken up between the breechblock bushing (through the stop bearing against it) and the retainer. The guide, because of its inertia, will continue forward until the firing pin strikes the primer. At the same time the retracting spring will be compressed because it is held between the stop and the head of the firing pin.

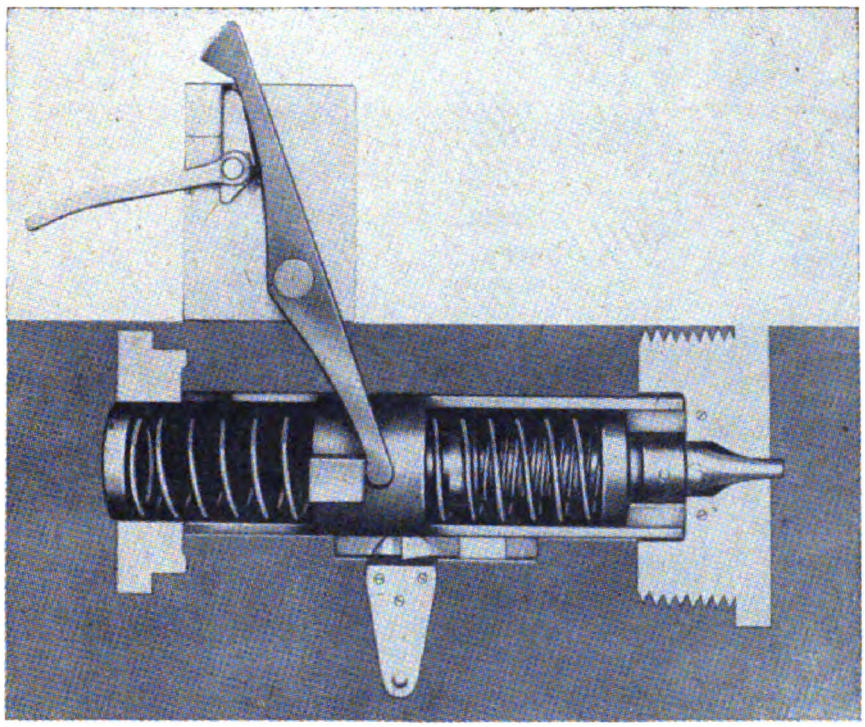

Figure 22. Inertia Firing Mechanism—Fired.

Retracting. To prevent the firing pin from being sheared off as the breechblock is opened, it must be retracted, that is, pulled back into the breechblock. The compressed retracting spring pushes rearward on the firing pin being restrained only at its forward end by the stop and breechblock. Since the guide (with the firing pin attached) is free to move to the rear, the compressed retracting spring expands and pulls the firing pin back into the breechblock recess. The system is now at rest and ready for subsequent cocking and firing.

On semiautomatic weapons cocking may be achieved either by hand or by a cam surface on the breechring which rotates the cocking lever as the breech is opened.

Electric and Friction Firing Mechanisms. The Seacoast Firing Mechanism M1903 is used on practically all of our seacoast cannon manufactured prior to World War I. It is designed to fire either by lanyard (using a friction primer) or by magneto (using an electric primer).

When fired by friction, the primer used is similar to a blank rifle cartridge with a serrated wire protruding from the base end. This wire has a lug on the rearmost end to provide a bearing or holding surface for the firing leaf. The firing leaf pivots about its upper end and has a hole in the lower end for the

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lanyard. Pulling the lanyard rotates the firing leaf to the rear, and draws the serrated wire through the primer charge, which sets up a high friction and fires the piece.

To fire electrically, the firing magneto must be used. One terminal being connected by an insulated wire to the wire part of the primer, and the other terminal grounded to the frame of the gun. The primer contains a fine platinum wire, connected at one end to the insulated protruding wire, and at the other end to the primer case. Upon closing the circuit (at the firing magneto), the current heats up the fine platinum wire, thus detonating the primer compound and firing the piece.

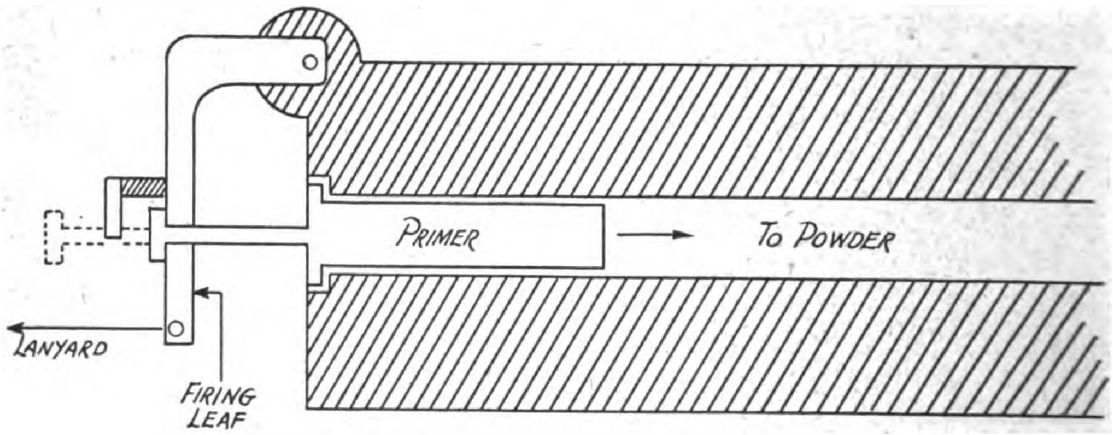

Figure 23. Hook-Up of Friction Firing Mechanism.

This mechanism has the following safeties:

1. The firing leaf cannot be drawn back for lanyard firing until the block is completely closed.
2. The firing circuit is not made at the breech until the block is completely closed.

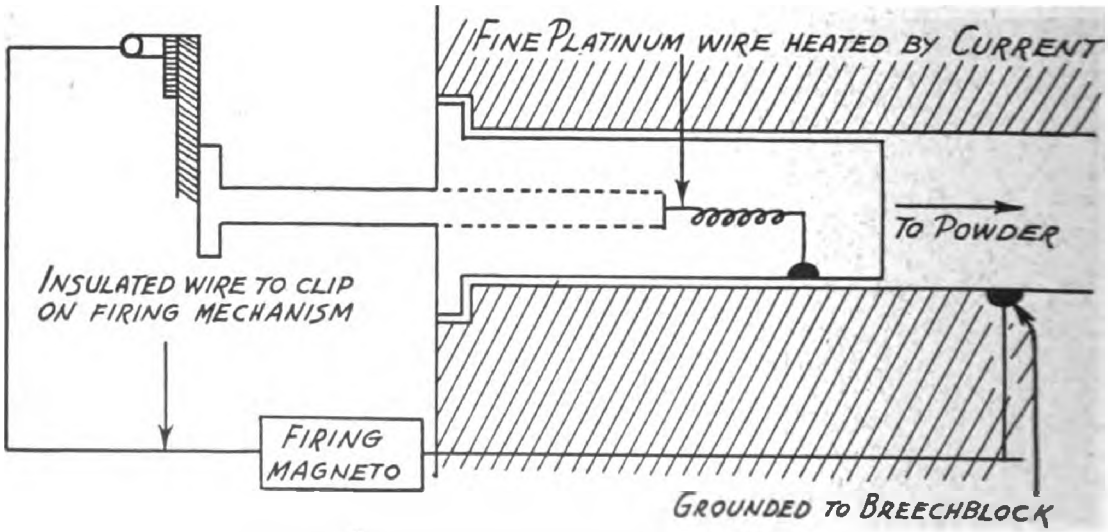

Figure 24. Hook-Up of Electric Firing Mechanism.

3. On mortars the short lanyard cannot be hoked into the firing leaf until the piece has been elevated at least 45 degrees; the plug for firing by electricity cannot be inserted until a similar elevation has been reached.
4. On disappearing carriages the short lanyard is not released and electrical circuit breaker is not closed until the piece is in battery.

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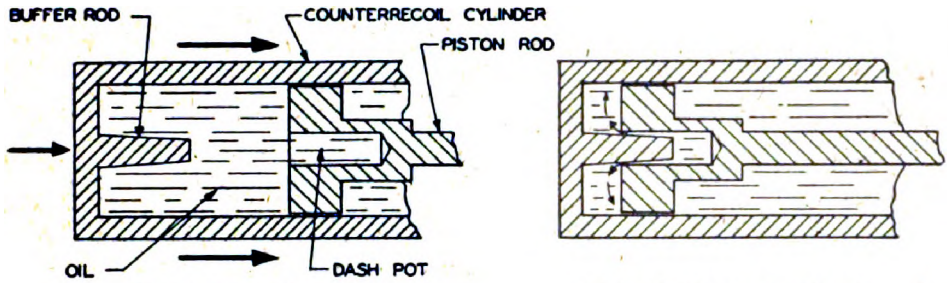
RECOIL MECHANISMS

Study of the definitions below will enable the reader to obtain a more clear understanding of the text that follows:

The *in battery* position is the position in which the cannon after recoiling and counterrecoiling is safe to be refired.

A *belleville* spring is a saucer shaped metal disc spring.



At Start of Recoil. At End of Counter-Recoil.

Figure 25. Dashpot Buffer.

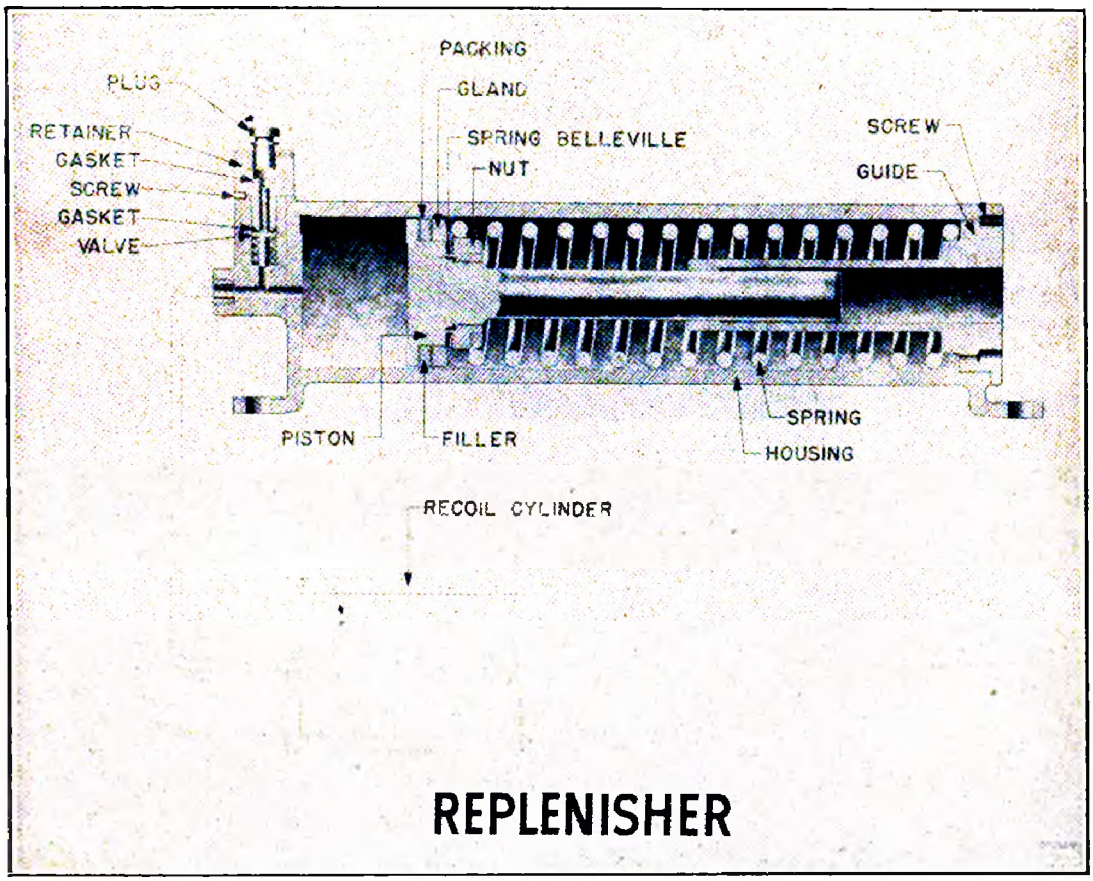


Figure 26. Replenisher.

A counterrecoil *buffer* is a mechanism which controls the last part of movement of a cannon into battery, eliminating shock and displacement of the carriage.

A *by pass* is a passage through which oil passes around an obstruction.

A *constant* recoil mechanism is one in which the length of recoil is *not* varied mechanically.

Counterrecoil is the returning of recoiled parts to their original position.

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A *dashpot* buffer is a type of buffer which consists of a close fitting rod fitting into a cylindrical cavity. Oil in the cavity is expelled by entrance of the rod through the small clearance between the two parts.

A *dependent* recoil mechanism is one in which the recoil and counterrecoil cylinders are joined together by a port, permitting movement of recoil liquid from one to the other.

A *floating piston* is a piston that has no piston rod and is free to move within a cylinder. It depends upon direct pressure of gas or oil for movement, and forms an oil and gas tight seal.

Hydro-Pneumatic is a term designating a machine or device that combines liquid and gas to accomplish work.

Hydro-Spring is a term designating a machine or a device that combines liquid and springs to accomplish work.

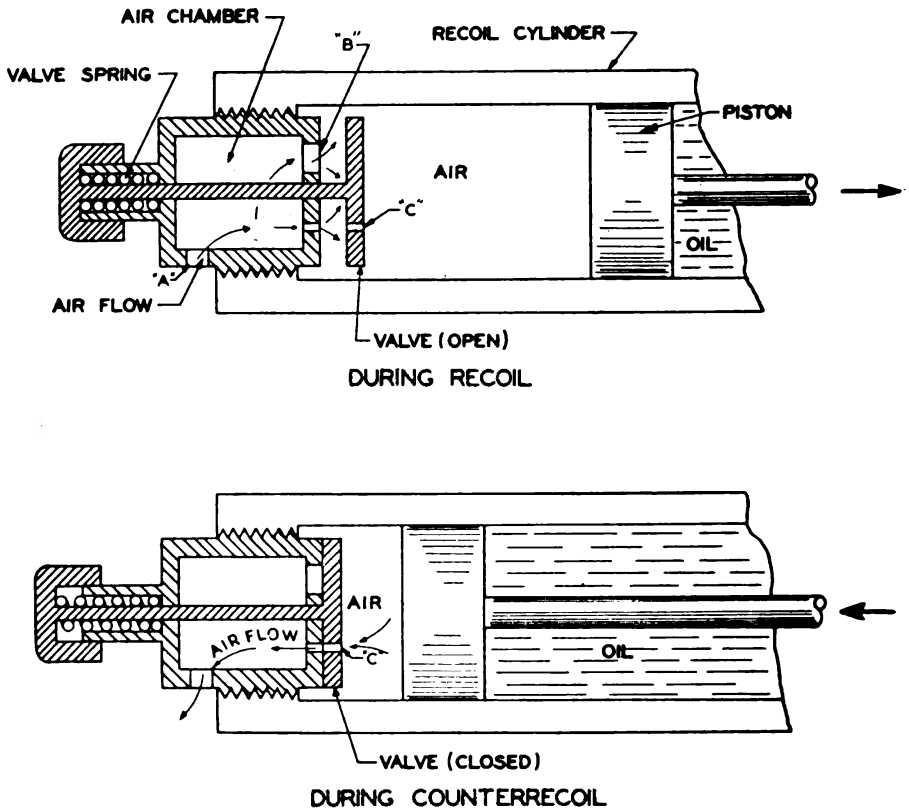

Figure 27. Respirator.

An *independent* recoil mechanism is one in which the liquid contained in the recoil cylinder can not come into contact with the liquid in the counterrecoil cylinder.

Nitrogen Gas is a gas that is inert, colorless, and odorless. It constitutes about four-fifths, by volume, of the atmosphere.

An *oil-index* is a device within a recoil mechanism that indicates the presence or absence of reserve oil.

An *orifice* is an opening through which liquid can flow.

Overrecoil is a recoil length longer than normal.

A *piston* is a thick disc or cylinder which slides within a cylinder and, through either a rod or direct pressure, receives or imparts motion.

Recoil is the backward movement of a cannon upon firing.

A *recoil brake* is a mechanism which limits and controls the recoil of a cannon.

A *recuperator* is a counterrecoil mechanism.

A *replenisher* is a small reservoir which takes up excess or fills a deficiency of oil in a recoil mechanism.

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The *reserve oil* is a quantity of oil used to maintain the pressure of the nitrogen gas upon the oil in certain hydro-pneumatic recoil mechanisms.

A *respirator* is a one-way air valve employed in certain hydro-pneumatic recoil mechanisms. It permits the recoil piston to draw in air as the piston moves rearward and during counterrecoil restricts the exit of this air, thereby slowing counterrecoil and aiding in buffing.

A *stuffing box* is an oil tight seal through which the piston rod moves in recoil and counterrecoil.

Throttling bars, grooves, and rods are devices used to restrict the flow of oil.

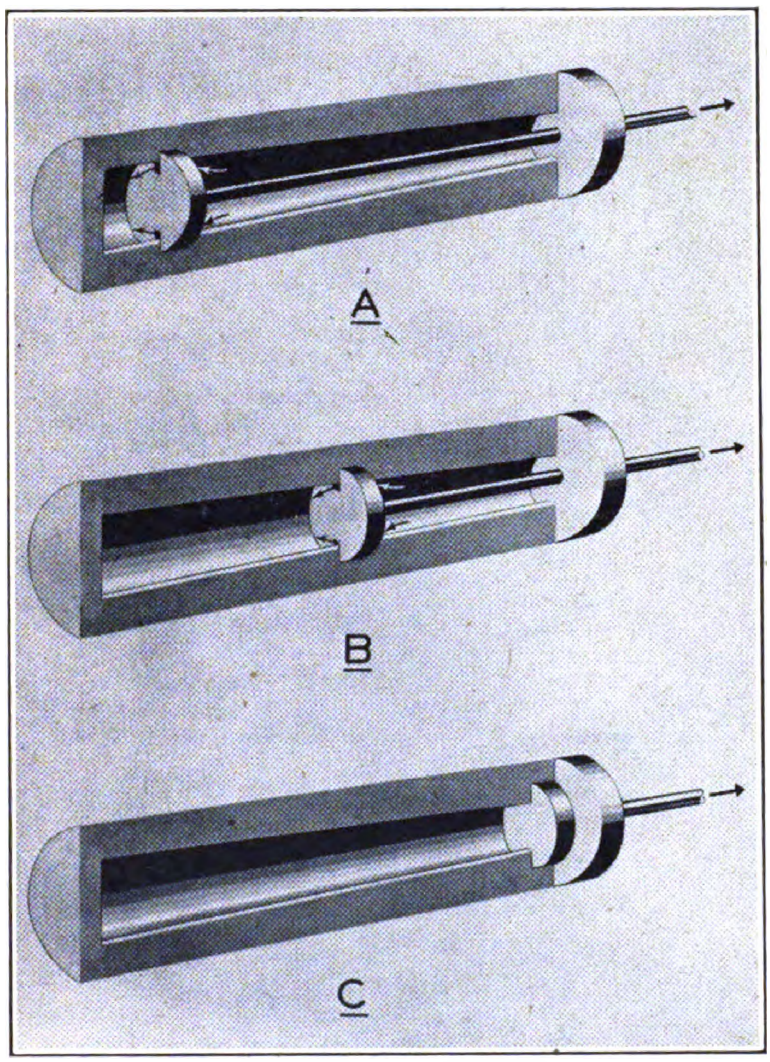

Figure 28. Throttling Bar.

A *valve* is a device that is capable of being opened or closed. This movement regulates the size of an orifice through which liquid or gas may flow.

Variable Recoil is a reference term for any recoil mechanism whose recoil length is mechanically shortened as the cannon is elevated.

A *muzzle brake* is a device that assists in overcoming and controlling the energy of recoil. Here is a description of how it works: As the projectile leaves the tube, the gases escaping from the barrel are deflected to the rear and against a curved portion of muzzle brake baffles. The gas is directed from the baffles against the rearward-inclined faces of slots in the muzzle brake sleeve. This action tends to push the gun forward, partially overcoming recoil and assisting in the braking action.

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Recoil Mechanisms

Purpose. The purpose of a recoil mechanism is to dissipate the energy of recoil without disturbing the laying of the piece and to return the recoiling parts without a shock to the 'in battery' position. These functions are accomplished by one, or a variaion of one, of three types of recoil mechanisms. All depend upon the incompressibility of liquid for dissipating the energy of recoil and prevention of shock at the end of counterrecoil. Some utilize the force of expanding springs or gas compressed during recoil to accomplish counterrecoil. Others depend upon the dropping of a heavy weight, raised by the energy of recoil, to accomplish counterrecoil.

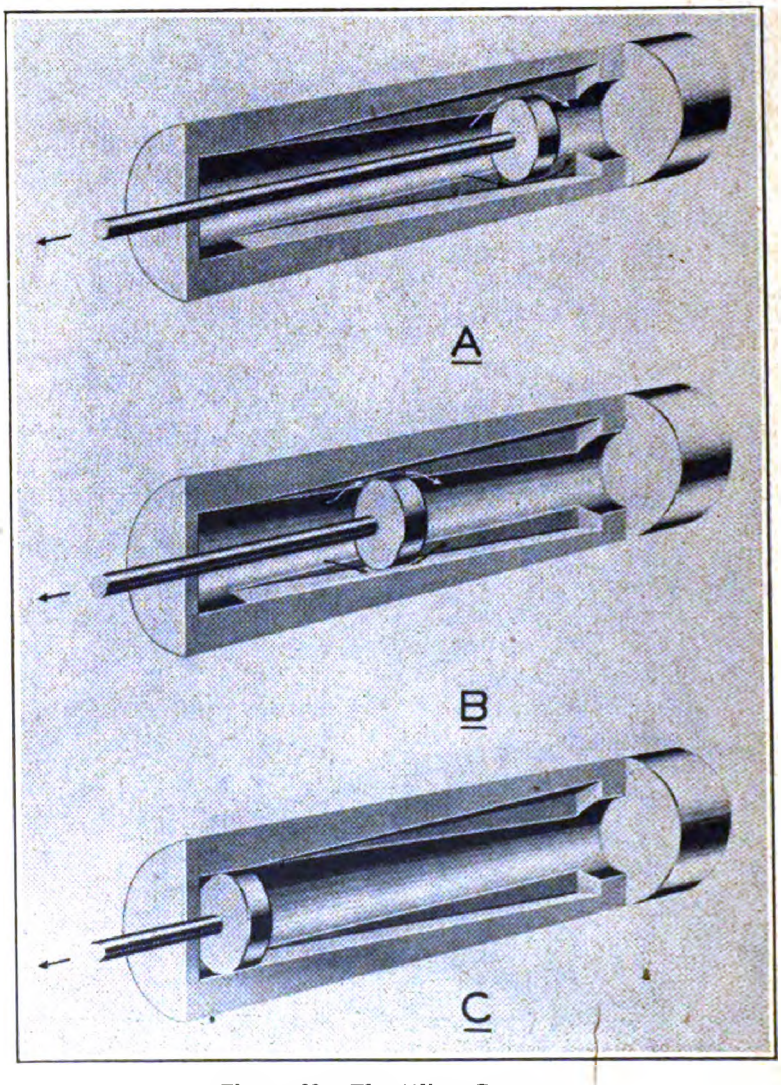

Figure 29. Throttling Grooves.

Hydro-Spring Type. A hydro-spring recoil mechanism is the least complicated type. Its simplicity permits field maintenance. In this type, the recoil cylinder may move in recoil while the recoil piston remains stationary, or the recoil piston may move in recoil while the recoil cylinder remains stationary. In both cases relative motion exists between the recoil piston and recoil cylinder. For purposes of discussion, it will be assumed that in all hydro-spring recoil mechanisms, the recoil piston is moved and the recoil cylinder remains stationary.

This is how the hydro-spring type works: As the piece is fired and expanding propellent gases force the gun rearward, a recoil piston, which is connected to the gun and fits inside the recoil cylinder, moves rearward also. The cylinder

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remains stationary throughout recoil and counterrecoil. Liquid, which is inside the cylinder and to the rear of the piston, is forced through one or any combination of the following devices: openings restricted by a spring operated one-way valve, tapered slots or grooves running the length of the cylinder, an orifice

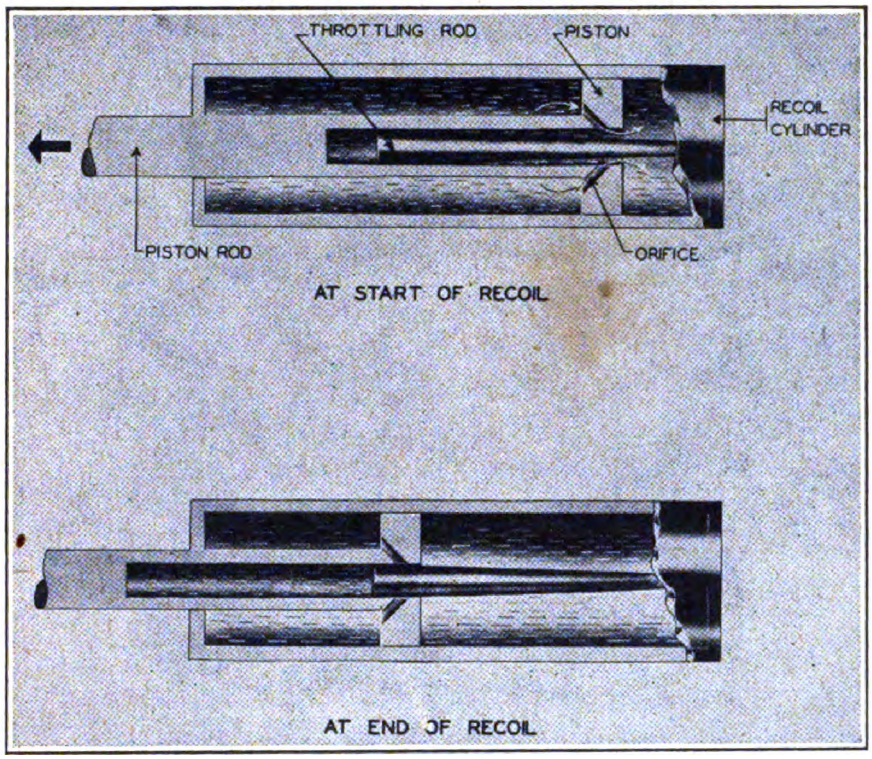

Figure 30. Throttling Rod.

in a bushing wherein the area of the orifice is constantly diminished by the entrance of a tapered control rod. Since the piston is capable of displacing a greater volume of liquid than can escape through the combined areas of the various openings in a given time and since liquid cannot be compressed, a resist-

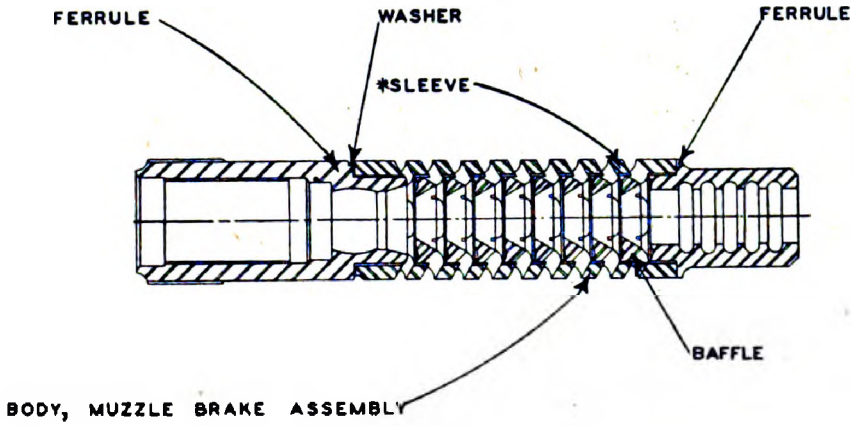

Figure 31. Muzzle Brake.

ance to the movement of the piston is set up. A uniform decrease in the velocity of recoil is accomplished by diminishing the size of the orifices through which the oil can flow as the gun moves to the rear.

In addition to the throttling effect of a liquid, two other factors must be considered in the dissipation of recoil energy. First, it requires energy to compress

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the springs which provide energy for counterrecoil. These springs may be inside the recoil cylinder, or mounted outside, surrounding the tube. Second, energy is required to move the weight of the recoiling mass against friction. It must be borne in mind, however, that the greater part of recoil energy is dissipated by the throttling of the liquid.

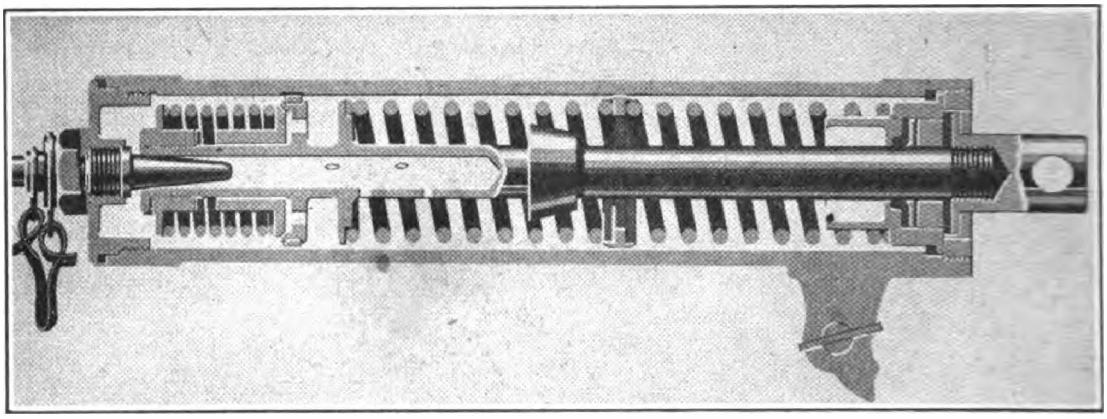

Figure 32. Hydro-Spring Recoil Mechanism.

A safety device may be used to prevent damage in event of overrecoil. Overrecoil could result from an insufficient amount of recoil fluid. This safety device is a dashpot and does not function unless overrecoil occurs.

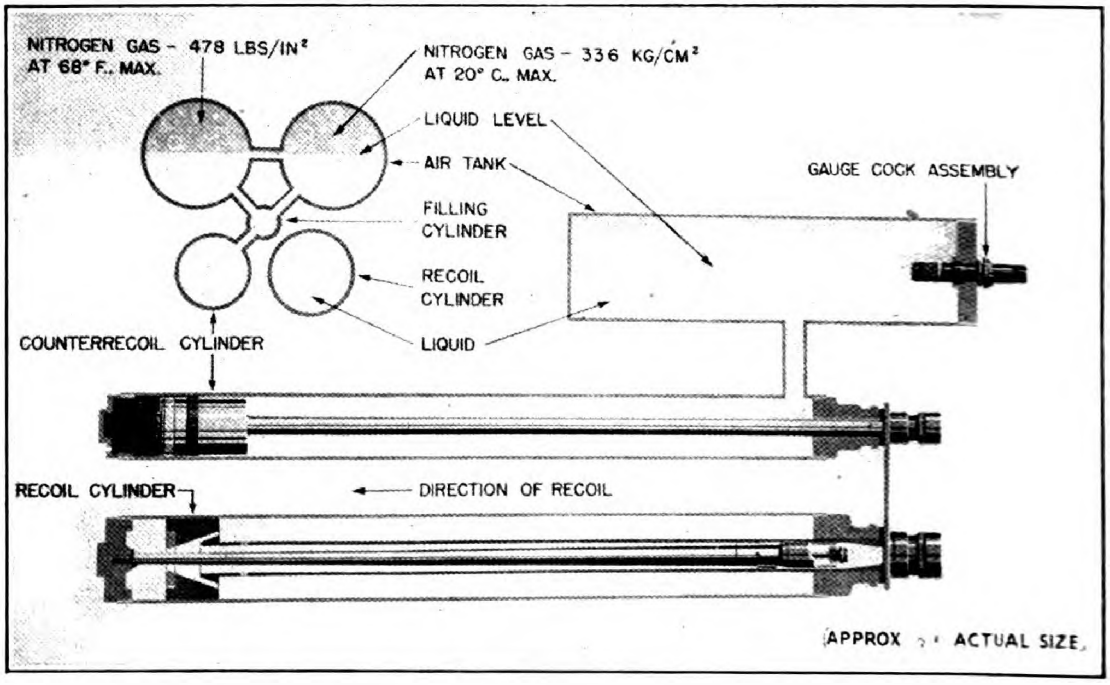

Figure 33. Hydro-Pneumatic Recoil Mechanism (Without a Floating Piston).

When recoil ceases, the springs compressed during recoil begin to expand and move the recoil piston forward. The liquid, which is now forward of the recoil piston, begins to flow to the rear of the piston through the same channels used during recoil, except when a one-way valve is used. A one-way valve is open during a part of recoil and liquid may escape through the channels provided. During counterrecoil the one-way valve remains closed, and the liquid cannot return through these passages.

Before the counterrecoiling parts reach the in-battery position, liquid is throttled

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to slow the movement. This prevents damage to parts and eliminates displacement of the carriage. This may be accomplished by any one, or a combination of, the following devices: a tapered buffing rod inside the front end of the cylinder that enters a hollow piston rod progressively filling the opening through which the liquid can escape (the gradual closing of this orifice by the tapered control rod restricts the flow of oil and buffs the gun into battery), grooves that become more shallow as the piston rod moves forward, or a dash pot buffer.

If it is desirable to vary the speed of counterrecoil, a valve which changes the amount of liquid that can flow through a counterrecoil device in a given time is incorporated in the design. A portion of this valve extends to the exterior and is readily accessible.

Hydro-Pneumatic Without A Floating Piston. This type is sometimes referred to as the hydro--pneumatic, direct contact type. The mechanism derives its name from the fact that the nitrogen gas, which is the source of counterrecoil energy, is in direct contact with the recoil fluid, and nothing prevents their mixing. Maintenance in the field is relatively simple, since assembly and disassembly are quite easily accomplished.

The function can be divided into three separate phases: recoil braking, counterrecoil, and buffing. The recoil brake and the counterrecoil buffer are located inside the recoil cylinder. Counterrecoil is accomplished by gas and liquid contained in two gas cylinders and the counterrecoil cylinder. The two gas cylinders and the counterrecoil cylinders are interconnected by means of ports. The recoil cylinder is not connected to the other cylinders.

Since the cylinders of the recoil mechanism form the sleigh, the howitzer and sleigh move together. The recoil piston rod and the counterrecoil piston rod are attached to the cradle and do not move during recoil and counterrecoil. The recoil piston rod is hollow and has a tapered counterrecoil buffer rod passing through it. The smaller end of the buffer rod is attached to the rear of the recoil cylinder. The counterrecoil buffer rod has a one-way valve attached to its forward end. Several holes are bored through the recoil piston toward its center terminating inside the hollow piston rod.

As the expanding gases from the ignited propelling charge force the howitzer and sleigh rearward, liquid moves from the front to the rear of the recoil piston through the holes in the piston. The liquid passing through these holes is throttled between the counterrecoil buffer rod and a throttling orifice in the rear face of the piston. Since the recoil piston can displace a greater volume of liquid than can flow in any given time between the buffer rod and the throttling orifice, pressure is established on the liquid. This pressure opposes the movement of the recoil piston and will gradually dissipate the energy of recoil. The tapered buffer rod causes the throttling orifice to be decreased in size, thus slowing the velocity of recoil.

Since more liquid is being displaced by the recoil piston than can flow through the throttling orifice, pressure will force some of it into the area previously occupied by the buffer rod. The liquid forces the one-way valve on the counterrecoil buffer rod open and passes through channels in the body of the valve.

During recoil, also, the counterrecoil is forcing the recoil liquid contained in the counterrecoil cylinder from the counterrecoil cylinder into the two gas cylinders. By increasing the volume of liquid in the gas cylinders the nitrogen gas contained therein is further compressed. Since energy is required to compress the nitrogen gas, this act of compression must be regarded as an aid in dissipating recoil energy.

Beside the two above means of dissipating recoil energy, a third means must be considered. It requires energy to move the weight of recoiling parts against the friction on the slides, and the energy thus absorbed is a part of the initiating force of recoil.

At the moment recoil ceases, the nitrogen gas contained in the gas cylinders and compressed during recoil expands, moving liquid from the gas cylinders into the counterrecoil cylinder. The liquid, being under pressure from the gas, forces the sleigh back into battery.

As the sleigh moves in counterrecoil, the counterrecoil buffer rod is being repositioned inside the hollow recoil piston rod, causing liquid inside the recoil

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piston rod to move towards the rear of the mechanism. The pressure of the liquid contained inside the recoil piston rod pushes the one-way valve against the counterrecoil buffer rod, effectively blocking the passages in the one-way valve and necessitating the liquid's flow between the exterior surface of the valve and the interior surface of the piston rod. This results in a throttling of liquid which accomplishes the desired buffing action.

Hydro-Pneumatic With a Floating Piston. This type, with its variations, is used on a large number of Army weapons. It is the most complex type of recoil mechanism, and therefore many repairs can be performed only by base shops or arsenals. This apparent disadvantage is off-set by superior performance records. The mechanism gets its name due to the fact that an oil and gas tight floating piston is used in a cylinder to separate recoil oil and nitrogen gas.

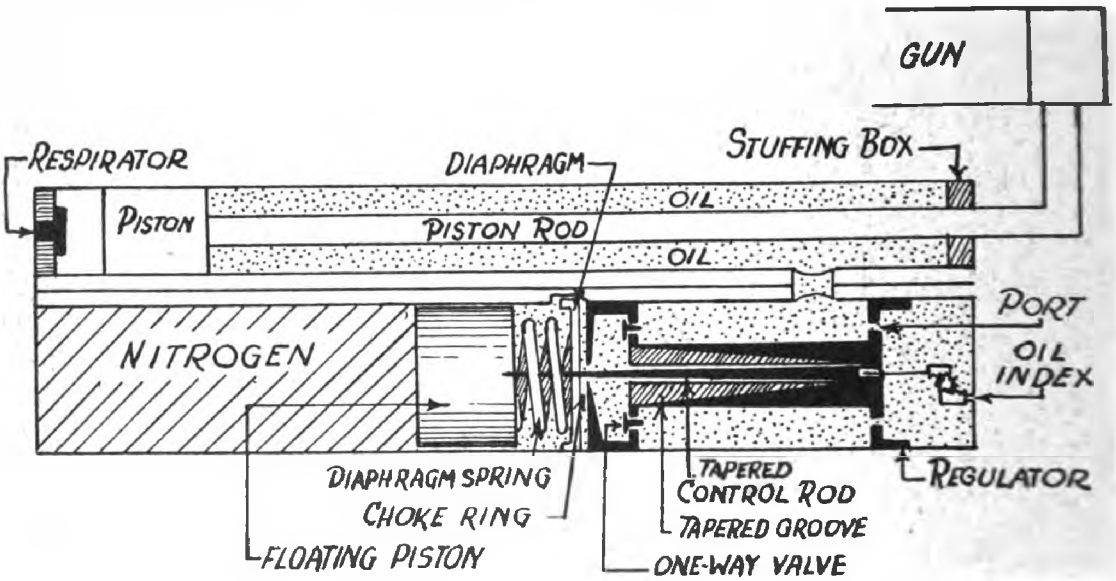

Figure 34. Hydro-Pneumatic Recoil Mechanism (With a Floating Piston).

The mechanism is composed of two cylinders. The smaller cylinder, known as the recoil cylinder, contains a quantity of recoil oil, the recoil piston, recoil piston rod, a stuffing box, and may or may not contain a respirator. The larger cylinder, known as the counterrecoil cylinder, contains a quantity of oil and compressed nitrogen gas separated by a floating piston, the regulator, control rod, diaphragm with spring, and an oil index.

The regulator in conjunction with the control rod acts as the recoil brake and the counterrecoil buffer. The regulator resembles in general appearance a dumbell and is screwed in the counterrecoil cylinder. It does not move in recoil or counterrecoil. In one end is housed the choke ring (throttling orifice) and some passages containing one-way valves. In the other end are ports which permit oil flow in either direction. The tube connecting the ends is hollow and has two tapered grooves. The control rod, when activated, moves inside this tube.

The tapered control rod, which passes through the regulator's central bore and the throttling orifice, is fastened at its smaller end to a disc-like diaphragm, which stands on edge.

When the piece is in battery, the diaphragm is held against the regulator by the diaphragm spring.

The oil reserve is made a part of the main body of oil through a small by-pass that has been scooped from the interior of the counterrecoil cylinder above the 'in battery' position of the diaphragm. Since the reserve oil is in contact with the floating piston, the pressure of the nitrogen is transmitted through the floating piston to the oil, and pressure is maintained on the oil as long as any quantity of oil separates the diaphragm and the floating piston.

When the tube moves rearward, the recoil piston rod and the recoil piston

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move rearward also. Oil in the recoil cylinder moves through a connecting port to the counterrecoil cylinder. In the counterrecoil cylinder the oil unseats the one-way valves, moves through the passages, and passes through the choke ring. Since the diaphragm is against the regulator, the oil passing through the choke ring forces the diaphragm, diaphragm spring, oil reserve, and the floating piston forward as one unit, further compressing the nitrogen gas. As the diaphragm is moved forward, the tapered control rod is drawn forward. Since the regulator does not move in recoil, a larger portion of the tapered control rod is constantly being introduced into the choke ring, continually decreasing the area through which the oil may pass. More oil is capable of being displaced by the recoil piston than can flow through the restricted opening of the choke ring, thus pressure is established on the oil. This pressure resists the movement of the recoil piston and eventually will stop recoil. Since the restricted opening is constantly diminishing in size, a uniform decrease in the velocity of recoil is obtained. The pressure of the oil is sufficient to move the floating piston and further compress the nitrogen gas. Some energy of recoil is absorbed in this compression of gas.

In addition to the throttling of oil and the compression of gas, another factor enters into the braking action. It is the moving of the weights of the recoiling mass against friction, which absorbs some of the energy resulting from firing.

As soon as recoil stops, the spring-loaded one-way valves close, and the nitrogen gas expands forcing the floating piston, diaphragm spring, reserve oil, and diaphragm to move rearward as one unit, reversing the direction of the flow of oil. Since the one-way valves in the regulator have closed, the oil passes through the choke ring and the central bore of the regulator, through the ports in the rear of the regulator, through the port connecting the recoil and counterrecoil cylinders, forcing the recoil piston forward and returning the piece to the in battery position.

As the oil passes through the central bore of the regulator, it is throttled between the head of the control rod and the tapered grooves in the regulator. These grooves are tapered so that the farther the piece moves into battery the smaller becomes the clearance through which oil may pass. This results in a restriction of the speed of the flow of the oil and slows down counterrecoil sufficiently to eliminate shock.

On mechanisms using a respirator, the recoil piston must, to some extent, compress the air occupying the space between the recoil piston and the respirator. In this manner the respirator aids in the buffing action.

VARIABLE RECOIL MECHANISMS

The recoil mechanisms described previously are used when the function of recoil is constant. For a variable function of recoil, some changes are made in the throttling devices, but the mechanism retains its original classification of hydro-pneumatic, hydro-spring, etc. It is desirable from the standpoint of stability to have long lengths of recoil at low angles of elevation, however, were the gun to recoil the same length at higher angles of elevation, the rear of the gun might strike the ground or part of the carriage. Two methods of obtaining a variable recoil function will be discussed. One type is in current use in some antiaircraft weapons, and for the purpose of our discussion we will designate it as the valve-controlled variable recoil device. The second type is used extensively on ground artillery weapons, and for our purposes we will call it the rod-controlled variable recoil device.

Valve-Controlled Variable Recoil Mechanism. The hydro-pneumatic recoil mechanism with a floating piston that includes the valve-controlled variable recoil device omits the regulator and allied parts. It functions as follows: As the recoil piston moves in recoil, the fluid is forced from the recoil cylinder, passing by the throttling valve. The amount the valve may be opened is governed by the angle of elevation of the gun. The cradle moves with the gun in elevation. As the cradle is elevated, a bar on the cradle contacts a cam on the top carriage and is forced inward, since the top carriage does not move in elevation. As the bar moves inward, it pushes the stop inward. The farther the stop moves the smaller becomes the distance the throttling valve may open. The throttling valve is opened by the pressure of the oil and remains open against the pressure

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of its spring until the oil pressure sufficiently decreases. A reduced opening resulting from elevation brings a corresponding decrease in the area through which fluid may flow and increases resistance to movement of the recoil piston, resulting in a decrease in the length of recoil. The counterrecoil valve does not open in recoil, as the oil pressure serves to seat it more firmly.

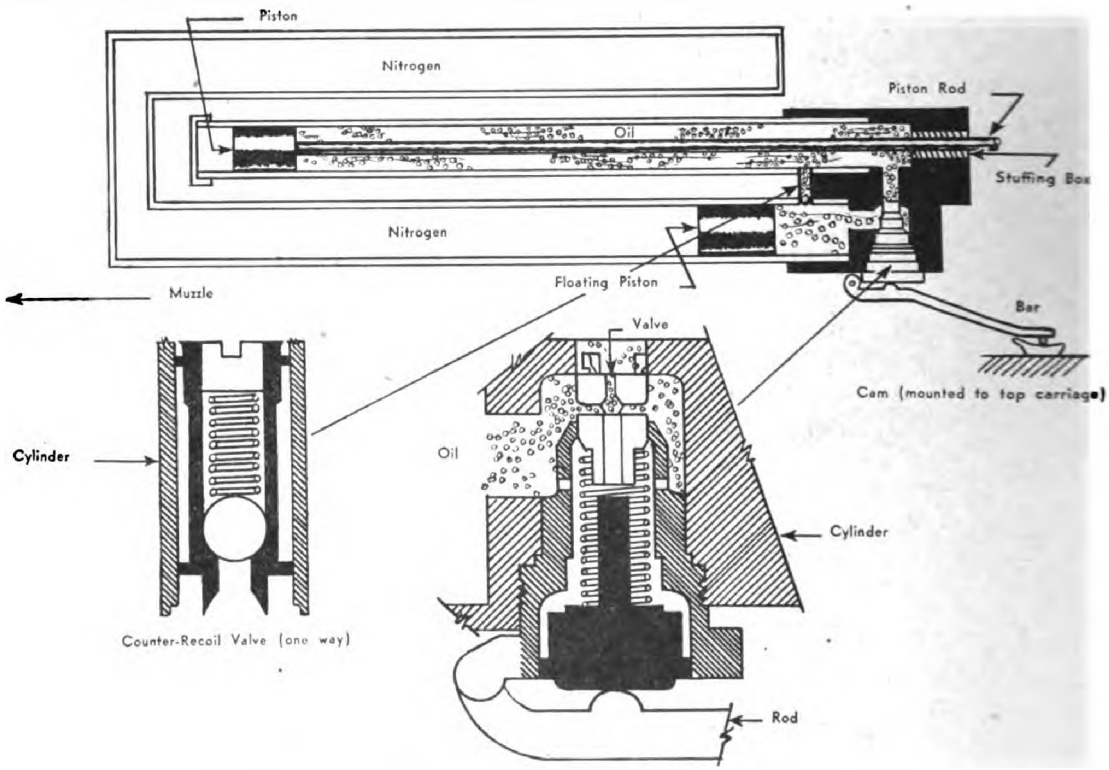

Figure 35. Valve-Controlled Variable Recoil Mechanism.

The oil upon entering the recuperator cylinder moves the floating piston forward, further compressing the nitrogen gas. When recoil stops, the nitrogen expands moving the floating piston rearward. Oil in the recuperator cylinder exerts its pressure on the counterrecoil valve, opens it, and moves back into the recoil cylinder, where the recoil piston is forced forward, returning the gun to battery. When oil pressure on the counterrecoil valve diminishes, the valve closes. Pressure is maintained on the oil through a small hole drilled through the throttling valve.

Counterrecoil Buffer. The counterrecoil buffer is independent from the recoil mechanism and is contained in a separate cylinder. During recoil of the weapon, the spring between the front of the cylinder and the piston extends and forces the piston to follow the breechring. A disk-shaped valve is moved away from the oil passage holes in the piston by the flow of oil and allows the oil to pass unrestricted from the rear to the front of the cylinder. In counterrecoil the gun assembly during return to battery contacts the piston. The reversal of oil slides the disk-shaped valve back to cover the holes in the piston; the oil is then forced through two grooves in the cylinder wall. The oil flow, being restricted by these grooves, slows and brings the weapon to a gradual stop.

Rod-Controlled Variable Recoil Mechanism. Through recoil, the recoil piston and the recoil piston rod are drawn rearward by the gun or howitzer. Oil moves from the rear to the front of the recoil piston through two ports in the piston. These ports are one hundred and eighty degrees apart and terminate inside the hollow piston rod, forming a throttling orifice in combination with the control rod.

Fitting inside the hollow piston rod is a control rod, which is stationary in recoil and counterrecoil, and in which are cut two pairs of throttling grooves.

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One set of grooves is shallow and long, the other set is deep and short. All grooves are tapered, being deeper at their forward end than they are at their rear end. The control rod is capable of rotation while the piston and piston rod only move to the rear and the front. The control rod is rotated by a gear segment, which is affixed to the control rod by splines. This gear segment is actuated by another gear, which is affixed to a variable recoil cam. The variable

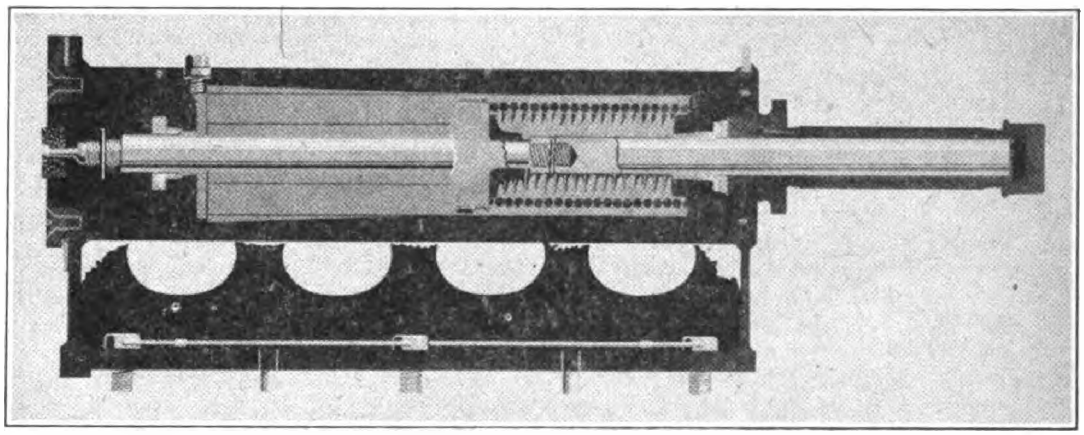

Figure 36. Independent Counterrecoil Buffer.

recoil mechanism assembly is connected to the top carriage in front and below the trunnions of the top carriage by a connecting rod. As the weapon is elevated, the distance between the rear of the variable recoil mechanism is lengthened. The connecting rod pulls a shaft out of the variable recoil mechanism which rotates a cam. This cam has the gear segment attached to it by means of splines. This permits the long shallow grooves, the short deep grooves, or any portion of the shallow grooves in combination with any portion of the deep grooves, to be rotated opposite the ports in the recoil piston. Since different

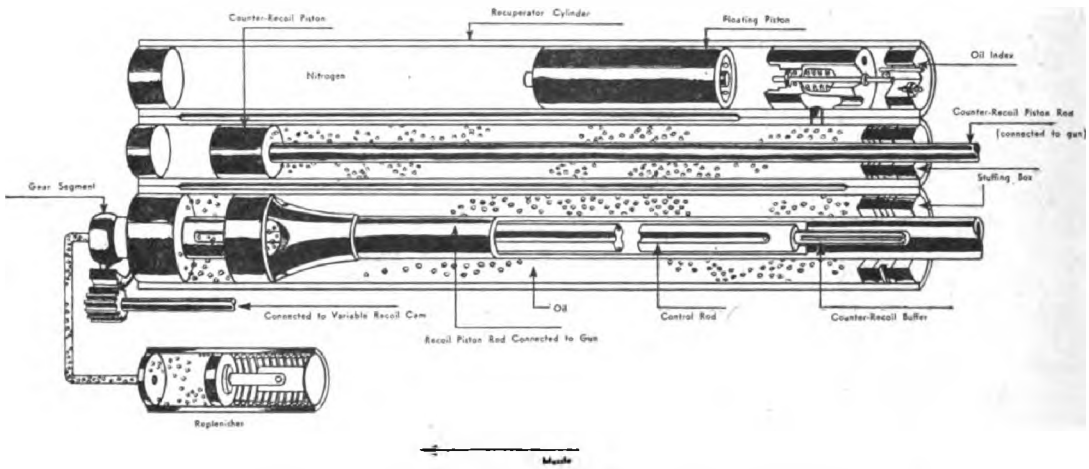

Figure 37. Rod-Controlled Variable Recoil Mechanism.

grooves may be exposed to the ports of the recoil piston, resistance to the movement of the piston may be varied. The set of grooves, or the amount of all four grooves, exposed to the piston will determine the length of recoil, assuring that the expanding propellent gases exert the same force each time the weapon is fired. The resistance to the piston's movement will increase as the length of recoil increases, because the throttling grooves become more shallow at their rear. This increasing resistance results in a uniform decrease in the speed of recoil.

The control rod also has a buffer rod on the rear, which fits inside a smaller

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cylindrical cavity in the rear of the hollow piston rod and acts as a dashpot buffer near the end of counterrecoil. The buffer rod has two tapered grooves, shallow at the front and becoming deeper towards the rear. Holes are drilled in the control rod at the end of the long shallow grooves and at the front end of the buffer rod; these holes are connected in the center. The buffer rod is withdrawn from the cavity in the recoil piston rod and is replaced with oil while the mechanism is recoiling. When the piston orifices no longer have any grooves exposed, the weapon is brought to a stop, because no more oil can pass from the rear to the front of the recoil piston.

When recoil cases and counterrecoil begins, the flow of oil is reversed. The oil flows from the front to the rear of the recoil piston through the orifice formed by the ports in the recoil piston in combination with the throttling grooves. Since the throttling area of these orifices is increasing as counterrecoil progresses, the resistance to the movement of the recoil piston decreases so that this action cannot be considered as a counterrecoil buffer. Oil, which during recoil moved inside the hollow piston rod, is expelled from the hollow piston rod during counterrecoil by the control rod. The clearance is small between the exterior of the control rod and the interior of the hollow piston rod, and as a result, the oil resists the forward movement of the piston rod. Just before the piston rod reaches the in battery position, the small cavity in the rear of the piston rod slides over the buffer rod. The oil contained inside the cylindrical cavity resists the piston rod's forward movement due to the displacement of oil by the buffer rod. The only means of escape is through the two tapered grooves. This increased resistance accomplishes the counterrecoil buffing, easing the gun into battery without undue shock to the carriage.

The counterrecoil mechanism consists of two cylinders. One of these cylinders is called the counterrecoil cylinder, the other the recuperator cylinder. The counterrecoil cylinder contains the counterrecoil piston, the piston rod, and a quantity of oil. The recuperator cylinder contains a one-way valve in a regulator body and a floating piston which separates the nitrogen gas from the oil.

As the piece recoils, the counterrecoil piston and piston rod are pulled out of the counterrecoil cylinder, forcing oil from the counterrecoil cylinder through a connecting port into the recuperator cylinder. As the oil enters the recuperator cylinder under pressure, it unseats a spring loaded one-way valve, permitting a restricted flow of oil around it and a small amount through two ⅛-inch holes in the face of the valve. The floating piston is moved forward by the greater quantity of oil, thus further compressing the nitrogen gas. When the force of recoil has been stopped, the compressed nitrogen gas moves the floating piston to the rear in counterrecoil, pushing the oil before it under pressure. Since the one-way valve is closed at the end of recoil due to spring compression and oil pressure, the only openings though which the oil can now pass are the two ⅛-inch openings in the one-way valve. After passing through these restricted openings, the oil moves through the connecting port of the counterrecoil and recuperator cylinders, applying pressure to the rear of the counterrecoil piston. This returns the piece to the 'in battery' position.

Since the oil is being restricted in its flow by the small openings in the one-way valve, a slowing down of counterrecoil results until the buffer in the recoil cylinder enters the dashpot.

The replenisher cylinder, which contains a spring-operated piston, will replenish the supply of oil in the recoil cylinder in the event of leakage or contraction of oil, and provides an expansion chamber for the relief of an excessive volume of oil in the recoil cylinder due to heat from atmosphere or firing. This assures return of the gun to the 'in battery' position.

THEORY OF THE MANOMETER TEST

Having discussed generally the operation of a typical recoil mechanism of the hydro-pneumatic type having a floating piston, let us now look to certain fundamental principles involved in the theory of the manometer test. It is to be remembered that some of the things to be determined by the manometer test are the actual gas pressure and the friction of the floating piston.

Suppose, as shown in figure 38, a man pushes in the direction of the arrow

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against a box which is resting on the floor. Between the box and a fixed vertical wall is arranged a coil spring. For every force exerted there is an equal force acting in the opposite direction. Stated more briefly—for every action there is an equal and opposite reaction. This is a fundamental principle of forces.

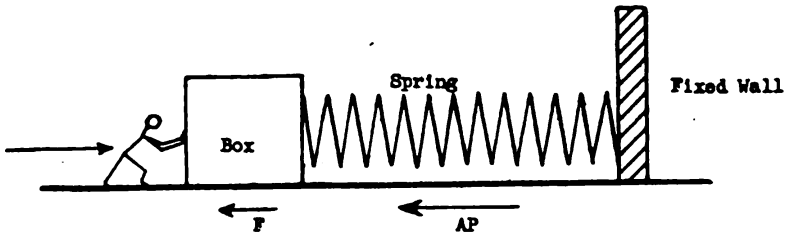

Figure 38. Force Exerted by Man = AP + F.

Referring to figure 38, the force exerted by the man is resisted, first, by the friction between the box and the floor, which friction is moving friction rather than static friction, and which acts in a direction opposite to the direction of movement of the box; and secondly, by the force exerted by the coil spring which also acts in a direction opposite to the direction of movement of the box. The friction is designated by F and the spring force is represented by AP. *Thus AP + F is the force exerted by the man.*

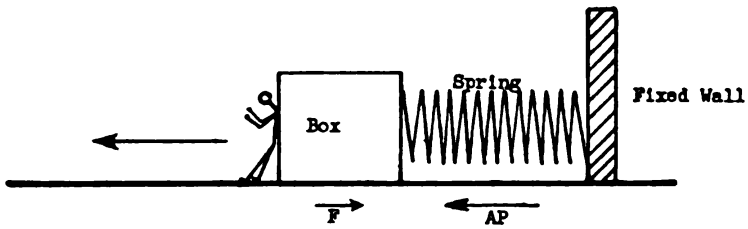

Figure 39. Force Exerted Against Man = AP — F.

Suppose now that the man has moved the box a certain distance closer to the wall. He leans his back against the box and allows the box to push him. Referring to figure 39, the box moves in the opposite direction as shown by the arrow. Remembering that the friction between the box and the floor always acts in a direction opposite to the direction of movement of the box, let us examine what force is acting against the man. This force comprises, first, the force of the spring which is acting in the same direction as the movement of the box, and, second, the friction which acts in opposition to the movement of the box. The resultant force acting against the man is the spring force minus friction of the box. *Thus the force exerted against the man is AP — F.*

By way of analogy, let us compare figures 40 and 41 to figures 38 and 39 respectively.

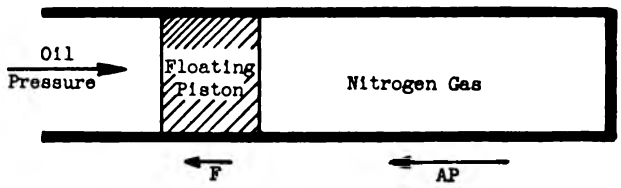

Figure 40. Oil Pressure = AP + F.

In figure 40 is shown a floating piston arranged in a cylinder containing a volume of nitrogen gas, under an initial pressure, between the floating piston and the closed end of the cylinder. Oil under pressure engages the opposite side of the floating piston.

The nitrogen gas under pressure is comparable to the spring so far as its elastic

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properties are concerned, and the friction between the floating piston and the cylinder wall is comparable to the friction between the box and the floor.

As diagrammatically represented in figure 40, suppose the oil pressure is increased until the floating piston moves in the direction of the arrow shown, thereby compressing the gas. The force resisting the oil pressure is made up of the friction of the floating piston, a friction which acts in a direction opposite to the direction of movement of the floating piston, and by pressure of the nitrogen gas. The friction of the floating piston is represented by F, and the force exerted by the gas pressure against the floating piston by AP. *Thus the oil pressure is equal to AP + F.*

It is readily seen how the forces involved in figure 40 are analogous to the forces involved in figure 38; the gas being substituted for the coil spring, the floating piston for the box, cylinder wall for the floor and fixed cylinder, and the oil pressure for the man.

Turning now to Figure 41, which corresponds to Figure 39, let us decrease the oil pressure so that the force exerted by the gas pressure is great enough to move the floating piston in the opposite direction, as shown by the arrow. The force acting against the oil, and thereby producing the oil pressure, comprises first, the force exerted by the gas pressure against the floating piston, which force acts in the same direction in which the floating piston moves, and second, by the friction between the floating piston and the cylinder wall, which friction acts in a direction opposite to the direction of movement of the floating piston. The force exerted by the gas pressure is again represented by AP and the friction of the floating piston by F. *Thus the oil pressure is equal to AP — F.*

We will now examine the application of the principles discussed above to a typical recoil mechanism. In figure 42 there is shown a piston and piston rod arranged in a cylinder and a floating piston arranged in a second cylinder. The interiors of both cylinders are placed in communication by a connecting port. Oil completely fills the space in both cylinders between the recoil piston and the floating piston. Nitrogen gas under an initial pressure fills the space between the floating piston and the end of the cylinder. For simplicity no throttling means for the oil are shown. A gage is suitably connected to the body of the oil.

A piston rod jack is arranged in the forward end of the recoil cylinder and by turning the handle of the jack the recoil piston can be moved to the rear, thereby displacing oil from the recoil cylinder through the port into the counterrecoil cylinder. The increase in volume of oil in the counterrecoil cylinder will force the floating piston to move, thereby compressing the gas.

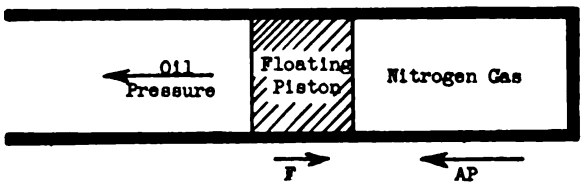

Figure 41. Oil Pressure = AP — F.

By operating the piston rod jack, the floating piston is caused to be moved to a position indicated by the line A-A as shown in figure 42. While the piston is moving past this position the reading on the gage is noted. *This reading represents AP + F.*

The jack is continued to be operated in the same manner to move the floating piston further past the position indicated by the line A-A. Operation of the jack is then reversed thereby causing the gas to expand and displace oil from the counterrecoil cylinder through the connecting port into the recoil cylinder. Again when the floating piston is in the position indicated by the line A-A, except that it is now moving in the opposite direction, the reading on the gage is noted. *This reading represents AP — F.*

It is important that the readings on the gage are taken only when the floating piston is moving so that the effect of the friction of the floating piston on the oil pressure is caused by moving friction.

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We now have two gage readings which represent AP + F and AP — F. How can we use these readings to ascertain the value of AP and F individually?

If we add AP + F to AP — F the result will be 2AP since the — F will cancel the + F. To find AP it is merely necessary to divide by 2.

Expressed algebraically:

$$(AP + F) + (AP - F) = AP + F + AP - F$$
$$AP + F + AP - F = 2AP$$
$$\frac{2AP}{2} = AP$$

Therefore:

$$AP = \frac{(AP + F) + (AP - F)}{2}$$

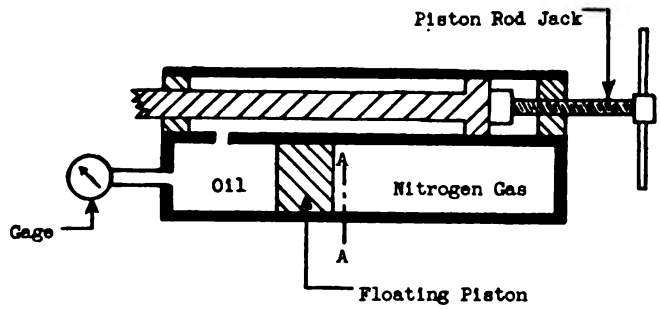

Figure 42.

It will therefore be seen that the gage pressure AP can be computed by adding together the two readings and dividing the sum by two.

Example:

Where AP + F = 1100 lbs. per sq. in.
AP — F = 900 lbs. per sq. in.

$$AP = \frac{1100 + 900}{2}$$
$$= \frac{2000}{2}$$
$$AP = 1000 \text{ lbs. per sq. in.}$$

If we subtract AP — F from AP + F the result will be 2F since the — AP will cancel the + AP. Dividing 2F by 2 leaves F.

Expressed algebraically:

$$(AP + F) - (AP - F) = AP + F - AP + F$$
$$AP + F - AP + F = 2F$$
$$\frac{2F}{2} = F$$

Therefore:

$$F = \frac{(AP + F) - (AP - F)}{2}$$

It will therefore be seen that the friction of the floating piston can be computed by subtracting the gage reading representing AP — F from the gage reading representing AP + F and dividing the remainder by two.

Example:

Where AP + F = 1100 lbs. per sq. in.
AP — F = 900 lbs. per sq. in.

$$F = \frac{1100 - 900}{2}$$
$$= \frac{200}{2}$$
$$F = 100 \text{ lbs. per sq. in.}$$

It is to be noted that the friction of the floating piston is not determined as

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such but rather its effect upon the pressure of the oil. This is the reason the friction is expressed in terms of pressure. Pressure is force per unit area, such as lbs. per sq. in.

It is a well known fact that the pressure of a constant volume of gas will increase as the temperature of the gas is raised. Conversely, the pressure will decrease if the temperature is lowered.

As a result of the manometer test the actual pressure of the gas AP is determined. However, this in and of itself does not tell us that the actual pressure of the gas is within the proper allowable limits. The actual pressure must be compared to the pressure under which the mechanism was charged with gas. The mechanism might have been charged with gas at a temperature different from that at which the manometer test was performed. It is therefore necessary to make a correction in the pressure of the gas, where the temperature at which the mechanism was charged is different from that at which the manometer test is made, before the actual pressure can be compared with the pressure of the gas that should be present.

The proper charged pressure is corrected to correspond to the temperature of the recoil mechanism existing at the time of the manometer test.

It has been found that the pressure of a gas will increase 1/272 of its pressure at 0°C (Centigrade) for every increase of 1°C in temperature, the volume of the gas remaining constant. Therefore, if the gas is cooled 273° below 0°C, it will lose 273/273 of its pressure at 0°C, that is, its pressure would become zero at —273°C. Since pressure is due to molecular motion, no pressure would mean no motion, hence no heat.

As graphically represented in figure 43, there is a direct proportional relation between the pressure and temperature of a constant volume of gas.

At 0°C assume the pressure of the constant volume of gas is **x** lbs. per sq. in. (PSI). At—273°C the pressure of the gas is 0 lbs. per sq. in. At an intermediate temperature there is a change of 1/273 **x** lbs. per sq. in. for a change of 1°C, as shown in figure 43.

A temperature of —273°C is the true absolute zero of temperature. Temperatures computed on the basis of this zero are called absolute temperatures. 0°C is 273° on the absolute temperature scale.

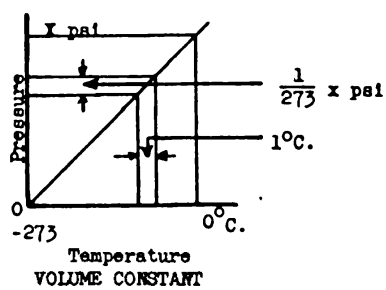

Figure 43. Temperature Volume Constant.

It is readily apparent that the pressure temperature relation must be expressed in terms of absolute pressures and absolute temperatures. Thus, if P_1 is the initial absolute pressure, T_1 the initial absolute temperature, P_2 the final absolute pressure, and T_2 the final absolute temperature, we can say:

$$P_1 : T_1 :: P_2 : T_2$$

Algebraically:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Solving for P_2:

$$P_2 = \frac{P_1 T_2}{T_1}$$

Problem: A constant volume of gas under an initial absolute pressure of 1000 lbs. per sq. in. at a temperature of 10°C is heated so that the temperature of the gas is raised to 30°C. What is the final absolute pressure?

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$P_1 = 1000$ lbs. per sq. in.

$P_2 =$ unknown

$T_1 = 10°C + 273 = 283°$

$T_2 = 30°C + 273 = 303°$

$$P_2 = \frac{P_1 T_2}{T_1}$$

$$= \frac{(1000)\ (303)}{283}$$

$P_2 = 1070$ lbs. per sq. in.

By correcting the initial known pressure P_1 to which the mechanism was charged with gas at an initial known temperature T_1, to a pressure P_2 corresponding to the temperature of the gas T_2 when the manometer test was performed, the actual pressure AP can be compared to the corrected pressure P_2 to ascertain whether it is within the allowable tolerance.

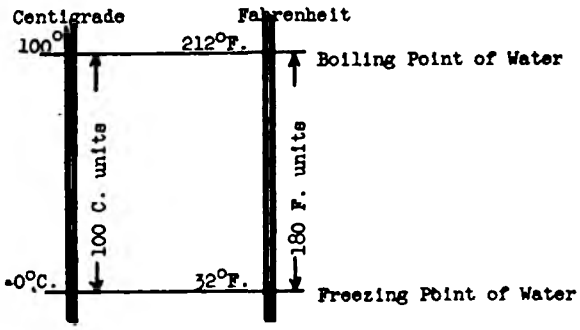

Figure 44.

Sometimes a temperature is given in Centigrade units, and it is necessary to convert it to Fahrenheit units or vice versa. It is well known that water freezes at 0°C and boils at 100°C; also, that water freezes at 32°F and boils at 212°F. 0°C and 32°F represent the same actual temperature, as also do 100°C and 212°F, although expressed in different units. This is illustrated in figure 44.

Since the same temperature range is divided into 180 equal units in the Fahrenheit scale and 100 units in the Centigrade scale, 180 Fahrenheit degrees are equal to 100 Centigrade degrees, or 9F degrees = 5C degrees, or 1F degree = 5/9C degree.

To obtain the number of degrees from any point on the Fahrenheit scale to the freezing point, 32° must always be subtracted from the reading. Thus 42°F is only 10° above freezing point, and —8°F is (—8 —32) or —40° below the freezing point. The following formula can be used to convert readings on one scale to the other;

$$\frac{F - 32}{180} = \frac{C}{100}$$

or

$$C = \frac{5}{9}(F - 32)$$

$$F = \frac{9C}{5} + 32$$

Let us now change a temperature expressed in Fahrenheit units to an absolute temperature using Fahrenheit units. In figure 45 is shown a comparison of Centigrade, Fahrenheit and Absolute scales, the latter employing both Centigrade and Fahrenheit units.

We have seen that —273°C is absolute zero on the absolute temperature scale. Absolute temperatures can also be expressed in Fahrenheit units. Using the formula to convert —273° to Fahrenheit proceed as follows:

$$F = \frac{9C}{5} + 32$$

$$= \frac{9}{5}(-273) + 32$$

$$= -492 + 32$$

$$F = -460°$$

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In other words —273°C is the same temperature as —460°F. Therefore absolute zero is also —460°F. To change a known Fahrenheit temperature to the absolute scale, add 460 to the Fahrenheit reading. Thus 50°F is 50 + 460 or 510 on the absolute temperature scale. Note that 0°F is 32° below the freezing point of water. The freezing point of water on the absolute scale is 460 + 32 or 492° absolute temperature. This is illustrated in figure 45.

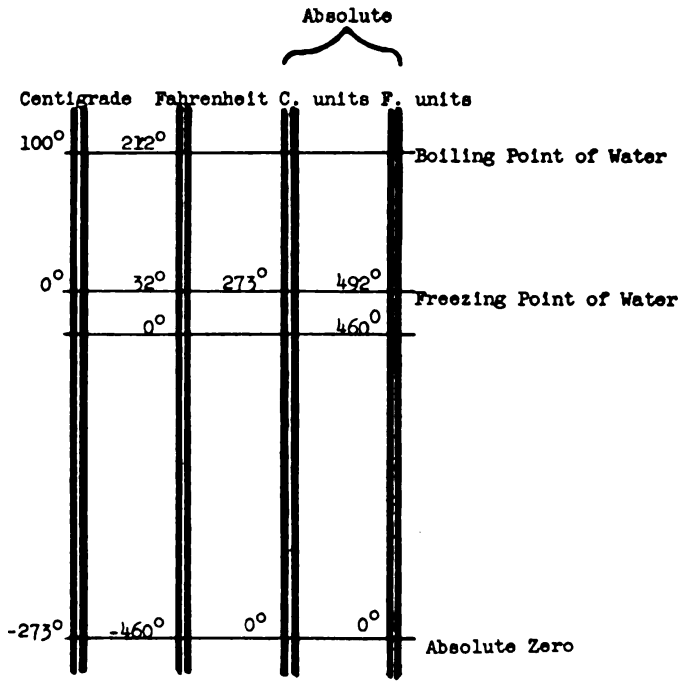

Figure 45.

Comprehensive Problem:

A recoil mechanism is charged with gas to a pressure of 1200 lbs. per sq. in. at a temperature of 20°C. A manometer test is made at a temperature of 77°F with the following findings: AP + F — 1300 lbs. per sq. in., AP — F = 1050 lbs. per sq. in. Find AP and F.

To find actual gas pressure:

$$AP = \frac{(AP + F) + (AP - F)}{2}$$

$$= \frac{1300 + 1050}{2}$$

$$AP = 1175 \text{ lbs. per sq. in.}$$

To find friction of floating piston:

$$F = \frac{(AP + F) - (AP - F)}{2}$$

$$= \frac{1300 - 1050}{2}$$

$$F = 125 \text{ lbs. per sq. in.}$$

Frictions of the floating piston, and combined friction of the recoil piston and stuffing box, will not be considered as affecting serviceability. Previously, inspection of recoil mechanisms has provided for determination of frictions by the manometer test; if above or below certain limits, the mechanism was declared unserviceable. Manometer test instructions, given in pertinent 1000-series Technical Manuals, prescribe measurement of frictions; however, those operations which pertain to the measurement of frictions will be disregarded in the future when making manometer tests. Mechanisms will not be declared unserviceable because of friction determinations.

To change 77°F to a Centigrade reading:

$$C = \frac{5}{9}((77 - 32)$$

$$= \frac{5}{9}(F - 32)$$

$$C = 25°$$

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To correct the changed pressures:

P_1 = 1200 lbs. per sq. in.

P_2 = unknown

T_1 = 20°C + 273 = 293°

T_2 = 25°C + 273 = 298°

$$P_2 = \frac{P_1 T_2}{T_1} = \frac{(1200)\ (298)}{293}$$

$$P_2 = 1220$$

Difference between corrected pressure and actual pressure:

P_2 — AP = 1220 — 1175 = 45 lbs. per sq. in.

Depending upon what tolerance for AP is permitted, the above difference may or may not be within the prescribed limits.

From the foregoing it will be seen that the procedure to be followed in performing a manometer test on a specific recoil mechanism was not discussed, but rather that this discussion covered a consideration of the underlying principles involved in the theory of the manometer test and certain computations of the results thereof.

SLEIGH, CRADLE AND CARRIAGE COMPONENTS

Sleigh. The sleigh, when present, is that part of a weapon which forms immediate support of a cannon. Usually it will house the recoil mechanism. In some cases the sleigh is a block of metal into which the cylinders of the recoil mechanism are bored; in others, the cylinders are separate tubes rigidly fastened together forming the sleigh. The cannon is securely fastened to the sleigh, and the sleigh moves with the cannon in recoil and counterrecoil.

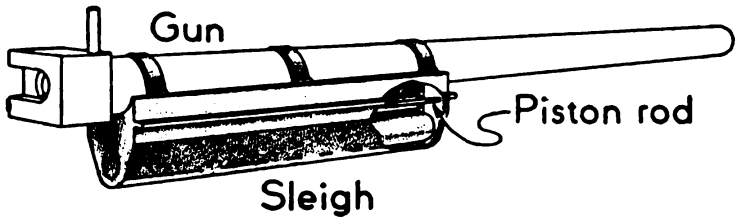

Figure 46. Sleigh.

Cradle. The cradle is that part of a weapoon which supports the cannon and the sleigh. When no sleigh is used, the cradle houses the recoil mechanism. In general, the cradle is a U-shaped trough which has slides or roller paths along which the gun recoils. When a sleigh is used, the recoil piston rod or rods are secured to the cradle. The cradle is provided with trunnions about which the tipping parts rotate in elevation.

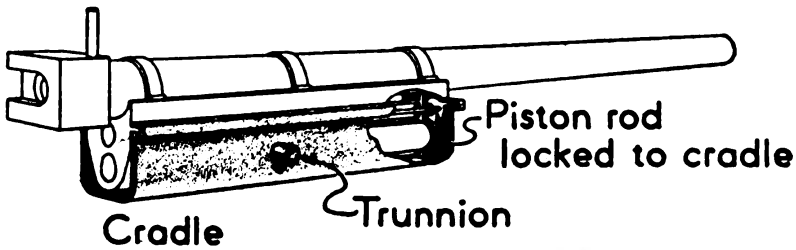

Figure 47. Cradle.

Top Carriage. The top carriage, when present, provides trunnion bearings into which the trunnions of the cradle fit. The top carriage supports the tipping parts and has mounted to it those parts of the elevating mechanism which do not move in elevation, and those parts of the traversing mechanism which move in traverse. The top carriage moves in traverse but does not move when the tipping parts are elevated. In traversing, the top carriage rotates in a horizontal plane pivoting about the pintle which is a part of, or attached to, the bottom carriage.

On weapons employing axle traverse there is no top carriage. Its functions are performed by the upper part of the box trail.

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Bottom Carriage. The bottom carriage is that part of the carriage assembly which supports the top carriage. It does not move in traverse or in elevation and has mounted to it those parts of the traversing mechanism which do not move in traverse. The bottom carriage provides the pintle about which the top carriage rotates.

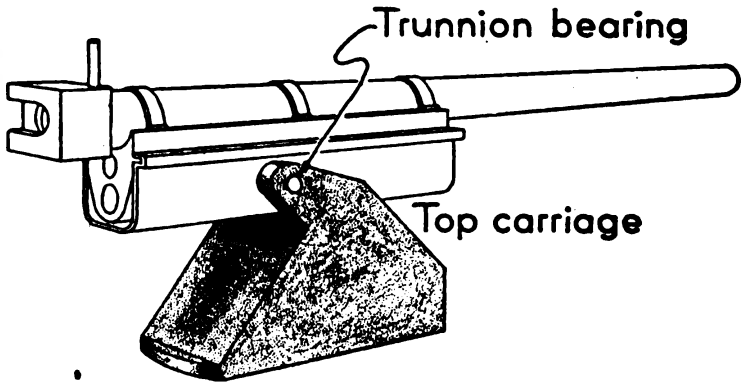

Figure 48. Top Carriage.

On mobile mounts, the wheels and axle, firing jacks, trails, and equalizing supports will be a part of the bottom carriage.

Function. Elevating mechanisms are used for placing and holding the axis of the bore at a desired inclination to a horizontal plane. There are two types of elevating mechanisms—the rack and pinion type and the screw type.

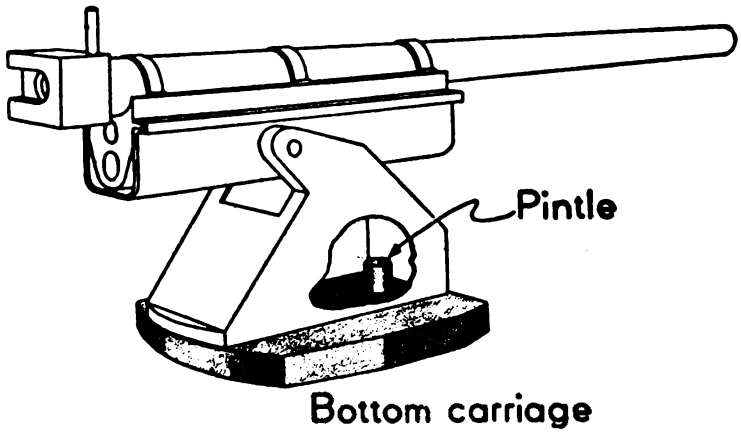

Figure 49. Bottom Carriage.

ELEVATING MECHANISMS

Rack and Pinion Type. The rack and pinion type of elevating mechanism consists of an arc, called the rack or segment, which is attached to the tipping parts. The rack is moved by a pinion which is attached to the top carriage. The pinion is rotated by a handwheel, which is connected to the pinion by a gear train. As the rack is moved, the tipping parts rotate about a pivot point. This pivot point is known as the trunnion.

In some cases it will be found that the arc is fastened to the fixed parts of the carriage, while the pinion is attached to the tipping parts. When such is the case, the pinion, upon rotation, will "walk" along the arc. As the pinion walks along the arc, the tipping parts are rotated about their trunnions.

The rack and pinion type of mechanism may contain a worm and worm wheel. The worms used are irreversible. This means that one cannot cause the pinion to rotate except by turning the elevation handwheel. The irreversible worms are used to provide a simple method of holding the tube at any point of elevation.

Where a higher speed of rotation is desirable, the worm may have a double

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set of threads. This arrangement is similar to the threads on an ordinary fountain pen. With two sets of threads, the speed of the worm wheel will be doubled, without increasing the speed of rotation of the worm.

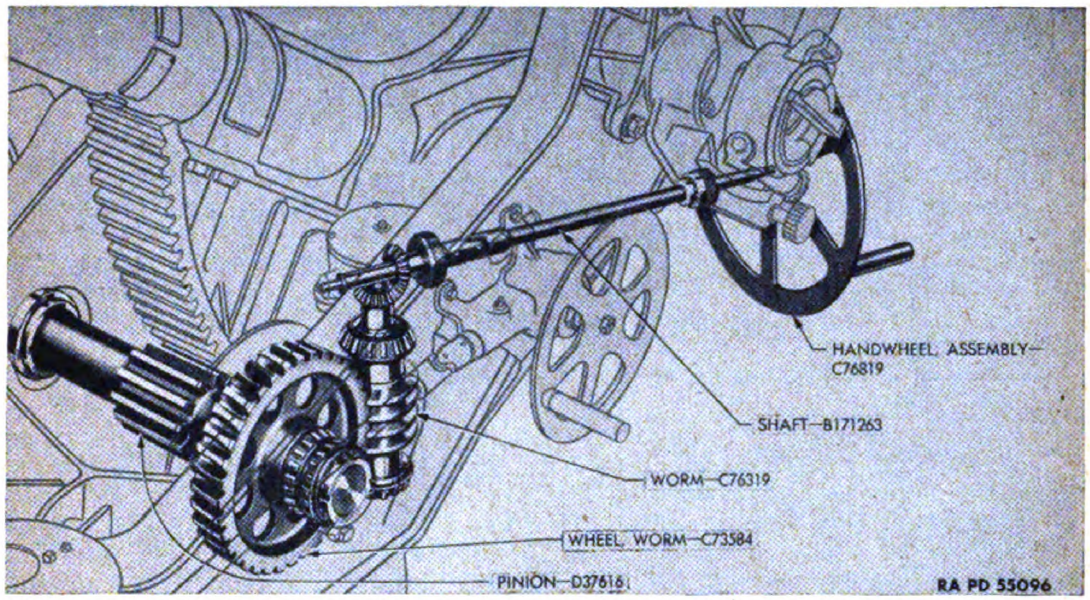

Figure 50. Rack and Pinion Elevating Mechanism.

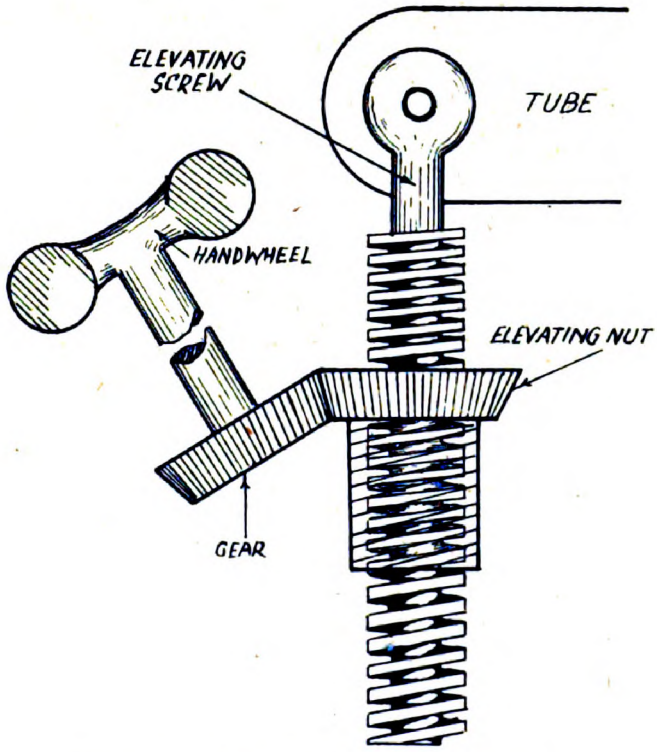

Figure 51. Screw Type Elevating Mechanism.

Both types of worms are irreversible, but, in the event of excessive strain being put upon the elevating mechanism, both the single and double thread worms may be capable of reversing motion. (An example of excessive strain is the removal of the tube without disconnecting the equilibrator.) In the case of the single

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thread worm, this reversing action is possible because of excessive wear; whereas in the case of the double thread worm, this reversing action results from an inherent weakness, due to the design. In either case the handwheel must be rotated, starting the movement before the excessive strain can cause the pinion to be rotated, reversing the flow of power through the gear train.

Those weapons, which in addition to being manually controlled, are operated by remote control systems will have some type of remote control operating motor, linked, by gears, to the elevating mechanism gear train.

Those rack and pinion types of elevating mechanisms which do not contain worms and worm wheels consist of simple gear trains. Incorporated in their construction are brakes which are used to hold the tube at any elevation.

Screw Type. The screw type elevating mechanism consists essentially of a screw and nut. The nut is fastened so that it is capable of rotation but will not have linear movement. The screw is incapable of rotation but may move up and down through the nut. The end of the screw is fixed to the tipping parts so that as the nut is rotated the screw causes the tipping parts to pivot about their trunnions.

The nut will be rotated by means of a handwheel through a gear train.

EQUILIBRATORS

An equilibrator is a mechanism for applying a force to the nonrecoiling tipping parts of a weapon to overcome the effect of muzzle preponderance. This force also insures a uniform handwheel effort throughout the range of elevation and depression. Some weapons have the trunnions mounted at the center of gravity of the tipping parts and do not require equilibrators. Included in this group are several types of antitank guns and some weapons of older design. Field and antiaircraft artillery, excluding the antitank guns, require high angles of elevation. In order to obtain high angles of elevation, the trunnions must be mounted near the breech end of the tube to the rear of the center of gravity of the tipping parts. Equilibrators are required to overcome the muzzle preponderance produced when the trunnions are arranged in this manner.

In the following paragraphs a description will be given of the different kinds, types, construction, and function of equilibrators which are found on field artillery and antiaircraft artillery weapons. There are several different types classified according to their construction:

1. SPRING .....Action of a compressed spring.
2. PNEUMATIC .....Action of a compressed gas—(nitrogen).
3. HYDRO-PNEUMATIC ....Combination of oil and gas pressure.

These types can be put into three general classifications according to the method by which they are employed with respect to the direction of the force applied and the position of the mounting of the equilibrator.

1. PUSHER .....Pushes up against the muzzle end of the weapon.
2. PULLER .....Pulls down on the breech end of the weapon.
3. LIFTER .....Lifts up on the muzzle end of the weapon.

Spring Equilibrators. On light field artillery weapons the force needed to overcome the effect of muzzle preponderance is small, enabling the use of springs without creating too much bulk or weight. The *Spring pusher* type of equilibrator consists of two telescoping sleeves which form the housing for a single helical spring always under compression.

The force of the spring is exerted downward against a non-tipping part, and upward against the cradle. This force is exerted to the muzzle end or to the front of the trunnions.

Figure 53 shows the piece fully elevated. It can be readily seen that the spring has expanded and aided in elevating the piece. It must be remembered that during depression the weight of the tipping parts must compress the spring, which neutralizes the force of gravity and insures uniform handwheel effort when depressing.

Field and antiaircraft artillery commonly employ the **spring puller** type equilibrator. Some digerences exist in the redesign and construction between those types used on the field artillery weapons and those used on the antiaircraft weapons, nevertheless they are both classified as Puller type equilibrators. The

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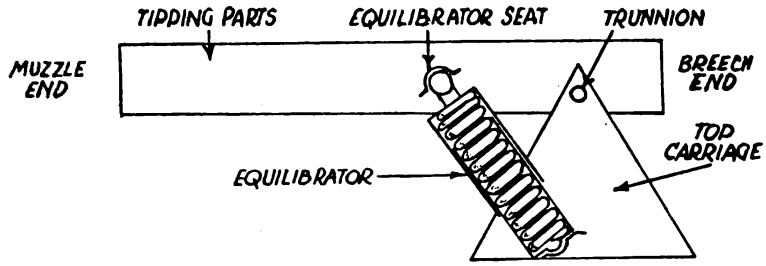

Figure 52. Spring Pusher Equilibrator, 0° Elevation.

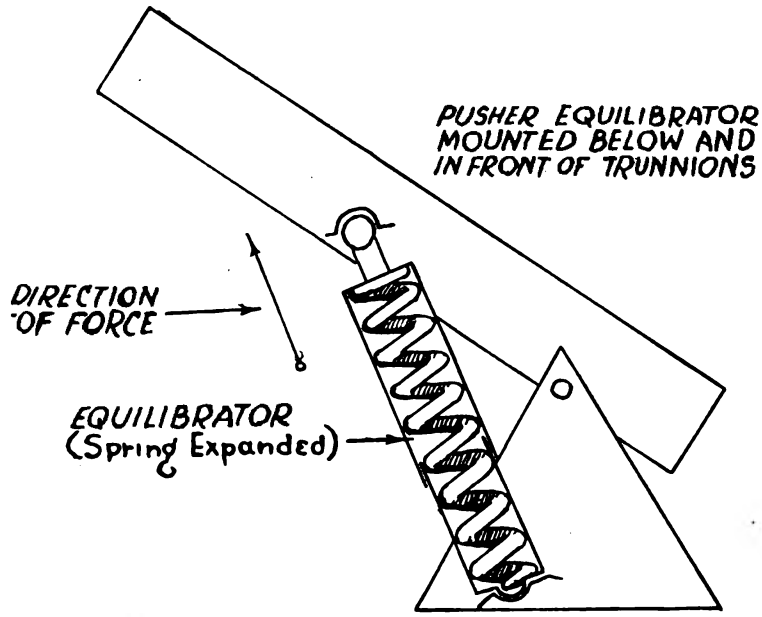

Figure 53. Spring Pusher Equilibrator. Full Elevation.

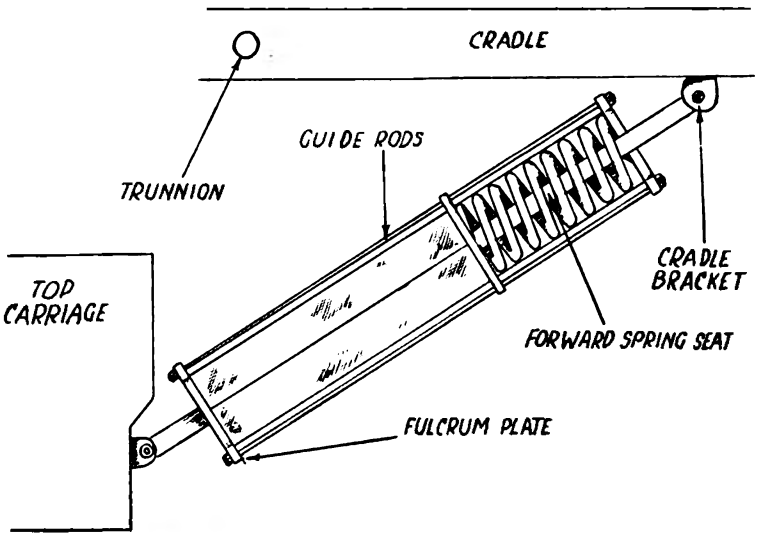

Figure 54. Spring Puller Equilibrator, Ground Weapon 0° Elevation.

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first of these to be described will be the type found on field pieces. From Figure 54. it can be seen that the spring exerts a downward pull on the cradle in the rear of the trunnions. The equilibrator consists of a double column of helical springs compressed between two spring seats. The forward spring seat slides along guide rods and is connected to the cradle bracket by the equilibrator spring rod. As the tipping parts are elevated the spring exerts a force against the spring seat and in turn pulls down on the rear end of the cradle. As the tipping parts approach the vertical plane of the trunnions, muzzle preponderance is decreasing and the spring expands decreasing the force exerted to the cannon. The equilibrator fulcrum is attached to the top carriage. It is well to remember that in all spring puller type of equilibrators the force of the spring is always applied to the rear portion of the cradle below the trunnions.

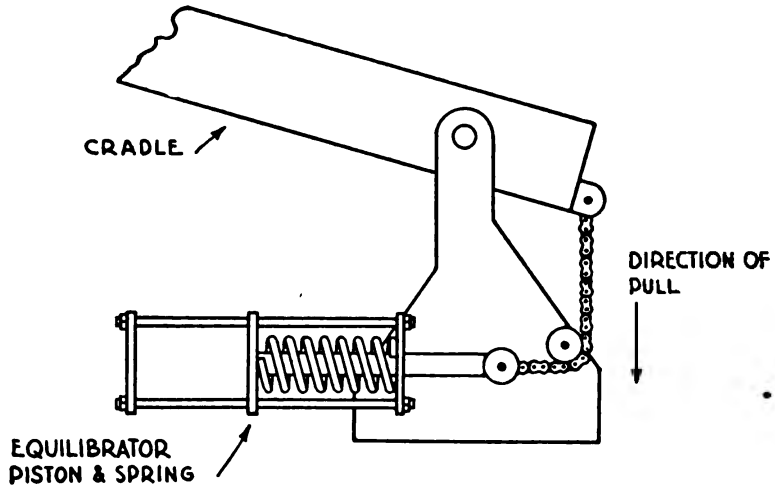

Figure 55. Spring Puller Equilibrator, Antiaircraft Weapon-Elevated

The spring puller type used on aircraft weapons can be seen in figure 55. A description of its functioning follows:

The force of the spring is exerted between the piston head and the rear end of the equilibrator cylinder. The cylinder is bolted to the top carriage and is held stationary. Connected to the piston rod on one end is the piston, and on the other end is a chain which is connected to the rear end of the cradle. As

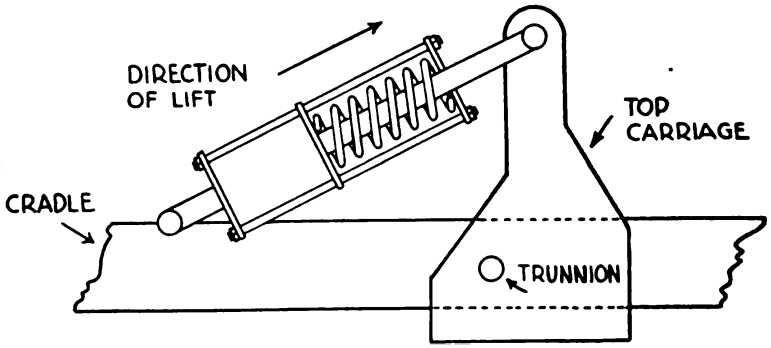

Figure 56. Spring Lifter Equilibrator, 0° Elevation.

the weapon is elevated the spring exerts its force against the movable piston, which tends to pull down on the rear end of the cradle thus permitting easy elevation. As full elevation is reached the force of the spring has decreased due to the spring's expansion.

The third general class to be described in the spring types will be that of the **Spring Lifter** type. It is very similar in design to that of the spring puller type and functions the same except that the force of the spring exerts its pressure so as to lift the front of the cradle.

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This type of equilibrator is mounted above and in front of the trunnions. It can be seen from figure 56 that the force of the spring is exerted to the rear spring seat forcing the front part of the cradle up.

The three general types of equilibrators just described are found on light and medium field artillery and on light antiaircraft weapons. They are ideally suited for these types of artillery because of their simple design, construction, light weight, ease of maintenance, and mechanical advantage.

Pneumatic Equilibrators use the force of nitrogen gas under compression for overcoming muzzle preponderance. This type is used on large ground weapons because an adequate spring for overcoming muzzle preponderance would be too bulky and have too much weight. The equilibrator consists primarily of cylindrical cases and plungers (hollow piston rod and a piston). The plungers are filled with nitrogen under pressure and the piston is equipped with a gas tight

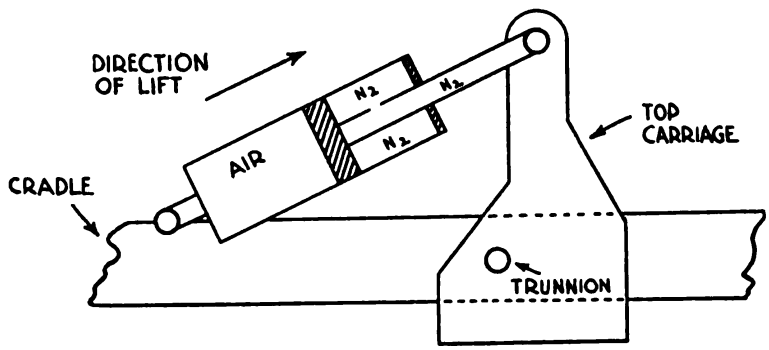

Figure 57. Pneumatic Lifter Equilibrator, 0° Elevation.

seal. The plungers are connected to the top carriage of the weapon as shown in figure 57, and the cases are connected to the tipping parts. As the weapon is elevated the nitrogen gas exerts its force against the immovable piston and the top end of the movable cylindrical case. This causes the cylindrical case to move up, which in turn aids in lifting the front of the cradle. It must be remembered that as the weapon is depressed the weight of the tube moving downward has to compress the nitrogen gas. This downward motion draws the top end of movable cylinder forward toward the stationary grease seal on the piston and further compresses the gas as shown in figure 57.

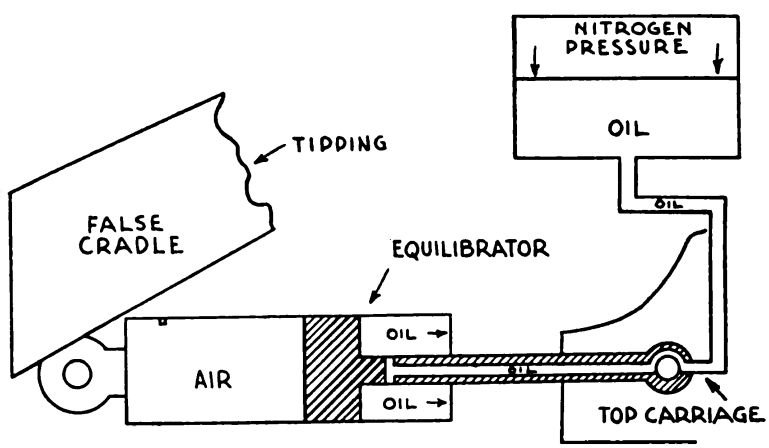

Figure 58. Hydro-Pneumatic Puller Equilibrator Ground Weapon—Maximum Depression.

Hydro-Pneumatic Equilibrators are used on both field and antiaircraft artillery weapons because the use of a large size spring would cause too much bulk and weight for the size of the carriage. The first to be described will be that which is used on field artillery weapons known as the *Hydro-Pneumatic Puller* type. It consists of a large tank, filled with nitrogen gas under pressure,

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a flexible copper tubing, and an equilibrator cylinder which is composed of a liquid-tight piston and piston rod which is hollow for the purpose of passing oil from the tank to the equilibrator cylinder. The equilibrator cylinder is connected to a false cradle, which supports the tube and recoil mechanism, and moves backward and forward as the piece is elevated or depressed. Referring to figure 58 it can be seen that as the piece is elevated the volume of the cylinder is increased, and that the nitrogen pressure through the oil is exerted upon the cylinder front head, moving it to the front and pulling downward on the rear end of the false cradle, thus overcoming the muzzle preponderance of the weapon. As the piece is elevated it will be noted that the nitrogen pressure decreases because of the increase in volume of the equilibrator cylinder.

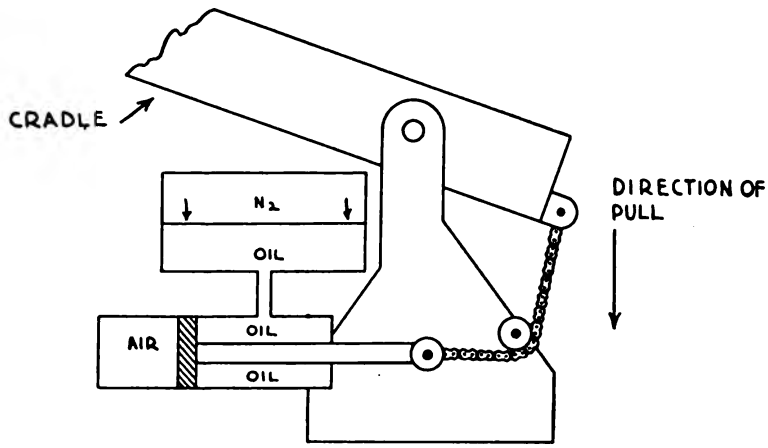

Figure 59. Hydro-Pneumatic Puller Equilibrator Antiaircraft Weapon Elevated.

The second type to be described is used on the large antiaircraft artillery weapons. It is similar in its function to the last described type as can be noted from figure 59. It is composed of two cylinders which contain nitrogen gas under pressure and oil, a liquid tight piston and piston rod, and a chain which connects the piston rod to the cradle. In this type it will be found that the piston and piston rod being connected to the cradle will move in and out of the cylinder when the piece is elevated or depressed.

TRAVERSING MECHANISMS

Function. A traversing mechanism is a device for making lateral changes in direction of the axis of a cannon bore. The moving parts may consist of only the cannon and the upper part of the carriage, or, in some cases, of the entire cannon and carriage except the axle. In the case of self-propelled artillery and certain types of railway artillery, the entire vehicle or railway car may be moved to traverse the cannon.

Traversing mechanisms are of three general types; axle, pintle, and base ring and racer.

Axle Traverse. In the axle type of traversing mechanism, the upper part of the carriage and the cannon are moved laterally along the axle, pivoting about the trail spade. The mechanism may consist of a threaded axle or a plain axle.

For axle traversing mechanisms incorporating a threaded axle, the axle may be considered to be a screw. The axle cannot move laterally since the tires are attached to the end of the axle and transmit the weight of the gun and carriage to the ground. Enclosing a portion of the threaded axle is a nut. The nut may have threads which mate with the threads on the axle, or it may contain ball bearings which use the threads of the nut as an outer race and the threads of the axle as the inner race. In either case the principle involved is the same.

The traversing nut is fastened to the carriage and upon rotation follows the threads of the axle. Since the traversing nut is fastened to the carriage and since the axle cannot move laterally, the gun and carriage are moved laterally, pivoting about the trail spade.

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Rotation of the traversing nut may be accomplished by a handwheel which is an integral part of the traversing nut. This type of mechanism is limited in its employment since the maximum amount of power obtainable is at best, small. In order to gain a greater amount of power the traversing nut may be

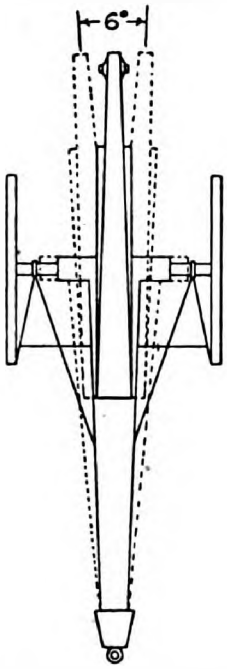

Figure 60. Axle Traverse (Schematic Drawing).

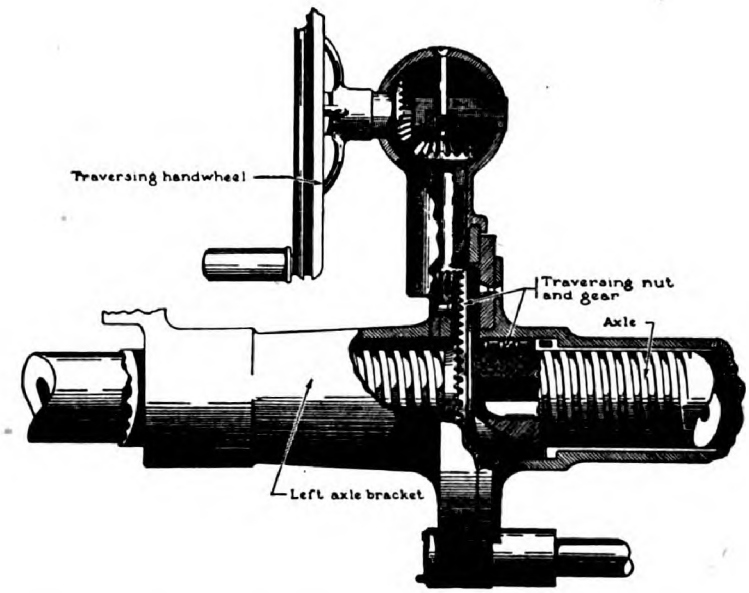

Figure 61. Axle Traverse with Threaded Axle and Traversing Nut.

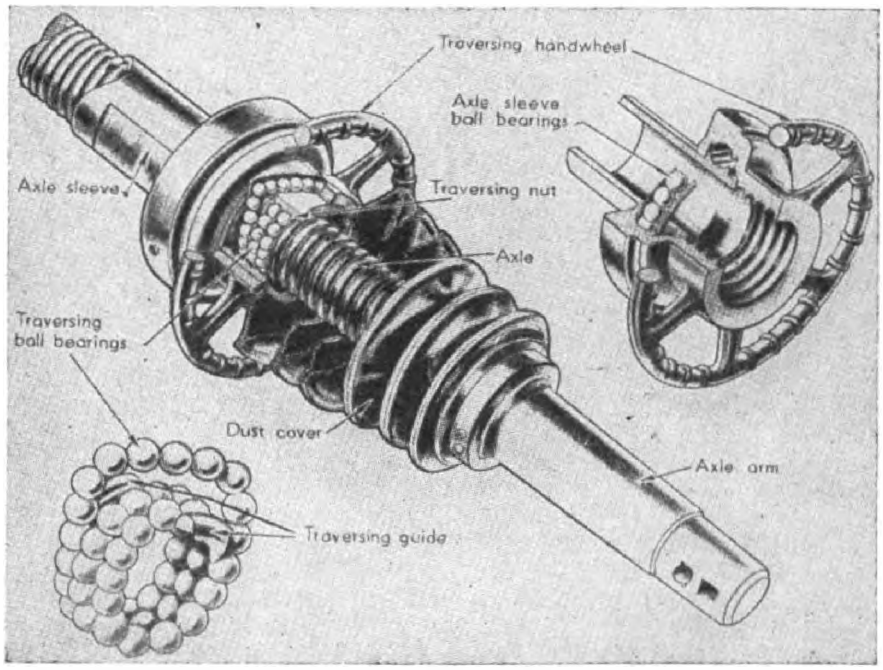

Figure 62. Axle Traverse with Threaded Axle and Handwheel-Nut Assembly.

rotated by a system of gearing whose movement is initiated by the operator through a handwheel.

In the mechanism employing a smooth axle, the axle is prevented from rotating by rods, which have one end fastened to the end of the axle and the other end

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affixed to the carriage. The axle cannot move laterally because the wheels are in contact with the ground. Two traversing rollers are mounted to the carriage. One roller is positioned at either end of the axle and contacts the axle. The weight of the carriage is transmitted through these rollers to the axle, while the weapon is in the firing position. Keyed to the axle is a traversing nut, through which passes the traversing screw. The traversing screw may rotate but cannot change its position inside of the carriage.

The traversing screw is rotated by the operator through a handwheel and gear train. Since the traversing screw works in the traversing nut, and since the traversing nut is keyed to the axle and cannot move in respect to the axle, the traversing screw must move. The traversing screw cannot change its position in the carriage so that as the traversing screw is rotated, the carriage is moved laterally along the axle.

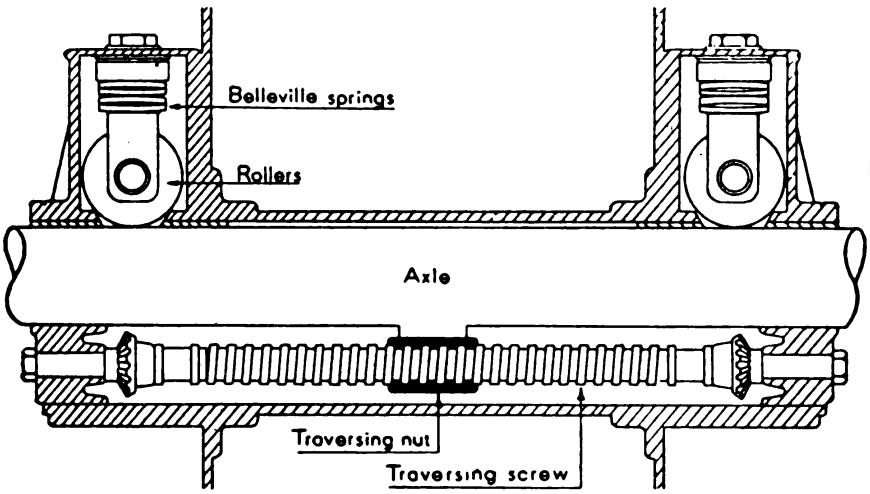

Figure 63. Axle Traverse With Separate Traversing Screw and Nut.

Pintle Traverse. In the pintle type of traversing mechanism, the top carriage is rotated about a vertical pivot which is fixed to the axle on the underpart of the carriage. This mechanism is the only type suitable for use with the split trail carriage.

The mechanism consists of a handwheel and a shaft which operate, either directly or through a train of gears, on a worm and rack or on a pinion and rack.

In most types, the rack will be secured to some fixed portion of the bottom carriage. The rack pinion will be attached to the top carriage. A pintle on the bottom of the top carriage fits into a corresponding bearing on the bottom carriage. The weight of the traversing parts is supported on a bearing or on a bearing assembly as may prove necessary for ease of traverse.

Movement of the handwheel will energize the power train moving the pinion. The rack pinion upon rotation walks around the rack and will move the carriage in traverse. The traversing rack is usually of necessary range to permit approximately 45° traverse in either direction. This type of traverse is adaptable to most ground and field artillery pieces and allows much more traverse than the axle type. Shock of the weapon firing is transmitted from the top carriage, through the bearing to the bottom carriage then through the trails to the ground.

Base Ring and Racer Traverse. Essentially the base ring and racer type of mechanism consists of a pinion which meshes with a circular gear, called the rack, and an antifriction bearing which permits ease of traverse. The rack is bolted to the bottom carriage and is positioned so that it is concentric with the center of rotation.

The pinion is mounted on the top carriage and meshes with the rack. As the pinion is rotated it walks around the rack. Because the pinion is mounted on the top carriage, as the pinion walks around the rack, it draws the top carriage with it, pivoting the top carriage about its own center. The mount may be traversed through 360° continuously an unlimited number of times. To prevent

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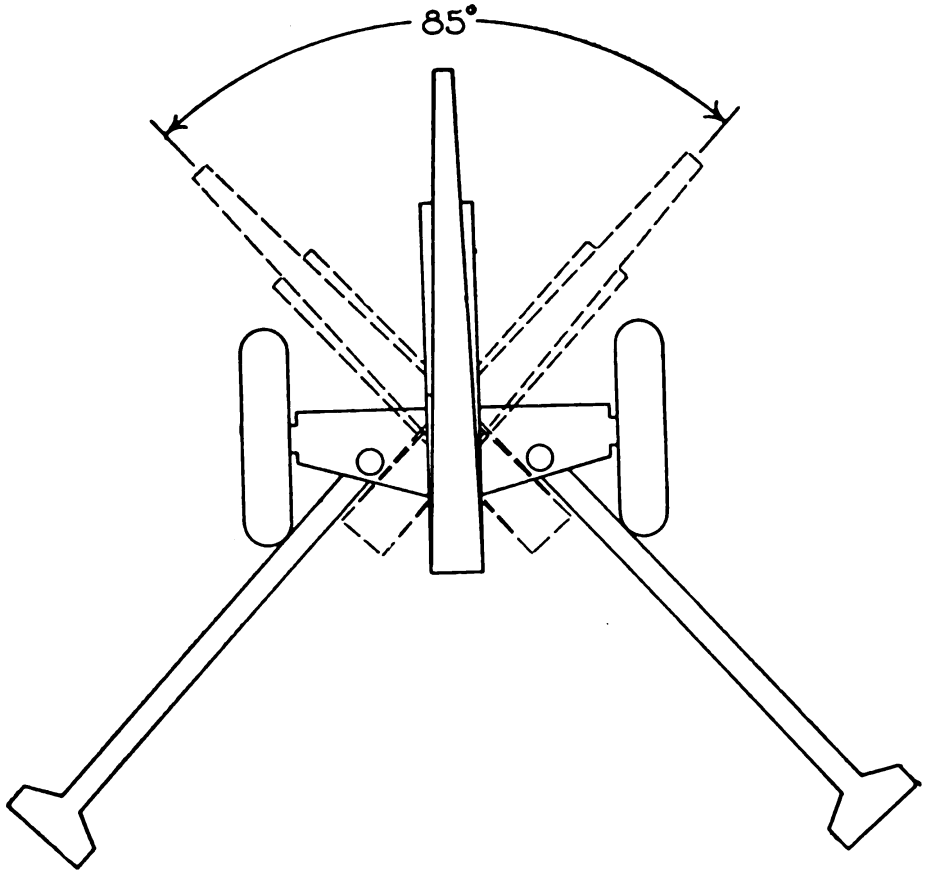

Figure 64. Pintle Traverse (Schematic Drawing).

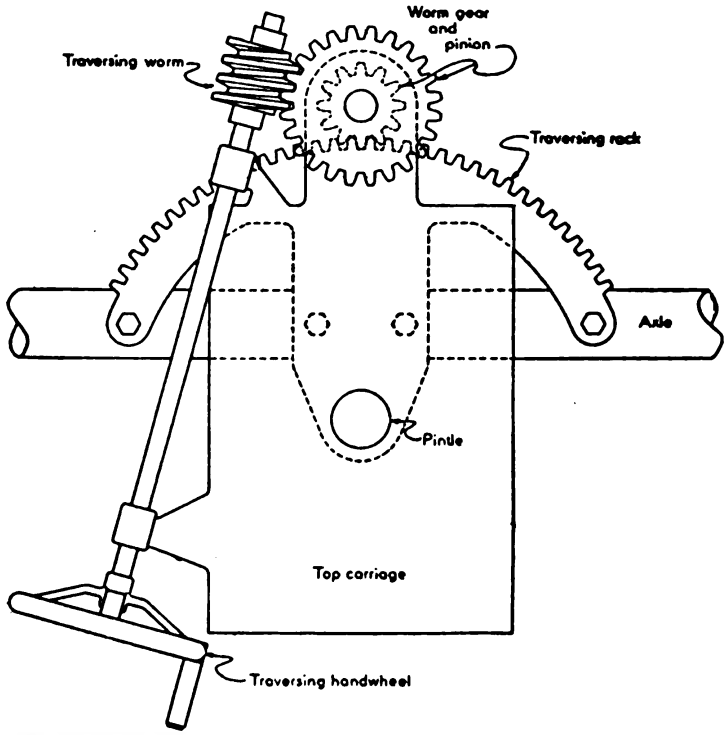

Figure 65. Pintle Traverse, Construction.

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the electrical wiring which passes through both the bottom and top carriages from entangling, a contact ring is used. Contact rings are discussed in Chapter III, Fire Control.

The weight of the top carriage is transmitted to the bottom carriage through an antifriction traversing bearing so that the mount may be traversed easily.

When the weapon is fired, or when the weapon is being towed and strikes an irregularity in the road surface, there is a decided tendency for the top carriage to be lifted off the bottom carriage. To make this movement impossible the top carriage must be bolted securely to the bottom carriage, yet the manner of bolting must permit free rotary movement of the top carriage independent of the bottom carriage. To accomplish these ends, one of two methods is used.

On weapons using a clip ring, the clip ring bears against the lower edge of the traversing gear which is bolted to the bottom carriage. A bolt connects the clip ring to the top carriage. In some traversing mechanisms an antifriction bearing, called the clip bearing, may be interposed between the traversing rack and the clip ring. Shims are placed between the clip ring and the top carriage to eliminate binding and to permit adjustment.

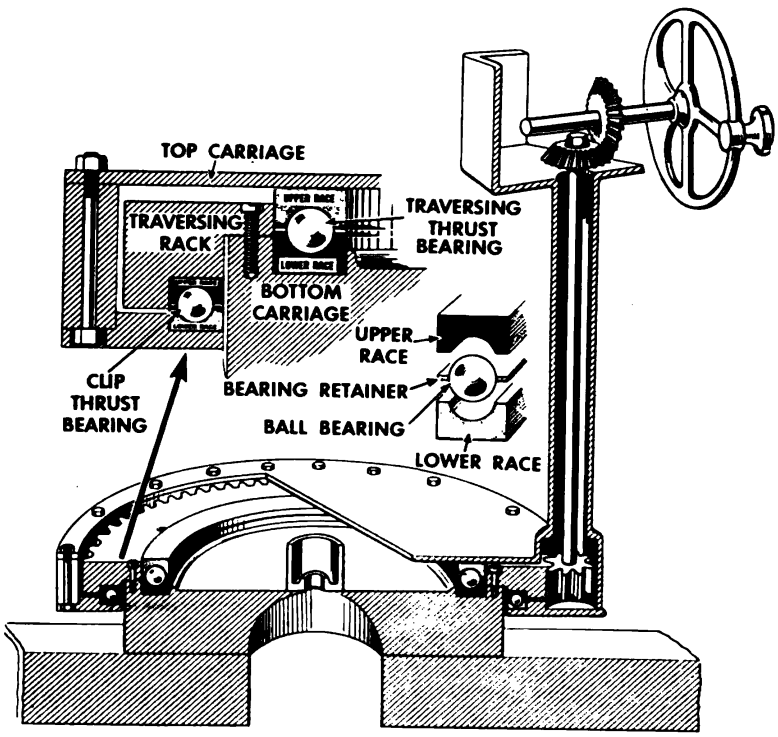

Figure 66. Base Ring and Racer Traversing Mechanism.

To make upward movement of the top carriage impossible, another method is employed which replaces the clip ring with a clamping ring and dispenses with the additional clip bearing, utilizing the traversing bearing to perform its function. The top carriage cannot rise, for in order to do so it must lift the traversing bearing upward. The traversing bearing is held down by the traversing gear, which, in turn, is bolted to the base ring. The base ring is securely fastened to the bottom carriage by bolts.

AXLES

Function. An axle is that part of a carriage which supports the weight of the carriage and cannon and has on its extreme ends spindles upon which the wheels are mounted.

Several types of axles are used on artillery pieces and may be classified as straight axles, equalizing axles, and bogies.

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Construction. An axle is made of steel in the form of either an I-beam or round construction and is often hollow to reduce weight. The outer extremes of the axles may be either tapered to form a spindle or be formed to receive a wheel carrier.

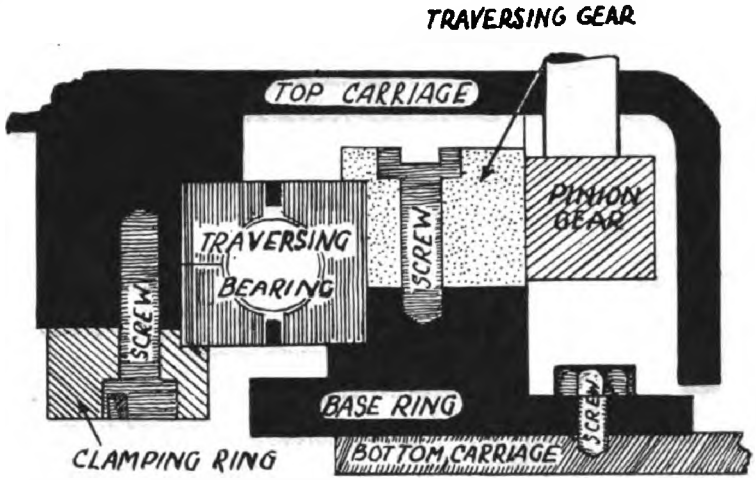

Figure 67. Base Ring and Racer Traversing Mechanism Without Clip Ring.

Equalizer Supports. The equalizer support with the axle provides a means by which the weight of the weapon and the shock of firing can be supported by the axle on uneven terrain. The support is fastened parallel to the axle by a horizontal pivot pin, allowing the support to move independently of the axle

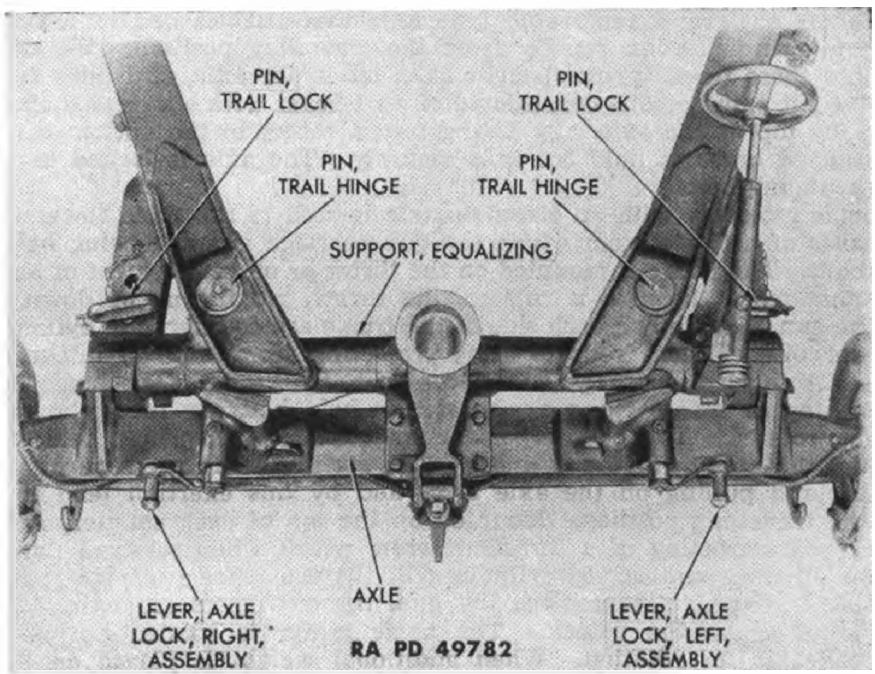

Figure 68. Axle and Support, Top View.

and providing an equalizing system. The equalizer supports the top carriage by a vertical pintle pin. To relieve strain from the horizontal pivot pin, the two ends of the equalizer are held parallel with the axle, by gib bearings. However, the gib bearings allow the equalizer to rotate in a vertical direction. The two trails, hinged to the ends of the equalizer, and the equalizer horizontal

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pivot pin form a three point suspension. When the trails are level and the wheels are not, the cannon will remain level along the axis of its trunnions. When the wheels are level and the trails are not or when both the wheels and trails are not level, the cannon will be canted. To level the cannon along the axis of its trunnions it will then be necessary to level the trails.

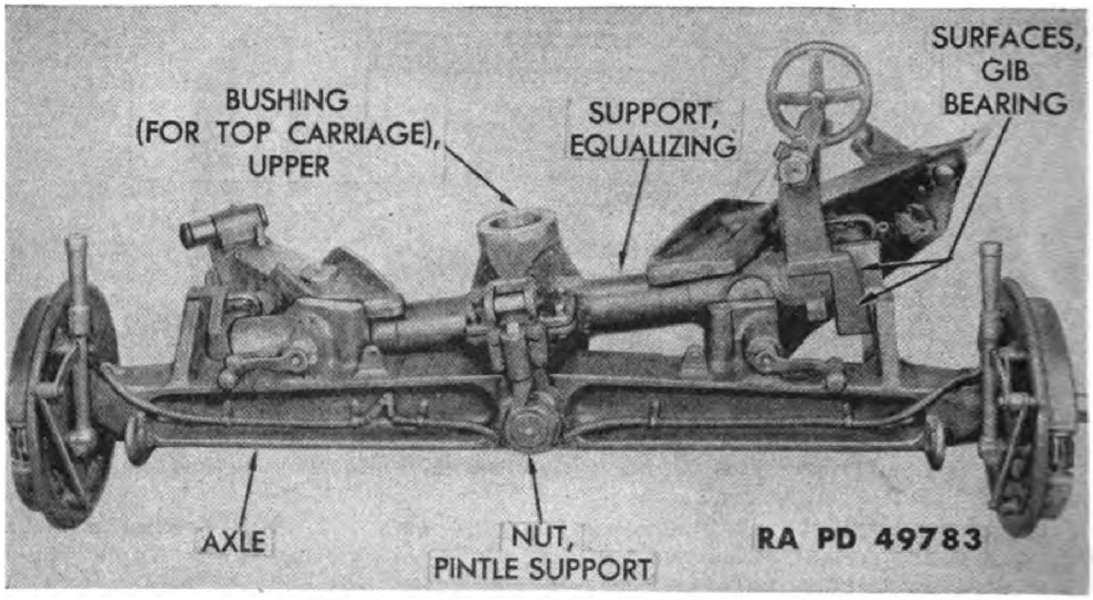

Figure 69. Axle and Support, Front View.

Bogies. A bogie is a removable type axle that enables one to lower the gun carriage to firing position rapidly from the travelling position. We can classify bogies into these three types: straight axle, off-center axle, and dual axle.

The **straight axle** bogie is constructed of an I-beam with a wedge-shaped bracket mounted on top of the axle. By fitting into a recess in the bottom carriage, the weldge-shaped brackets hold the axle securely. The axle is locked in that position by swinging bolts.

The bogie assembly with an **eccentric axle** is used to raise and lower the mount and consists of a frame from which the gun carriage is slung being held in position by bolts. The frame is mounted on the throw or off-set segment of an eccentric axle so that when the axle is rotated, the throw, moving up or down, raises or lowers the gun. Mounted on each side of the frame are counterpoise cylinders linked by counterpoise cylinder rods to arms projecting from, and an integral part of, the axle. A third arm, integral with the axle, fits between the bogie buffer and a rubber stop so that as long as the arm is held between them the axle throw cannot be rotated. The counterpoise cylinders contain springs held between a piston and the bottom of the cylinder. The springs exert pressure on the piston and piston rod pulling on the axle arms and by this exertion tend to hold the gun in the travelling position. Mounted on the top of each counterpoise cylinder is a gear box consisting of a threaded screw which when screwed down against the piston in the counterpoise cylinder will lift the wheels off the ground when the gun is emplaced. To emplace the gun, the outriggers are extended and the mount balanced on the wheels. The bogie buffer is rotated out of the way, freeing the axle for rotation. When additional weight is placed on the mount, the spring pressure of the counterpoise cylinder is overcome, and, with the wheel spindles as an axis of rotation, the eccentric axle is rotated permitting the mount to settle to the ground. With the mount on the ground, the gear boxes are engaged and are screwed down, pushing the piston further down the counterpoise cylinders. The axis of rotation is now changed to the eccentric so that the counterpoise rods are pushed out by means of the gear boxes. The wheels will be raised free of the ground.

The **dual axle** bogie supports the weight of the carriage on two axles which are

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connected to a cross beam; this cross beam is held in the center of and parallel to, the axle by means of two upper and two lower torque rods. To take up the shock of travel, two leaf springs are attached at the center of the cross beam with the extreme ends of the springs resting on machined surfaces on top of the two axles. The bogie lifting and lowering is accomplished by two compound screws with external right hand threads that are screwed through the cross beam. The internal threads of the compound are left hand and are assembled to the

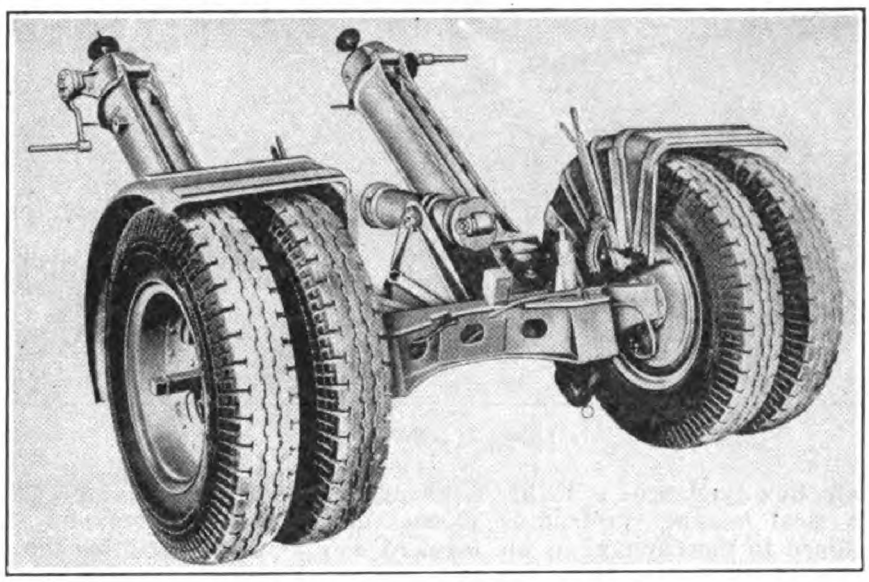

Figure 70. Bogie Assembly.

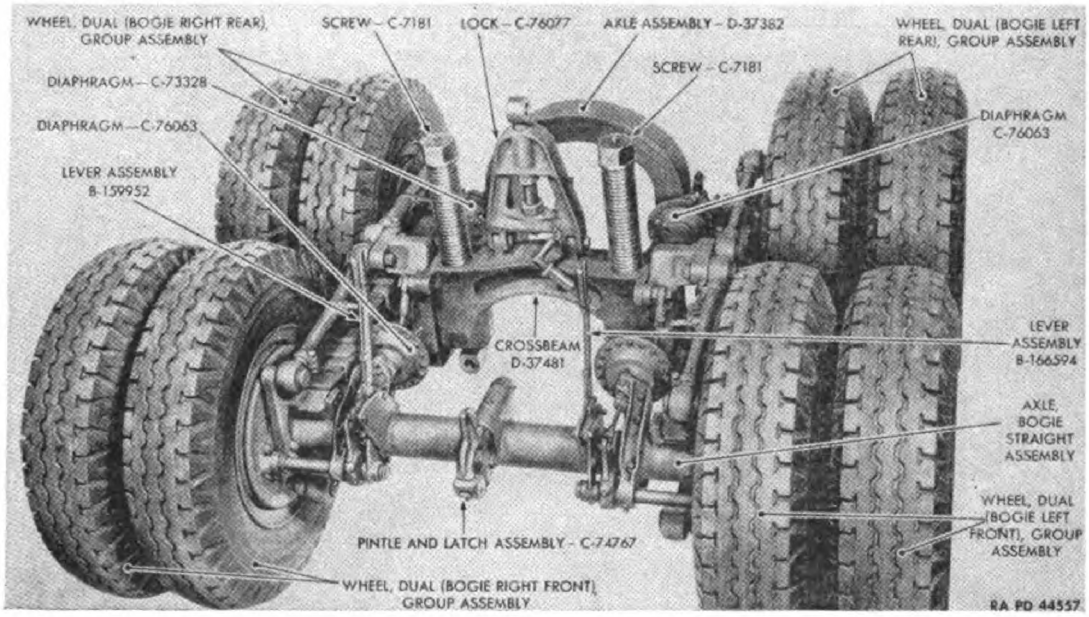

Figure 71. Dual Axle Bogie.

front end of the bottom carriage by pins that fit into holes. By rotating the compound screws the carriage is lifted or lowered to travel or firing position.

TRAILS

Functions In order that the forces of recoil do not displace the carriage to the rear, steel supports called trails are provided to transmit those forces to the

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ground. Trails are found only on towed artillery. They provide a means for connecting the weapon to its prime mover for travelling. The forward end of the trail is connected by some means to the carriage, and the rear end terminates in a spade.

Trails are classified as Box, Modified Box, or Split type of trail.

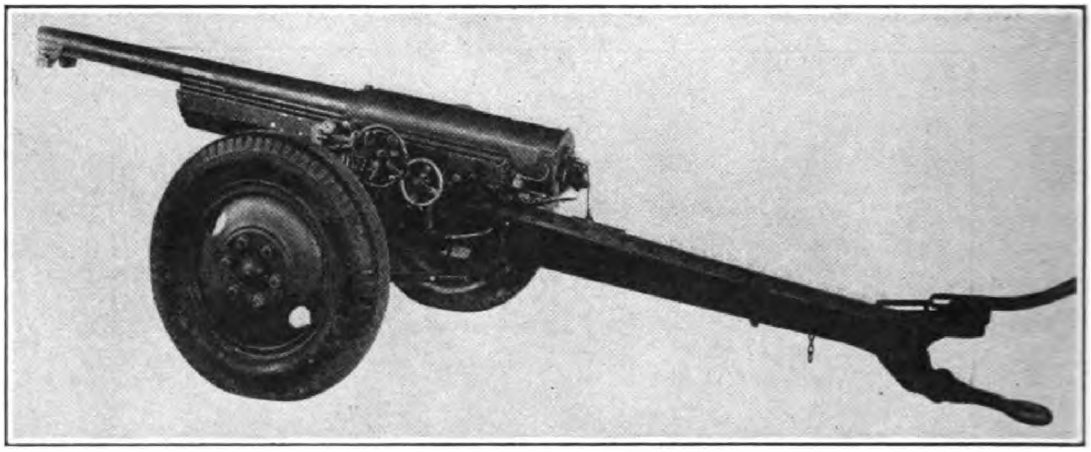

Figure 72. Box Trail.

A Simple Box type trail is to be found only on older artillery pieces. It consists of a steel member protruding to the rear of the weapon, and instead of being fastened to the carriage at the forward end, actually performs the functions of a top carriage and contains the bearings in which the tipping parts of the weapon pivot. This type of trail is quite stable, but limits the weapon considerably in both elevation and traverse.

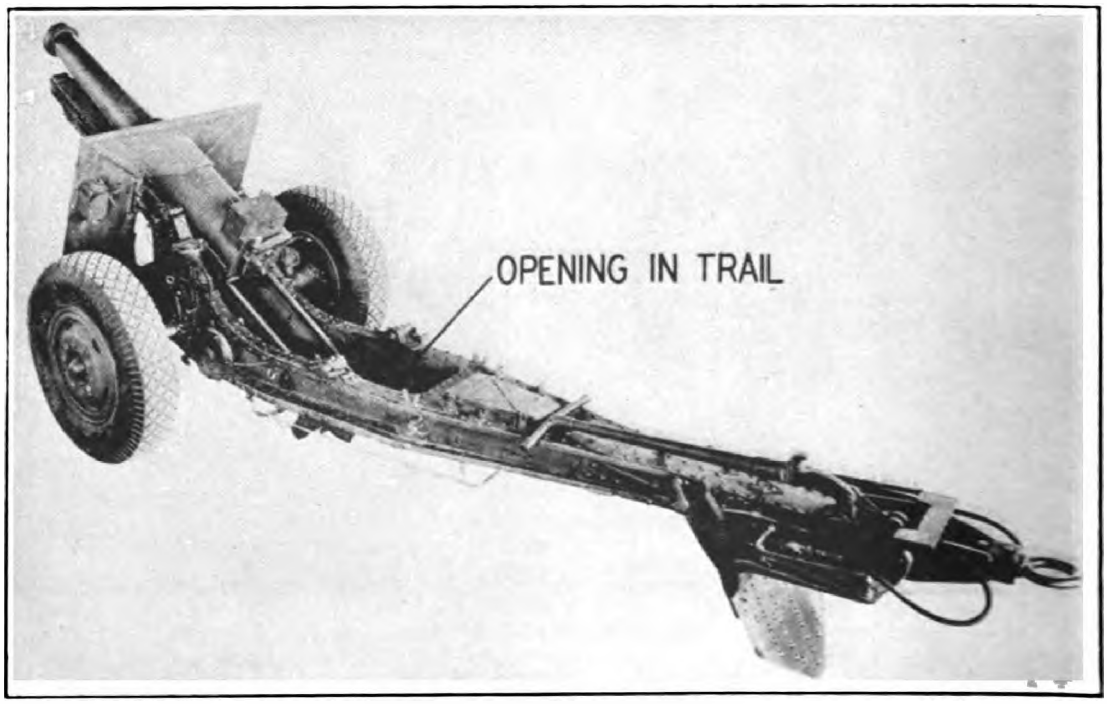

Figure 73. Modified Box Trail.

A Modified Box type trail is very similar to the simple box type, except that in the case of the former, an opening has been provided in the trail through which the piece recoils at higher angles of elevation. While the traverse is still

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limited to approximately three degree right or left as in the case of the simple box type trail, larger angles of elevation are made possible.

The Split type of trail, unlike the other types, is in two sections. Also, instead of actually forming a part of the top carriage, as the others do, the split trail is fastened to the carriage at its forward end. The rear ends of sections may be locked together for towing or spread apart for firing. In the firing position,

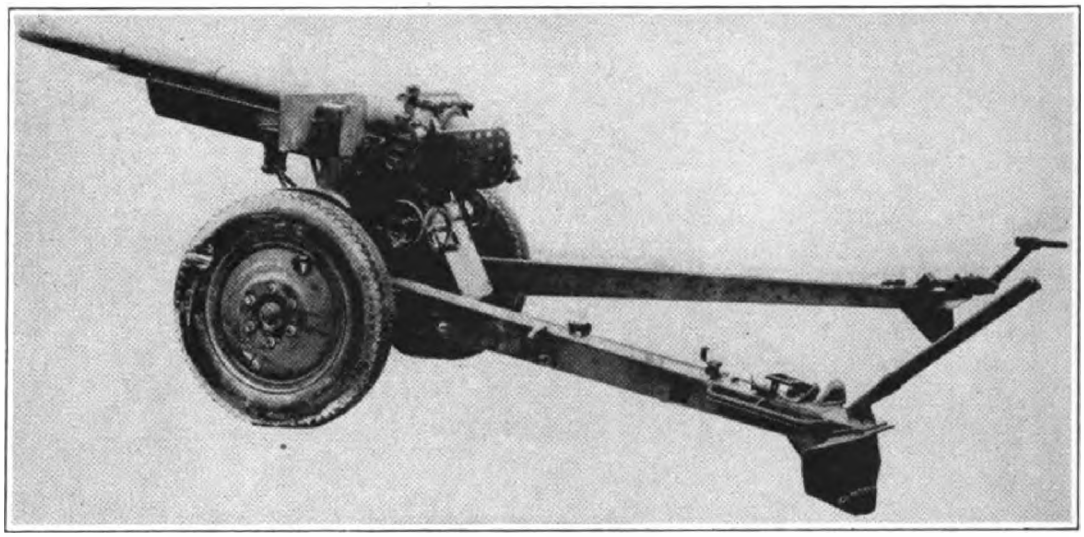

Figure 74. Split Trail.

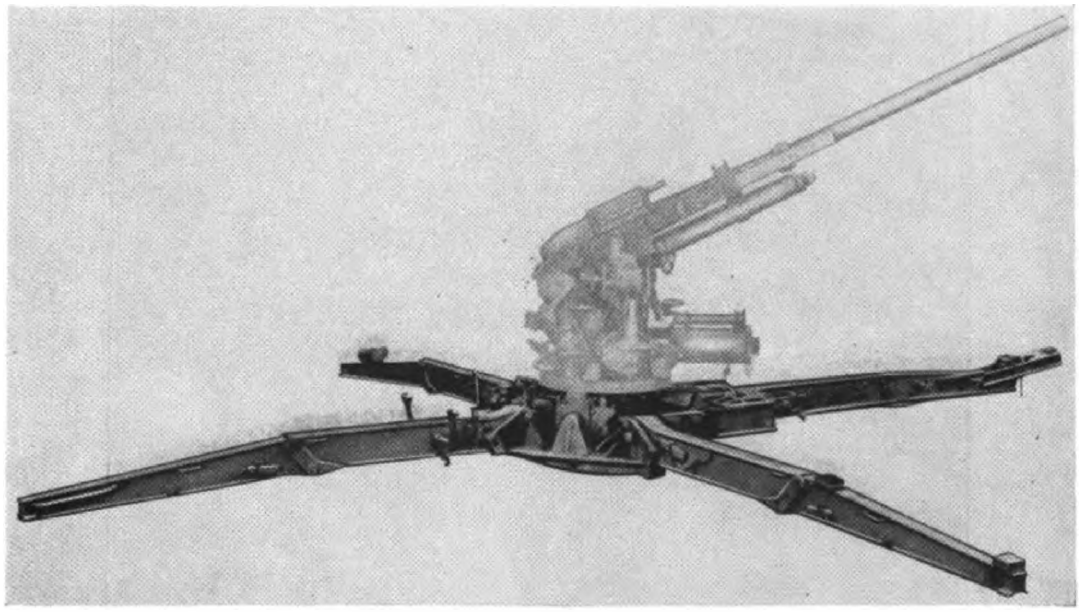

Figure 75. Outrigger—AA Weapon.

the sections are not directly behind the breech of the weapon, and therefore do not limit the elevation. Traverse is also increased to an amount approximately equal to the included angle formed by the spread sections. The split type of trail is found on nearly all modern field artillery carriages.

OUTRIGGERS

When it is desirable to traverse a weapon 360 degrees as in the case of anti-aircraft weapons, or railway artillery, additional supports must be provided to prevent displacement of the mount by the energy of firing. These auxiliary

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trails or supports are called outriggers. When used with railway artillery, auxiliary outriggers are detachable and are placed on the car for travelling. In the case of antiaircraft carriages, the outriggers are hinged in order that they may be snubbed to the side of the mount for travelling.

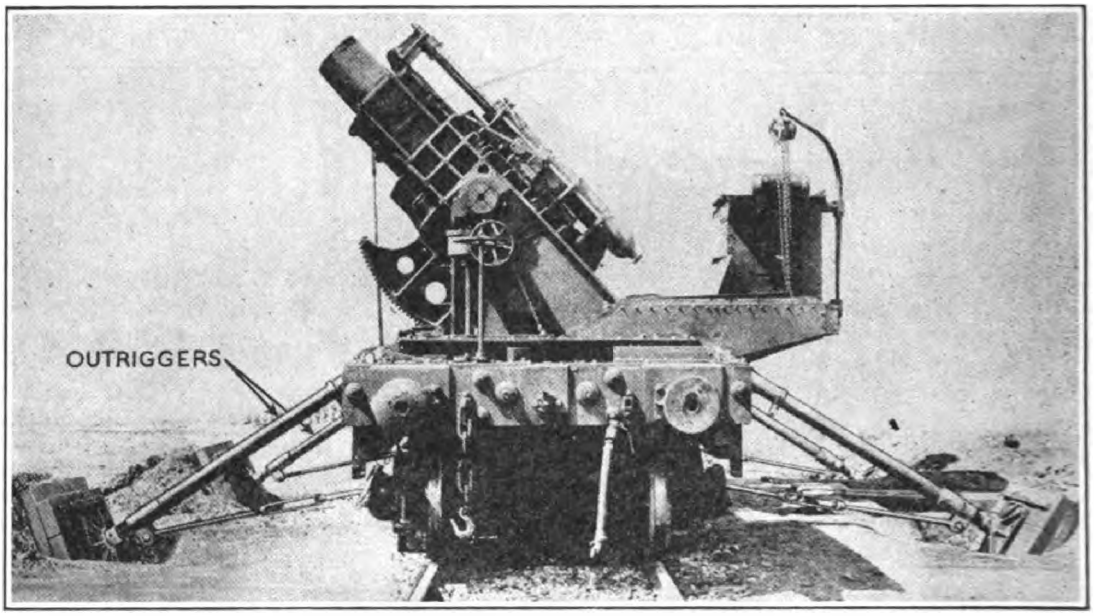

Figure 76. Outrigger—Railway Artillery.

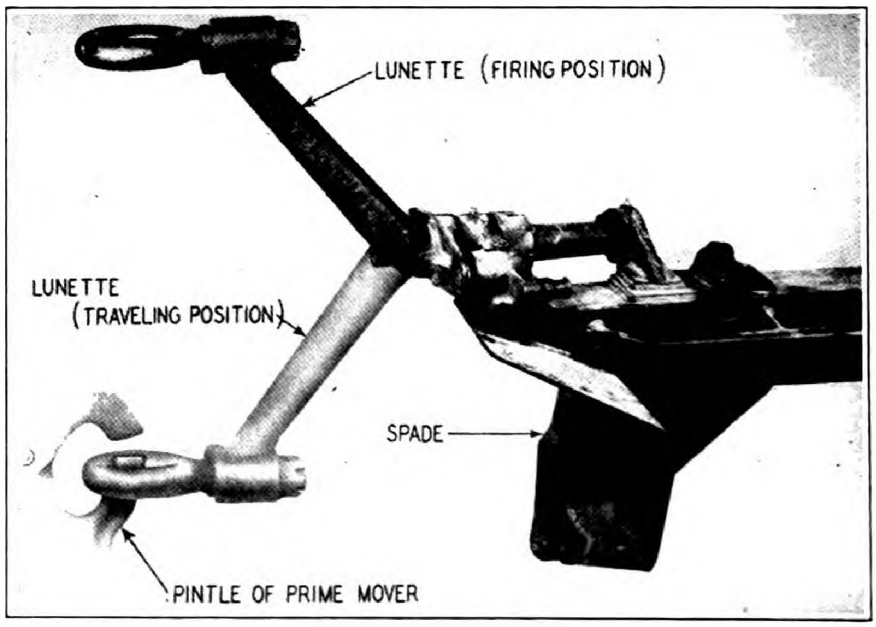

Figure 77. Fixed Spade.

SPADES

A spade is a scoop shaped piece of metal on the end of the trail of a weapon, which is forced into the ground to prevent movement of the carriage in recoil.

Spades are classified as Fixed, Detachable, and Hinged.

The **Fixed** type is a forge, cast, or a builtup spade attached permanently and rigidly to the end of the trail. It is generally found on the light artillery weapons. In most cases the towing lunette is offset to provide clearance between the spades and the ground. In travelling position the lunette is low, keeping the spades

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high above the ground to prevent them from dragging when the prime mover is traversing rough terrain. In firing position the drawbar is rotated and the lunette is high, clearing the ground when the spades are dug in.

A **Detachable** spade is attached to the weapon only during firing. In travelling position the spades are removed and carried elsewhere on the carriage. This

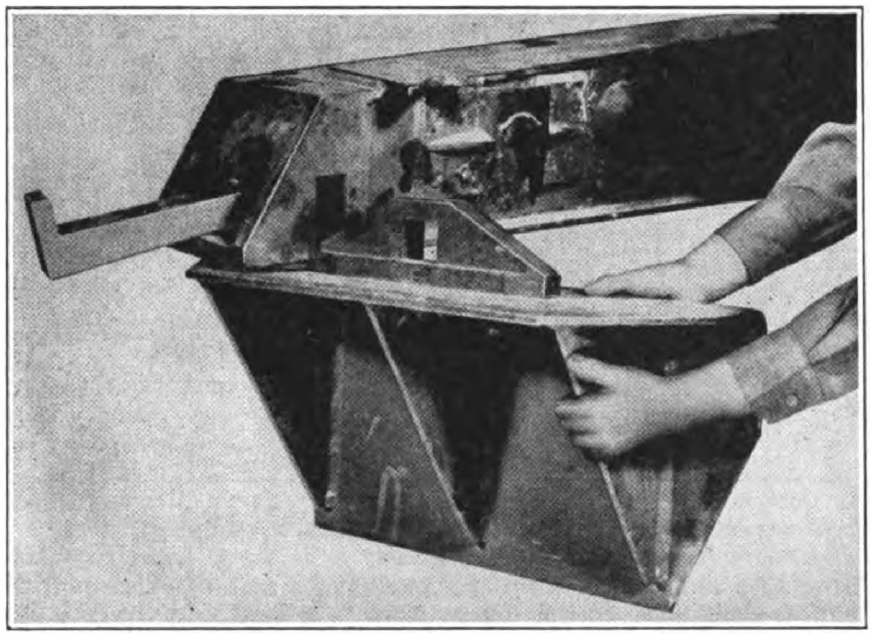

Figure 78. Detachable Spade.

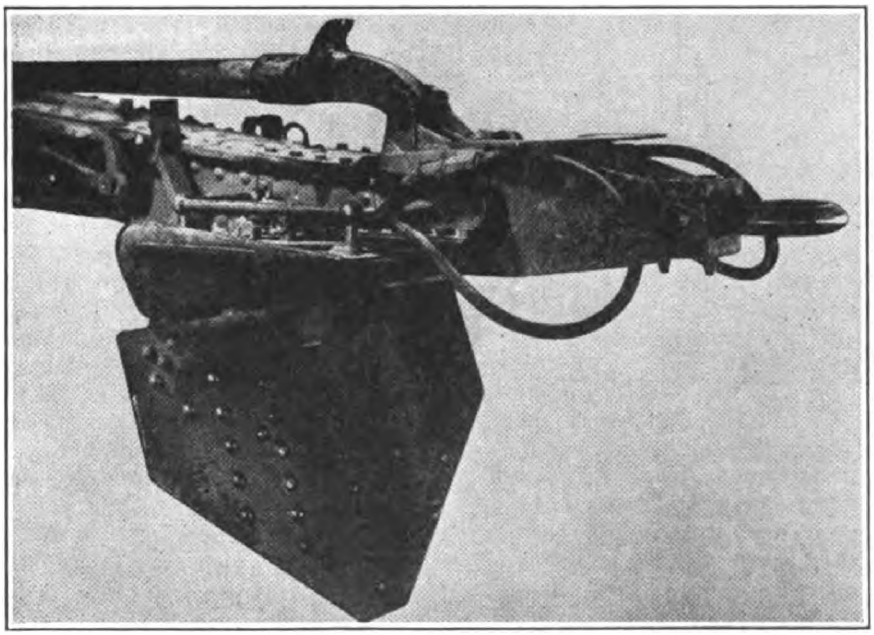

Figure 79. Hinged Spade.

allows the weapon to be attached directly to the prime mover or limber without fear of the spades dragging the ground. The method of attachment is a square, L-shaped key which fits through two holes in the end of the trails and the eye in the spades. This type of spade is generally used on medium and heavy artillery.

A **Hinged** spade is a combination of the fixed and the detachable types of spade. It is hinged at the point where the spade is attached to the trail, so that the

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spade may be adjusted for various soils and emplacements. There are three positions for the spade: fully down, 60°; half way up, 30°; and fully up in travelling position where it is out of danger of dragging on the ground. This type of spade is found on the 155mm Howitzer, M1917 and M1918.

FIRING SUPPORTS

The shock of firing tends to lift the lighter field weapons off the ground and bounce them out of position when they are fired while resting on the tires, so a more stable firing base than the tires is required.

There are three types of firing supports: firing jacks, firing bases, and firing segments.

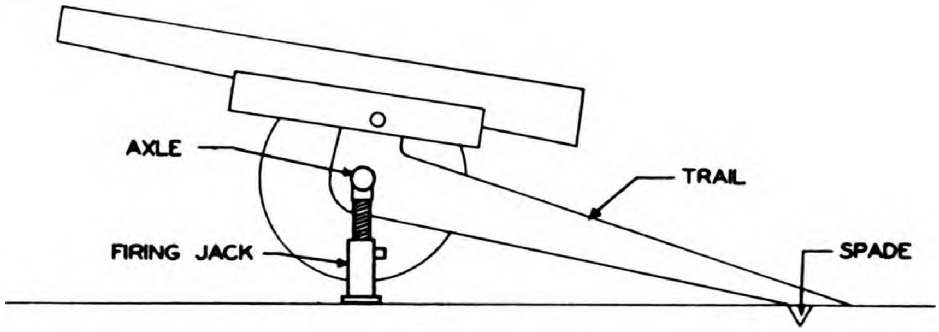

Figure 80. Firing Jack.

The Firing Jack is a device to lift the wheels of a mobile weapon off the ground and provide a solid base during firing. The jack assembly consists of the jack, either mechanical or hydraulic, a connection to the bottom carriage of the piece, and a base plate to keep the jack from sinking into the ground. The connection to the bottom carriage contains the working parts of the jack: worm, wormwheel,

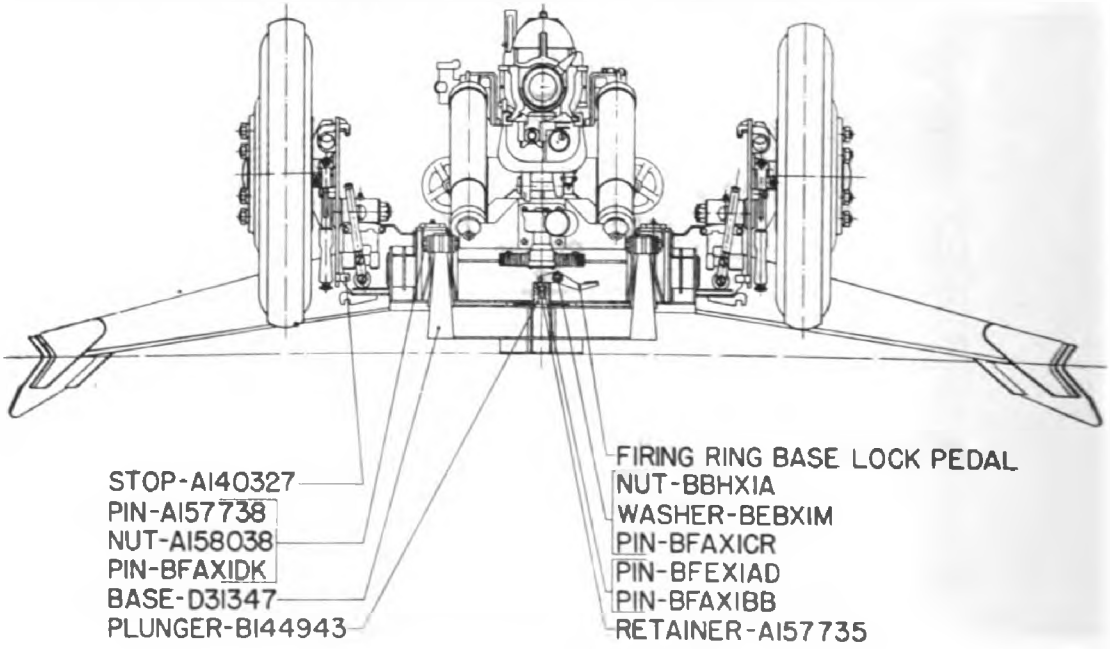

Figure 81. Firing Base.

and pinion in the case of the mechanical jack, and the oil reserve and pistons in the case of the hydraulic jack. The jack is the third point in the stable three point suspension system. The two trails are the other two points of suspension.

A **Firing Base** is that part of an artillery carriage that rests on the ground during firing, taking the place of a firing jack. In function, the firing base acts

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similar to the base of the jack. The difference is that the jack lifts the weapon off the ground, and the firing base is lowered to the ground with the rest of the weapon. The weapons of field artillery employing this type of support are equipped with eccentric axles, so that the axle can be rotated and the piece lowered gently to the ground. In medium and heavy antiaircraft artillery the weapons are equipped with hydraulic jacks to raise and lower them into and out of firing position.

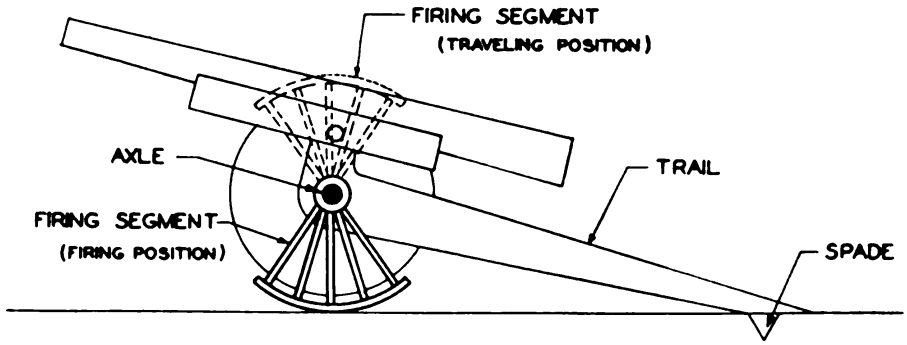

Figure 82. Firing Segments.

A **Firing Segment** is actually a pie-shaped segment of a steel wheel. The radius of the segment is slightly larger than the radius of the tires with which the carriage is equipped. Thus when the segment is rotated down, the wheels are lifted from the ground. The firing segments are located next to the wheels, so that they give wide support to the carriage and make it stable. In the firing position the segments are down, and in the travelling position they are rotated up and out of the way. This type of support is used on those light field pieces which must be emplaced in a minimum of time. The only motion necessary to emplace the weapon is to rotate the segments and push the weapon forward onto the firing segments.

SUBCALIBER EQUIPMENT

Subcaliber equipment provides a solution to instructing field artillery soldiers in training exercises, which present a serious problem due to: high cost of service ammunition, shortening of combat life of the major tube, cost of replacing the tube, and limited range areas.

General Principles. Subcaliber equipment is generally a gun tube of much smaller bore diameter, either of the small arms or of the artillery class, that is affixed to the major weapon. The equipment can be either a weapon, called a subcaliber gun, complete with breech and recoil mechanism, that is fired over the barrel of the piece, or a tube called a subcaliber tube, that is placed in the bore of the parent weapon. When a subcaliber tube is used loading and firing is sometimes accomplished with the breech and firing mechanisms of the major weapon. In either case, subcaliber gun or tube, the lands and forcing cone of the parent weapon are protected from the normal erosion accompanying service firing. Thus the serviceability life of the weapon's tube is not affected. A saving in the cost of practice ammunition is gained by the use of the much smaller caliber rounds.

RIFLE, SUBCALIBER, CAL. .22 M2A1.

RIFLE, SUBCALIBER, CAL. .30 M1903A2.

These two rifles are used with the 37mm A.T. Gun M3A1 on carriage M4A1; the 37mm Gun M3A1 on motor carriage M6; and the 57mm A.T. Gun M1 on carriage M1A3.

The rifles are the .22 caliber M2 and the .30 caliber M1903 with stocks and sights removed. They are fired with their own trigger and magazine housings through the tube of the parent weapon. Their position in the tube is located with bronze bushings having an outside diameter equal to that of the gun, that are affixed to the rifle barrel. Thus the assembly is centered in the bore of the larger gun.

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Rifle, Subcaliber, Cal. .22 M5. This rifle is used for practice firing in the 37mm Tank Gun M6 when mounted in the M5 Light Tank series and the Armored Car M8.

The rifle consists of a short commercial type, Cal. .22, M2 Rifle barrel, mounted in a bronze casting similar in form to a 37mm cartridge case. It is arranged in such a way that, when inserted in the chamber of the 37mm tank guns, the centered firing pin of the cannon can strike the rim of the .22 cartridge.

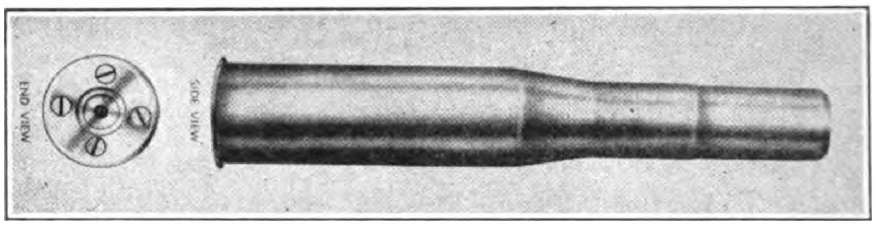

Figure 83. Rifle, Subcaliber, Cal. .22, M5.

The M5 rifle is loaded before insertion in the barrel of the 37mm weapon. The casting has a steel flange which engages the extractors of the tank gun, so that after firing, the breech mechanism of the larger gun is opened, extracting the subcaliber rifle. The fired cal. .22 cartridge is then removed by the use of a rod or a hand extractor.

Cartridge, Subcaliber, For 3-in Guns. This equipment is used with the 3-in Seacoast Guns M1902M1 and M1903.

The subcaliber cartridge consists of a caliber .30 rifle barrel mounted axially in a bronze cartridge case which has the same weight and exterior dimensions as the cartridge case for service ammunition.

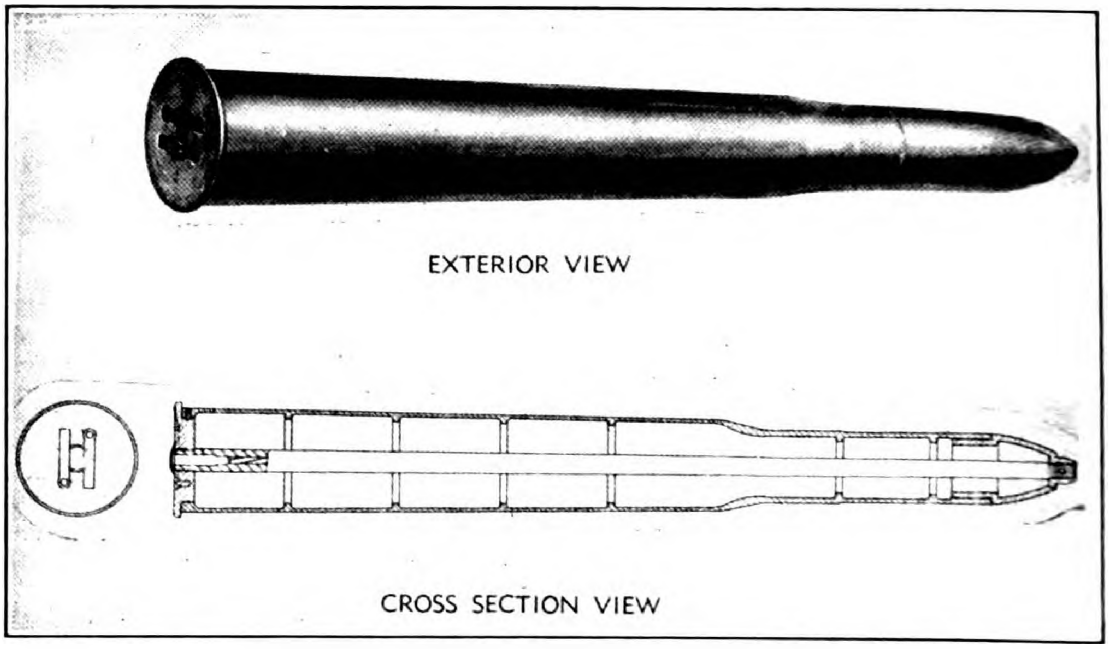

Figure 84. Cartridge, Subcaliber For 3-In Guns.

The 3-in subcaliber cartridge is inserted in the gun after which the cal. .30 cartridge is placed in the chamber of the subcaliber barrel. The primer of the subcaliber ammunition is centered so it can be fired by the firing pin of the major weapon. A special cal. .30 cartridge must be used in this cartridge, the regular cal. .30 primers not being adapted for the blow of the firing pin of the cannon. The fired cal. .30 cartridge is extracted from the chamber by two extractor springs.

Gun, Machine, Cal. .50, M2, HB, Flexible. This equipment is used with the

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3-in A.T. Gun M5 on carriage M1; 3-in Gun M7 on Gun Motor Carriage M10A1; and 76mm Gun M1A1.

This subcaliber equipment was designed to meet the requirements for constant training of antitank gunners in firing at moving targets, especially in camps where range facilities are not available for firing service ammunition. The machine gun and its mount are secured to the tube by steel securing straps, which vary in length to fit the tube on which the equipment is to be mounted.

Two types of firing arrangements are provided. When used with the 3-in Gun M7 and with the 76mm Gun M1A1, the machine gun is fired by a solenoid, with a relay provided to enable firing single shots. When used with the 3-in Gun M5 a mechanical trigger attachment is provided so that single shots may be fired by the use of the lanyard.

Gun, Subcaliber, 1-Pounder. This equipment is used in the 8-in Railway Gun M1888M1A1, and with a number of disappearing carriages, which are now obsolete.

The 1-pounder is actually a 1.457 in gun which fires a 1-pound projectile.

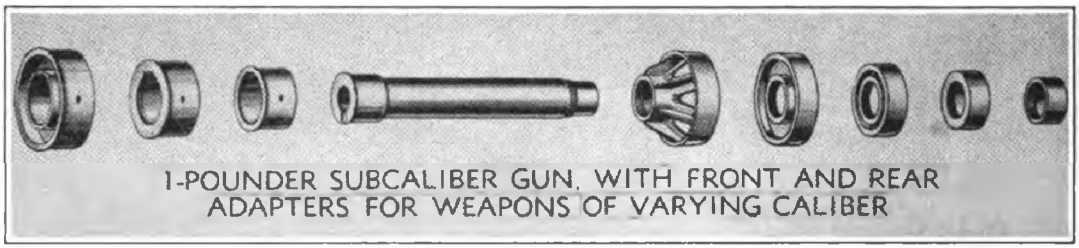

Figure 85. 1-Pounder Subcaliber Gun With Front and Rear Adapters for Weapons of Varying Calibers.

The subcaliber gun is inserted in the chamber of the larger cannon, where it is held in place by means of adapters screwed over the muzzle and breech of the small weapon. When the subcaliber gun is inserted, the adapters are expanded to hold it firmly in position. A center support screws on threads near the middle of the 1-pounder tube in order to insure rigidity of the gun. The round of ammution is fired by the firing mechanism of the major weapon, and the subcaliber cartridge case is removed by means of a hand extractor.

Gun, 37mm, M1916; Exterior Mounts. This equipment is used as subcaliber for various mobile artillery weapons. It is used for the 75mm Howitzer materiel on carriages M1, M3A3, and M8; for 105mm Howitzers on carriage M2A2 and Motor Carriage M7; 4.5-in Gun on carriage M1A1; 155mm Howitzers on Carriages M1918A3, and M1A1; 8-in Howitzer on carriage M1; and 155mm Gun on carriages M3 and M1A1; and 75mm Gun on carriage M2A3.

The subcaliber gun consists of the Gun M1916 with its cradle and is complete with its own recoil, breech, and firing mechanism. It is mounted in all cases on top of the larger gun by means of a mount designed for that materiel. During firing the recoil is handled by the subcaliber equipment, and the recoil mechanism of the major artillery weapon is not operated. The complete subcaliber round weighs 1.6 pounds with 1.2 pounds being the weight of the projectile.

Gun, Subcaliber, 37mm Interior Mounts. Used with 75mm Howitzers M1A1, M2, and M3; 105mm Howitzers M2A1, M3 and M4; 90mm Gun M1A1 on Mount M3.

Gun shields interfering with subcaliber tubes mounted on the outside of guns necessitated adopting subcaliber tubes mounted internally. The 37mm Subcaliber Guns M12, M13, and T25 are examples of this type of interior mounted tubes designed to supplement and to replace the 37mm M1916, subcaliber materiel. Length of gun and travel of projectile are the same for both the internal and external type guns. Gun tubes used in the interior mounted guns are the same as those of the M1916 subcaliber guns.

The M12, M13, and T25 gun tubes make use of the breechblock and firing mechanism of the parent weapon. It is possible to install this internal type gun tube in an already bore-sighted weapon. Installation and removal requires less time than for externally mounted guns. All three models are identical in every respect with one exception, that being the base of the width of the adapter

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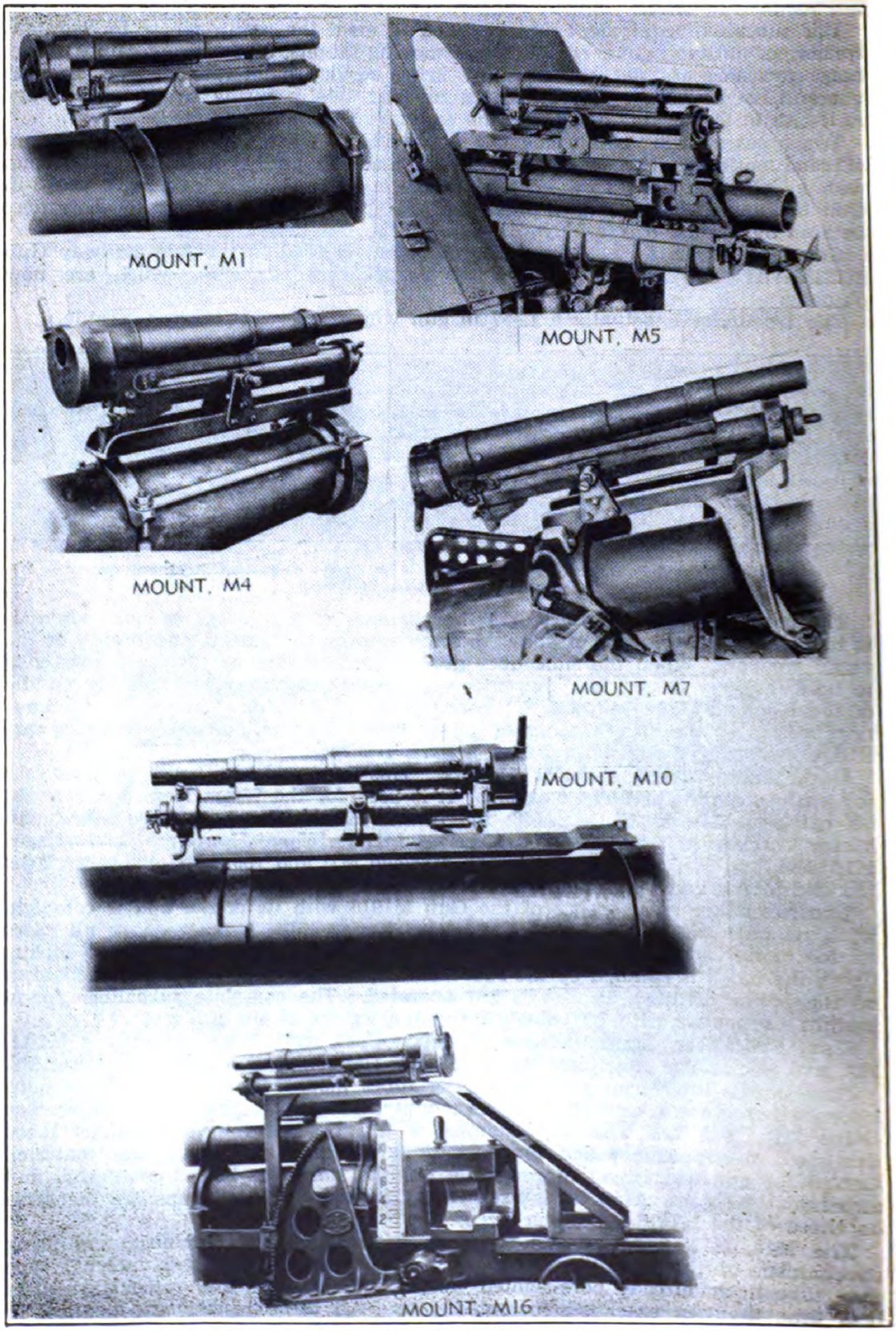

Figure 86. Exterior Mounts.

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which varies depending upon the diameter of the bore of the gun in which the subcaliber tube is mounted.

Gun, 75-mm, M1916; Exterior Mounts. Used with 12-in gun on Barbette carriage M1917; 16-in Gun on Barbette carriage M1920; 16-in Gun on Barbette carriage M1919M1; 14-in Gun on Railway Gun Mount M1920.

This 75mm Gun is the same as that formerly used for beach defense purposes, and has mounts that are tailor-made to fit the major artillery piece. It has its own recoil, breech, and firing mechanisms. It is fired independently of the major weapon with a lanyard.

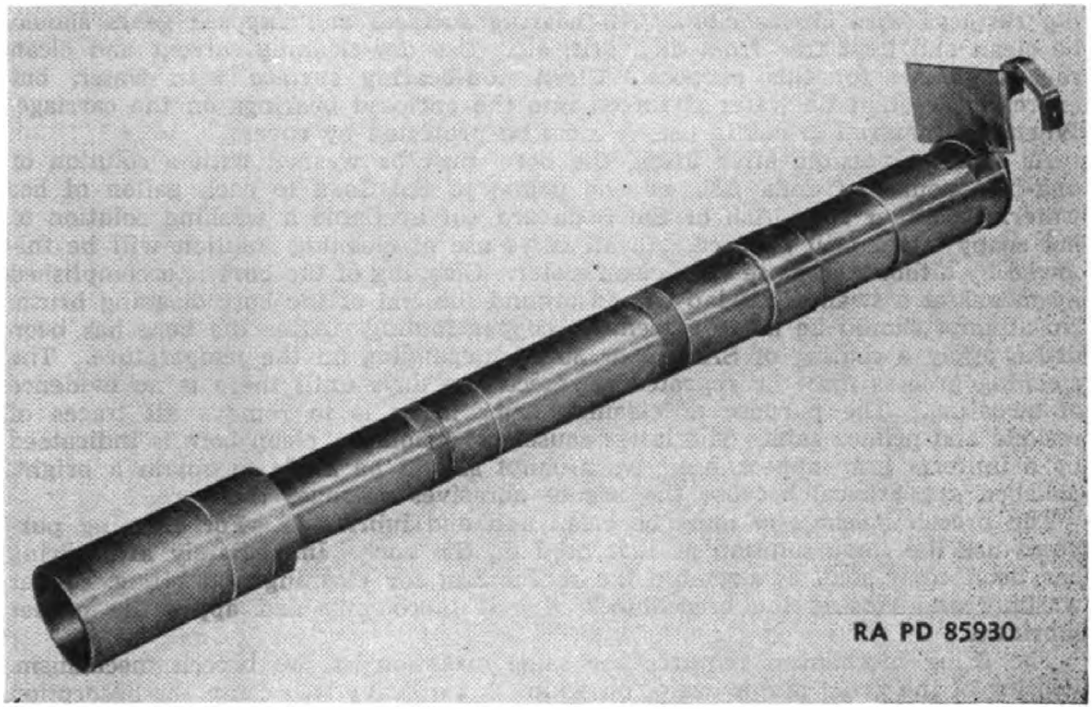

Figure 87. Interior Mounts.

Gun, Subcaliber, 75-mm; Interior Mount. This subcaliber equipment is used with 12-in gun on Casemated Barbette Carriage M1917; 16-in Gun Mk. II, Mod. 1 on 16-in Barbette Carriage (Casemated); 16-in Gun M1919 MII and M1919 MIII on Barbette Carriage; 8-in Gun on Barbette Carriage MI and Railway Mount M1A1; 16-in Howitzer M1920; 6-in Gun M1903A2; 6-in Gun M1905A2; 6-in Gun T2.

Present subcaliber guns externally mounted cannot be used with casemated batteries without extensive provisions for counterbalancing of the added weight when the subcaliber gun is mounted outside the shield. Sides, roof and parapet of the casemate interfer with the line of fire of the subcaliber gun when it is mounted outside of the shield. In view of this fact, 75mm subcaliber guns are mounted inside the gun chamber for casemated gun batteries.

The 75mm Subcaliber Tube is the same for all of the above weapons with the exception of the differences in required adapters. Power extractors are used to remove the subcaliber gun from the bore of the weapon in which it is mounted.

CARE OF ARTILLERY

General. Keeping all parts of artillery material in proper condition for immediate service is of vital importance. The correct use of lubricants, cleaning and preserving materials, and paints will keep the material in proper condition. In each Technical Manual is a section devoted to care and preservation which, when followed, insures correct use of lubricants, cleaning and preserving material and paints.

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Use of Lubrication Orders. Supplementing the Technical Manuals are War Department Lubrication Orders (formerly called Guides). The Lubrication Orders are two-sided cards issued with each item of equipment. On the lubrication order is a schematic diagram of the gun and carriage. The proper lubricants and the correct intervals of lubrication are shown by means of letters. Arrows designate each point of lubrication. Additional lubrication and service instructions on individual units and parts are given in a portion of the lubrication order designated "Notes".

Cleaning. Rust, dirt, grit, gummed oil, and water cause rapid deterioration of the mechanisms and unpainted surfaces. Rust should be removed from *bearing surfaces* with *crocus cloth.* All bearing surfaces and exposed gears should be clean and kept free from dirt, grit, etc. Use dry-cleaning solvent and clean rags or waste for this purpose. Clean non-bearing surface with water, but exercise care that no water is forced into the enclosed bearings on the carriage. When the material is not in use, it must be protected by covers.

As soon as possible after firing, the bore must be washed with a solution of one-half pound of Soda Ash, or one pound of Sal Soda to each gallon of hot water. If either Soda Ash or Sal Soda are not available a washing solution of hot soapy water will be used. In all cases use of cleaning solution will be followed by a thorough rinse with clean water. Cleaning of the bore is accomplished by means of a swab of burlap wound around the end of the bore cleaning brush. No attempt should be made to remove copper fouling. After the bore has been dried, apply a coating of SAE 10 or 30 oil, depending on the temperature. The cleaning process must be repeated on successive days until there is no evidence of sweating. The purpose of cleaning after firing is to remove all traces of residue and primer salts. The latter causes corrosion. A clean bore is indicateed by a uniform gray appearance. No attempt should be made to obtain a bright, polished appearance, because the use of abrasives damages the bore.

The breech mechanism must be clean and and lubricated. For cleaning purposes use the same solution as that used on the bore. Immediately after firing has been completed, disassemble the mechanism for cleaning and oiling. After washing and rinsing the breechblock, dry it thoroughly and apply the proper lubricant.

The firing mechanism requires the same attention as the breech mechanism. Fouling of the firing pin or use of oil which is too heavy will cause the absorption of the energy of the firing spring and may result in a misfire. This is especially true in cold weather, when a light application of oil will suffice.

The carriage will be kept free of dirt, grit, etc., and will be lubricated according to the instructions contained in the pertinent Technical Manual and War Department Lubrication Order.

Service of the recoil mechanism is usually limited. It is most important that the recoil fluid be maintained at its proper level. Failure to do so results in long or short recoil lengths and may cause damage to the recoil mechanism. The stuffing boxes should be watched carefully for leakage. Water must not be introduced into the recoil mechanism. All recoil oil must be observed closely for water content. If water is found to be present in recoil oil, the oil must be turned in. Recoil oil should be kept in the original marked container until used. It should not be transferred to other receptacles or exposed to dirt or moisture. The greatest care must be exercised to prevent contamination of recoil oil.

The principles of operation and care for carriage components, mounts, and self-propelled vehicles as pertaining to automotive mechanisms generally are discussed in Chapter VII, *Automotive.*

INTERIOR BALLISTICS

Ballistics is a science that deals with the motion of projectiles and the conditions which affect that motion. The two most important divisions of this science are interior ballistics and exterior ballistics. The former deals with the projectile while it is in the bore of the gun, and the latter deals with the projectile in free air.

There are many things that affect the projectile while it is in the bore of the gun, namely, the mode of combustion of the propellant, the pressure developed, the velocity of the projectile in the bore, the capacity of the powder chamber,

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Cal	Sighting System	Weight (Firing Position)	Time to Emplace (Minutes)	Maximum Rate of Fire R/M	Prime Mover	Muzzle Velocity F/S	Weight of Average Projectile (pounds)	References	S N L
37-mm M1A2 Combination Gu with 2 Cal. 50	M5	20,000	———	120	M15A1 Combination Gun Motor Carriage	2600	1.34	TM9-235 TM9-1235	A-29 G-102
37-mm M3A1 Anti Tank Gun	———	912	1½	15-20	¾T 4 x 4 ¼T 4 x 4	2900	1.61 or 1.92	FM23-70 TM9-1245	A-44
37-mm M6 Mount M44 Tank Gun	———	16,500	———	15-20	M5 Tank M8 Armored Car	2900	1.61	TM9-1250 FM23-81	A-45 A-55
40-mm M1 Antiaircraft Gu	———	5,549	2	120	2½T 6 x 6	2870	2.06	TM9-252 TM9-1252 TM9-1253	A-50
40-mm M1 Antiaircraft Gu Airborne	———	4,190	2	120	¼T 4 x 4	2870	2.06	———	A-50
57-mm M1 Anti Tank Gun	———	3,148	1½	30	1½T 6 x 6	2950	6.28	TM9-303	C-36
60-mm M2 Mortar	———	42	½	30-35	———	189 518	2.96	FM23-85	A-43
75-mm M1897 A4 Gun	———	3,460	3	6	2½T 6 x 6	2000	14.60	TM9-305 TM9-1305	C-12
75-mm M1897 A Gun Mounts M3, M	———	1800 (Approx.)	———	6	M3 Gun Motor Carriage	2000	14.60	TM9-306	C-48
75-mm M3 Mounts M34 o Tank Gun	———	2,712	———	20	M4 Series Medium Tank	2050	14.70	TM9-307	C-44
75-mm M1A1 Field Howitzer	———	2,089	3	6	6 Horses w/ Light Limber M4	1250	14.6	TM9-320 TM9-1320	C-26
75-mm M2 & h Mount M7 Howitzer	———	34,580	———	6	Howitzer Motor Carriage M8 Light Tank	1270	14.6	———	C-51
75-mm M1A1 Pack Howitzer	M1	1,270	3	6	M1 6 Pack Animals	1250	14.6	TM9-320 TM9-1320	C-20
	M8	1,442			M8 ¼T 4 x 4			TM9-319	C-54
76-mm M1A1 Mount T1 Tank Gun	———	37,500	———	20	M18 Gun Motor Carriage	2700	15.44	TM9-308	C-58
3" M5 Antitank Gun	———	4,785	3	20	M3 Half-track	2800	15.44	TM9-322	C-40
3" M7 Mount M5 Gun	———	66,000	———	20	M10 Gun Motor Carriage	2800	15.44	TM9-323	C-43
81-mm M1 Mortar	———	136	½	30-35	———	71.6 to 213.4	15.15	FM23-90	A-33
90-mm M1 Antiaircraft Gu	———	5,600	Fixed	20-30	Fixed	2700	23.4	TM9-373	D-37
90-mm M2 Mobile Antiaircraft Gu	M7	31,500	7	20-30	M4 Hi Speed Tractor	2700	23.4	TM9-379 TM9-372A	D-38
105-mm M2A1 Howitzer	———	4,260	3	4	2½T 6 x 6 or M5 Hi Speed Tractor	1550	33.0	TM9-325 TM9-1325	C-21
105-mm M3 Howitzer	M8	2,495	1	15	¾T 4 x 4 Weapons Carrier	1020 to 1550	33.0	TM9-326	C-50
105-mm M2A1 Mount M4 Howitzer	———	52,000	———	4	M7105 Howitzer Motor Carriage	1550	33.0	TM9-731E TM9-1325	C-45
105-mm M4 Mount M52 Howitzer	———	68,400	———	4	M4 Series Medium Tank	1550	33.0	TM9-324	C-21
4.5" M1 Gun	———	12,341	5	4	4T 6 x 6 M5 Hi Speed Tractor	2275	54.90	TM9-328	C-38
120-mm M1 Antiaircraft G	———	48,800	40	12	M6 Hi Speed Tractor	3100	50.0	TM9-380	D-32
155-mm M1 Gun	———	29,900	30	1	7½T 6 x 6 M4 Hi Speed Tractor	2800	94.71	TM9-350 TM9-1350	D-24
155-mm M1918 Mount M4 Gun	———	58,000	———	4	M3 Medium Tank Chassis	2410	95.0	TM9-345 TM9-1345	D-36
155-mm M1 Howitzer	———	11,966	5	3	4T 6 x 6 M5 Hi Speed Tractor	1850	95.0	TM9-331	C-39
8" M1 Gun	———	69,500	1 to 2 Hrs.	1	M6 Hi Speed 38T Tractor	2840	240	TM9-336	D-33
8" M1 Howitzer	———	28,000	½ to 1 Hr.	1	7½T 6 x 6 or M4 Hi Speed Tractor	1950	200	TM9-1350 TM9-335	D-29
8" Mk VI M Gun	———	113,860	———	2	———	2840	260	TM9-442	E-55
8" Mk VI M Gun	———	230,000	4 Hrs.	2	R. R. Engine	2840	260	TM9-463	E-34
240-mm M1 Howitzer	———	64,700	1-2 Hrs.	1	M6 Hi Speed 38T Tractor	2300	360	TM9-341	D-31
16" Mk II M Gun	———	1,172,500	———	1	———	2650 2750	2240 2100	TM9-471	E-58

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and the powder used to give the desired muzzle velocity while not exceeding the maximum permissible pressure.

A gun is designed to withstand a certain pressure. A pressure curve is determined for the gun. This curve shows the maximum pressure which any portion of the tube can withstand without exceeding the elastic limit of the metal. The maximum pressure varies along the tube as shown by curve A in Figure 89. Every tube must have a safety factor; and after this is considered, a permissible pressure curve is drawn, curve B. The pressure along any part of the tube must not exceed the value shown on this permissible curve.

Different powders give different pressure curves. Figure 89 shows the pressure curves for several powders designated as C, D, E, and F respectively. Each powder will impart the same muzzle velocity to the projectile although the corresponding pressure will vary greatly due to the different rates of burning of the powder. Curve C, in Figure 89, shows the effect of a relatively fast progressive powder. Curve D which shows a smaller maximum pressure is the result of a slower burning progressive powder, and curve E shows the curve for a still slower progressive powder.

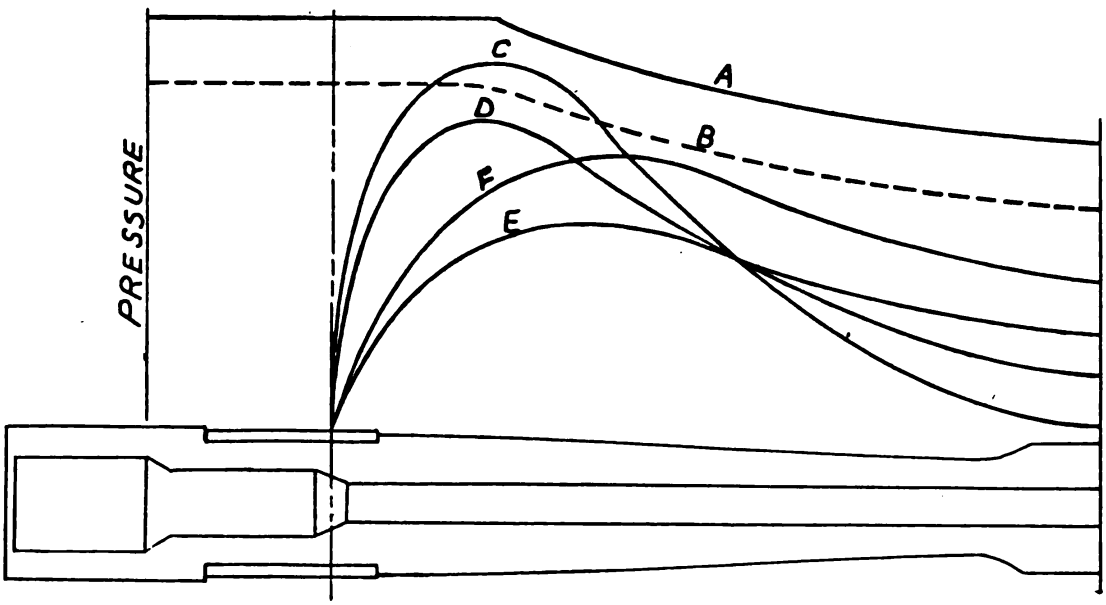

Figure 89. Powder Pressure Curves.

As shown in the above figure, the permissible pressure curve is exceeded by the maximum pressure of powder C. Powders shown by curves D and E are the only powders that could be used with this tube. If it were desired to increase the velocity of the projectile, it would be possible to do this by using powder E and increasing the powder charge. This would increase the pressure and also increase the muzzle velocity as shown in the diagram by curve F. Notice that the areas under curves C, D, and E are equal because the muzzle velocity is constant for all three powders. However, the velocity was increased when the extra charge was added to powder E; this is shown by an increase in the area under curve F.

The ideal situation from a ballistic point of view would be to have the powder pressure curve coincide with the permissible pressure curve. If, however, a powder could be developed to give such a powder curve, it would be impractical to use, because the pressure and temperature would be so high that the tube would wear away, resulting in excessive clearance and non-uniformity in velocity. In selecting a suitable powder granulation, wear, flash, and uniformity must be considered. Wear, or erosion, increases with the weight of powder, velocity, and temperature. It is not possible to obtain the maximum energy from a gun without reducing its accuracy life.

From a practical point of view the prescribed velocity is somewhat below the

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maximum obtainable, and the best grain is that which will give uniformity and not exceed the permissible pressure at any point.

Smokeless powders, which are used for propelling charges, are granulated into many geometic forms of different sizes and lengths, such as strip, solid cord, single perforated, multiple perforated, and the rosette. The grains give different pressure curves due to their burning characteristics. The multiple perforated type has been adopted as the standard for American cannon powders because it gives high velocities with low pressures owing to its increasing burning surface. The single perforated grain is used for small arms, because of the impracticability of making multiple perforated grains so small.

If these grains were to burn in air, they would burn very slowly; however, as the pressure increases rapidly so does the rate of burning. As the grains burn, the rates of combustion and of pressure variation will depend upon the area of surface changes. The burning area of solid grains continually decreases during combustion. This is called *degressive* buring. The burning surface of multiple perforated and rosette grains increases as burning progresses. This is called *progressive* burning.

In developing any desired muzzle velocity, a degressive form of powder will produce its maximum pressure early and the pressure will decrease rapidly. If given the same maximum permissible pressure, a high velocity can be developed by using a progressive burning powder. The pressure will increase and subside much more slowly.

The velocity and the maximum pressure may be varied by changing the density of loading. Density is the weight per unit volume. Therefore the density could be varied by changing the weight of the powder charge at the same time keeping the volume of the powder chamber constant. The density could also be changed by using the same weight of charge but by varying the volume of the powder chamber. This could be done by using a different size gun or projectile or by non-uniform seating of the projectile. Using the same gun and projectile the density could be changed only by varying the weight of charge or non-uniform seating. A decrease in the density of loading decreases the maximum pressure and hence the velocity. Velocity varies as the square root of the density.

As stated previously the velocity of a projectile is greatly affected by the condition of the bore. When the bore is worn and enlarged, gases escape past the rotating bands, thus decreasing the pressure and consequently the velocity. Enlargement of the bore may be caused by erosion, a result of firing or it be caused by corrosion, the effect of neglect. The condition of the bore and the accuracy life of the gun will depend on the amount of care given the gun.

When manufactured, each powder has a definite amount of moisture. These powders may also contain graphite, a stabilizer, and inert materials. Their contents should never change until the powder is fired. Varying the percentage of any of these materials will greatly effect the energy content of the powder which in turn will increase or decrease the velocity and range of the projectile. Powder should be cared for and should not be exposed; otherwise, the characteristics and composition will vary.

Temperature of the powder has a great effect upon the velocity of a projectile. An increase in temperature increases the burning rate of the powder, resulting in a greater velocity. Conversely a decrease in temperature would cause a decrease in velocity. A tabulation of the effects of the variation of temperature from standard temperature is incorporated in firing tables. If at all possible, ammunition should be left in the magazine where the temperature is known until just before using. When ammunition is moved into the field, it should be covered so as to keep the temperature change at a minimum.

Part of interior ballistics is the calculation of muzzle velocity of a projectile. The velocity is not measured at the muzzle, but at a short distance from the muzzle so that the errors due to muzzle blast will be eliminated. Velocity is calculated by measuring the time it takes a projectile to move a certain known distance. The instrument used is called a chronograph, which measures time very precisely.

It is also possible by instruments to measure the pressure change as a projectile moves along the bore of the gun. By measuring this pressure and knowing the

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velocity, correct granulations and powder changes can be selected and developed to give the best characteristics in firing.

Although correct gun tubes, powder granulations, projectiles for great accuracy, etc., have been developed and made available for use, these tubes, powders and projectiles must be cared for, otherwise, the accuracy of our weapons will be greatly diminished as the result of mere neglect and carelessness.

EXTERIOR BALLISTICS

Exterior ballistics is a science that deals with the motion of a projectile in free air. As the body moves through air, its center of gravity traces a path. This path is called the trajectory of the projectile. The principal problem of exterior ballistics is the calculation of this trajectory for different types of projectiles, so that when the gun is fired under a given set of conditions the projectile will fall at a predetermined spot.

Before discussing exterior ballistics futher, there are a few definitions that are characteristic and should be mentioned.

With regard to the trajectory, figure 90, the *origin* is the position of the center of gravity the instant the projectile is released by the projecting mechanism. The *end or terminal point* is its position upon bursting or encountering a medium other than air. The *line of departure* is a line tangent to the trajectory at the origin.

Quadrant angle of departure, θ (theta), is the angle made by the line of departure with the horizontal. As a projectile moves through the air, its axis of symmetry forms an angle with the direction of motion, this angle is called the *angle of yaw* Δ (delta). The angle of yaw can lie in any plane. To express the plane that it is in, the angle between the plane of yaw and the vertical plane including the tangent to the trajectory is given. This angle is called the *angle of orientation,* Φ (phi).

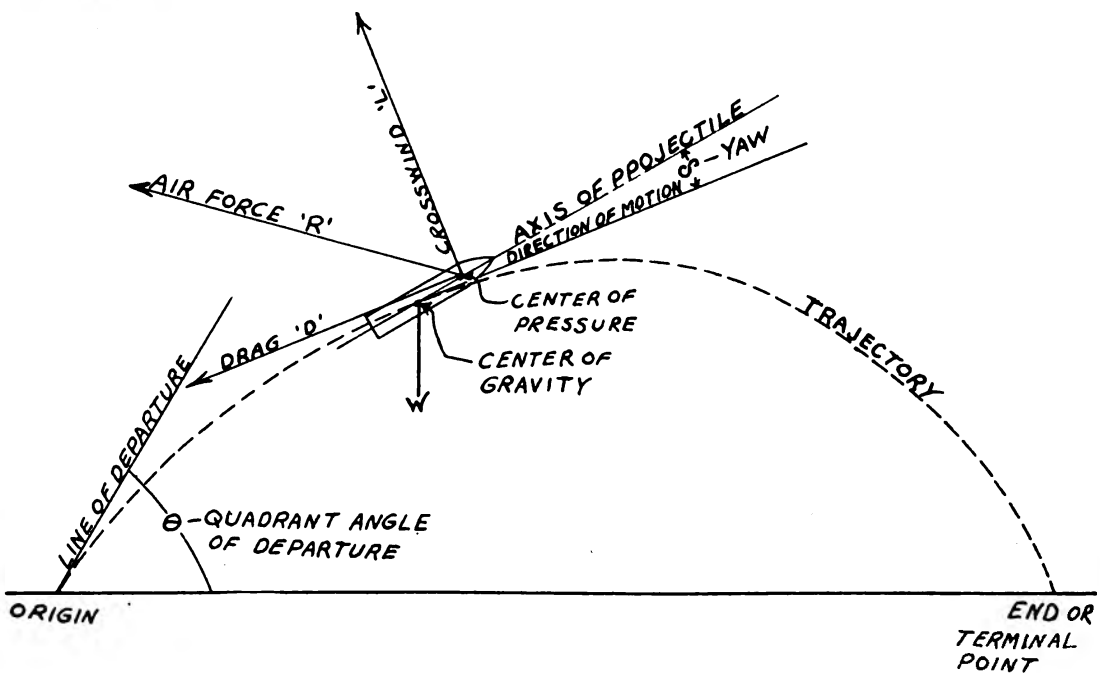

Figure 90.

As the projectile moves through air, it is acted upon by an air force R, and by the force of gravity W, which is a force acting vertically downward through the center of gravity of the projectile. The magnitude and direction of the air force depend upon the velocity of the projectile, the airspeed, the characteristics of the air and the projectile, and the angle of yaw. This air force acts on the side of the projectile toward the direction of motion and can be considered as acting through the center of pressure. The center of pressure, as shown by figure 90, is nearer

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the nose of the projectile than the center of gravity. If the projectile is tilted more, that is, has a greater angle of yaw, there will be a greater area exposed to the resisting air, and therefore a greater force resisting the forward movement of the projectile. To simplify the calculations for the air force, R is considered as an equivalent of two components, one having a direction opposed to the motion of the projectile called the drag, D, and the perpendicular to the direction of motion called the cross wind force, L.

The angle of yaw has a great influence on the cross wind force and also on the amount of drag. In fact an angle of yaw of 13° will produce a drag twice as great as no yaw. Figure 91 shows the great increase in the drag coefficient, hence drag, as the angle of yaw increases. Also the cross wind force which acts through the

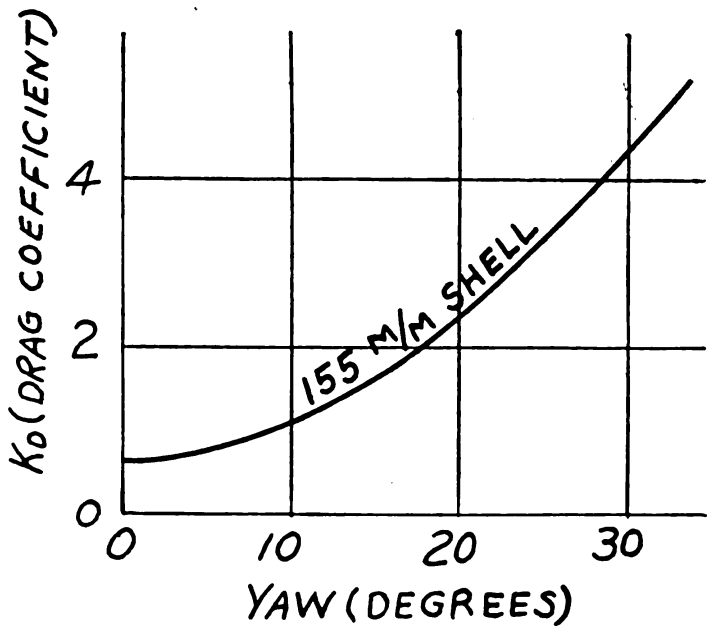

Figure 91.

center of pressure, produces a moment about the center of gravity that tends to make the projectile tumble and therefore it is a necessity to keep the angle of yaw at a minimum. This is done on artillery projectiles by imparting a spin to the projectile. The spin of a projectile produces the same effect as spinning a top. If the projectile is rotated fast enough, it will not wobble, but will become very stable. When a gun is fired there are many disturbances which cause the projectile to wobble giving it an angle of yaw. Although the nutations (similar to the nodding motion of a spinning top) dampen out farther away from the gun and the angle of yaw caused by the disturbance diminishes, the greater curvature of the trajectory farther away from the gun increases the angle of yaw.

The tendency for airplane bombs to tumble is minimized by the use of fins or tail assemblies. These assemblies change the center of pressure to the rear of the center of gravity thereby reducing the overturning moment, and hence the tendency to turn over.

As a result of the curve of the trajectory, the axis of the projectile tends to point above the trajectory. From the angle of yaw thus produced, a moment arises (cross wind force about center of gravity) which causes the axis of a projectile with a right handed twist to deviate to the right. For most trajectories with a quadrant angle of departure less than 40° the projectile continues to point to the right for all parts of the trajectory except near the gun. Since the projectile is pointing to the right and the cross wind force is in the plane including the tangent to the trajectory and the axis of the projectile, the cross wind force acts to the right, pushing the projectile to the right producing the phenomenon of drift, the component of deflection not due to wind.

There is a great difference in the motion of air around a projectile when the

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projectile exceeds the speed of sound. As the projectile approaches the speed of sound, the eddy currents which are formed by the moving projectile produce audible waves of small amplitude. As the velocity of the projectile exceeds the speed of sound, the amplitude of these waves increases rapidly and there is a decided rise in air resistance. The waves which are produced give the cracking sound which is heard as a bullet passes over head.

Figure 92 shows the great increase on the drag coefficient, hence drag, as the velocity reaches the speed of sound. U is velocity of projectile, A represents speed of sound.

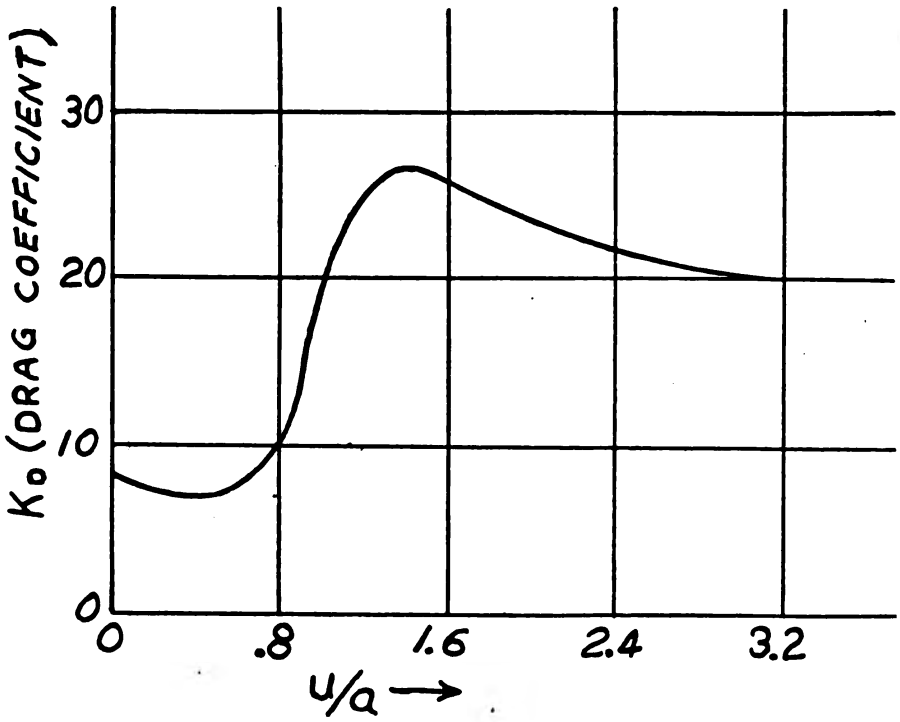

Figure 92.

Air characteristics play an important part in determining the trajectory of a projectile. Change in temperature will cause a change in range. Also, as the density of the air increases or decreased, the air resistance will rise or fall. It is important to consider all of these changes in order to get accurate results in firing. Firing tables which are made for each gun and kind of ammunition list compensations for changes from the standard for temperature, air density, wind, etc. When making such a table for a certain projectile, trial firings are conducted and all the characteristics such as air density, temperature, wind, range, elevation, are recorded for different gun settings. With this data, equations are developed. These equations, and curves representing these equations, are solved and then give the information for all ranges, elevations, temperatures, etc.

As stated previously the characteristics of the projectile will affect the trajectory. Each projectile has a constant called the ballistic coefficient. The larger this coefficient the smaller will be the retardation, and hence the longer the range. It is possible to compensate for a change in the ballistic coefficient by remembering that it varies as the reciprocal of the air density. Therefore if a projectile with greater ballistic coefficient is used, compensations can be made by considering a corresponding decrease in air density. The ballistic coefficient of a projectile can be changed in various ways, such as scratching or denting the projectile, thus changing the trajectory. It is therefore necessary to handle projectiles with care so as not to damage them in any way.

A few of the more important phases of exterior ballistics have been considered. From these it should now be possible to comprehend some of the many forces and conditions that affect a projectile as it passes through the air.

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MORTARS

The mortar is a high angle trajectory weapon having a barrel of less than 10 calibers in length. It is generally employed against personnel and open emplacements. The ammunition fired is normally high explosive, smoke, or of the chemical filler type, although modified projectiles have been used for offensive operations against barbed-wire defended positions. The discussion following applies to 60mm and 81mm mortars since these are the principal types in current use. The reader is referred to publications of the Chemical Warfare Service for data pertaining to the 4.2 inch chemical mortar.

Description. The unit consists of the mortar and mount. The mortar consists of the barrel, base cap, and firing pin. The mount consists of the bipod and base plate. The bipod is composed of the legs, the elevating and traversing mechanism assemblies.

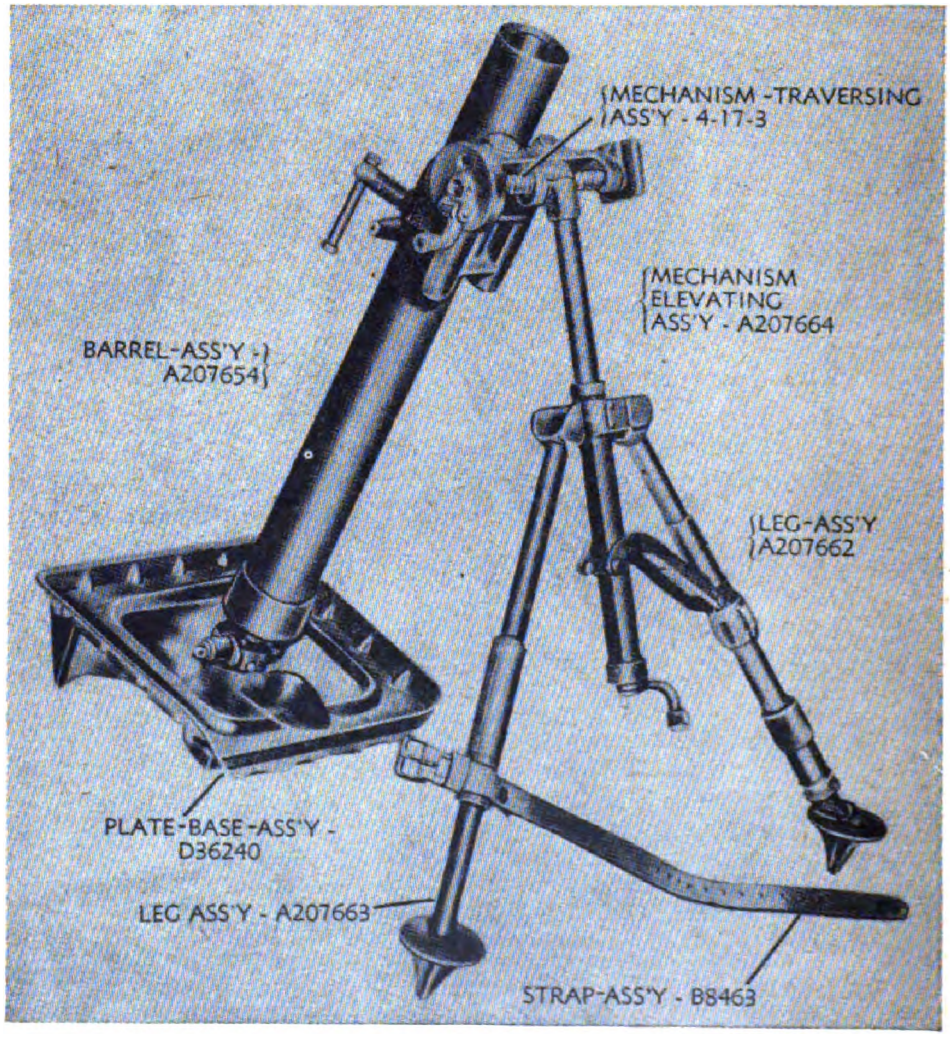

Figure 93. 60mm Mortar.

The mortar is attached to the bipod by the mortar clamp and is fitted to the base plate by inserting the base cap projection into a socket in the base plate. There is one socket in the 60mm mortar base plate and three sockets in the 81mm mortar base plate.

The mortar sighting equipment consists of the Sight M4 which has a collimator, elevating and lateral deflection mechanisms, and longitudinal and cross levels. The Sight M4 is supported by a bracket with a dovetailed base which fits in a slot in the mortar yoke and which is latched in position.

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The breech end of the barrel is threaded on the outside. The base cap is hollow and threaded on the inside in order to screw on the barrel, thereby closing the breech end of the mortar. The firing pin is held stationary in the base cap with its point protruding into the barrel. It is threaded into the base cap.

Operation. The mortar squad makes use of three men for transporting the weapon and will use additional men depending upon ammunition requirements. Generally, mortars provide support for rifle companys and battalions. They will be mounted in the most strategic position forward with regard to suitability of terrain for emplacing and concealing the weapon. Line of fire is designated by the aiming stake which is positioned prior to emplacing the mortar. The base

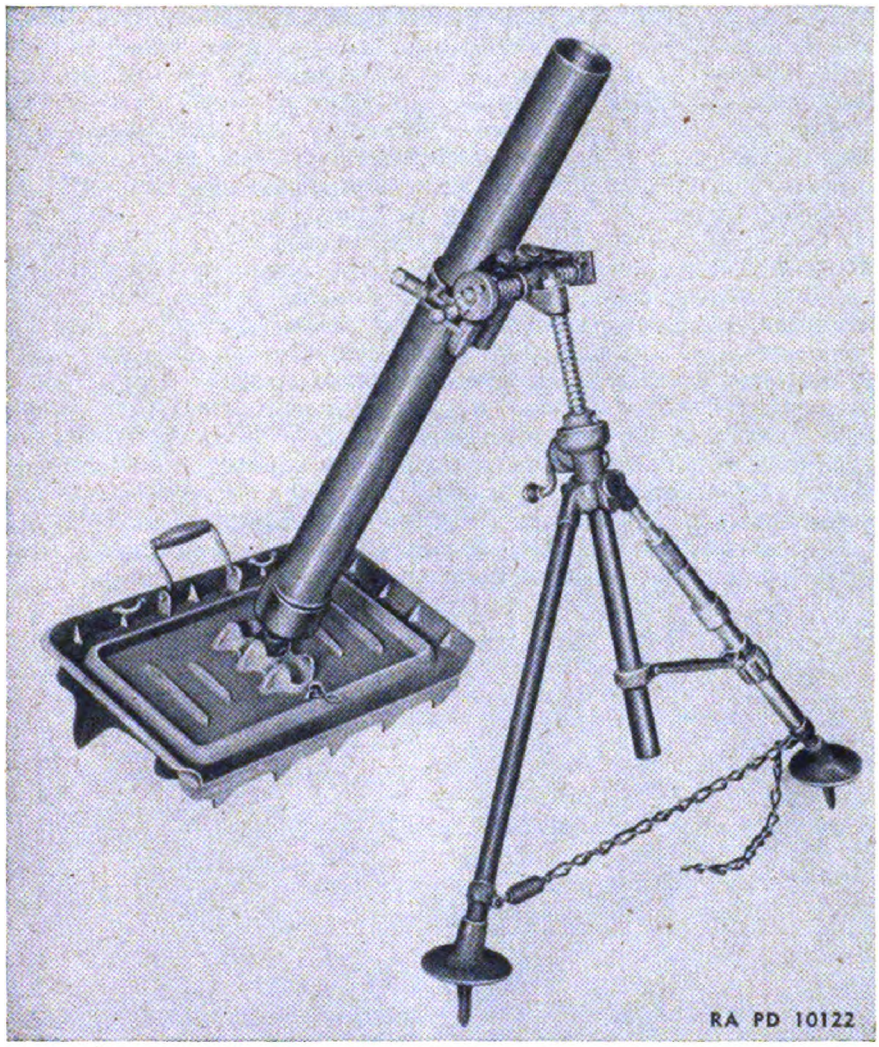

Figure 94. 81mm Mortar.

plate, bipod and mortar are mounted in the order mentioned. The 60mm mortar is carried with the bipod attached to the barrel assembly. The bipod is carried separately in transporting the 81mm mortar. Speed and accuracy of set-up determine the effectiveness of mortar fire.

While the gunner is checking the weapon emplacement for stability and clearance along the line of fire, range data, deflection, and powder increments are being determined by the squad leader. After completing these checks, the squad leader orally transmits firing data to the gunner and to the ammunition men. The safety pin is then removed from the fuze by the assistant gunner.

The shell, with fins down is dropped into the muzzle end of the mortar barrel,

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and, falling under is own weight, causes the primer cap to strike on the firing pin when the bottom of the barrel is reached. Flame from the primer ignites the propelling charge (powder increments). The shell moves up the barrel and is discharged from the barrel under the pressure produced by the burning gases. Mortar shells are bore-safe in event of a primer misfire, but caution is required in removing misfired shells from the mortar barrel.

The mortar barrel may be traversed up to a maximum overall deflection of 250 mils for 60mm mortars and 180 mils for 81mm mortars. The traversing mechanism is operated by a handwheel and consists of a screw and nut device attached to the bipod. The barrel may be safely elevated from 40° to 85° measured vertically above the horizontal position.

The elevating mechanism of the 60mm mortar is of the screw and nut type. In the 81mm mortar the nut is replaced by a bevel gear, which is moved along the elevation screw by a driving bevel gear attached to the elevating crank.

A cross-leveling mechanism permits the gunner to check his alignment against canting after the weapon has been emplaced. The mechanism is fitted to the left leg of the bipod and cross-connected to the elevating screw.

Adjustments and Precautions. Relatively simple adjustments will ensure dependable mortar operation. The firing pin must be screwed securely in place to prevent gas leakage around the firing pin during firing. Play in the traversing nut may be reduced by prompt adjustment of the traversing nut adjusting bushing. End play in the traversing screw will be reduced by replacing the traversing screw spring on the traversing screw bushing. Play in the elevating mechanism is normally taken up automatically by the elevating screw spring. Play in the elevating mechanism indicates a defective elevating screw spring which will be corrected by replacing the spring. Replacement of mortar parts, other than firing pins, is performed by Ordnance Department or other qualified personnel.

An important mortar operation safeguard is to keep the barrel clean and coated with a light film of oil. Cleaners prescribed for artillery in general are suitable for mortars. Special preservative lubricating oil should be used on mortars when available but SAE 10 Engine oil or SAE 30 Engine oil thinned with cleaning solvent may be substituted in emergencies.

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CHAPTER 3

FIRE CONTROL

INTRODUCTION

Scope. Fire control materiel, a very broad term, includes many pieces of equipment all of which are intended to aid the using arms, directly or indirectly, in laying weapons so that their fire will be effective. Included in that classification are such definitely different items as the pocket compass, carried by a private, and the complicated apparatus used to determine how a 120mm antiaircraft gun shall be aimed in order to hit an airplane which may have changed its position by a mile or more while the shell is in flight.

Classification. Classification of fire control materiel may be made along several broad lines. Standard Nomenclature Lists use the classifications "sighting equipment" and "fire control instruments." These groupings include, generally, on-carriage and off-carriage items respectively. Another classification might be made so as to group items which make use of optical principles primarily, and items which include mechanical and electrical devices.

The rapid development of antiaircraft *fire control materiel* has brought about still another rough grouping, one which acknowledges that such instruments and equipment must meet requirements entirely different from those presented in the use of other ground weapons. Thus it has been found convenient, in the discussions of fire control materiel to follow, to consider instruments and equipment used with small arms, automatic weapons (other than antiaircraft), mortars, field artillery pieces, and similar weapons under the heading General Instruments. This classification is also construed to include some items which are used in conjunction with specific pieces of antiaircraft fire control devices, yet which have the characteristics of general instruments.

General Instruments are those which are essentially optical in nature and are used by all branches of the Army except antiaircraft artillery. All the various arms of the service fire weapons of one kind or another and will have need of some type of fire control equipment. To fire at the target is not enough; hitting the target is the important thing. It is evident that with the many different kinds of weapons encountered throughout the Army, there will necessarily be as many different kinds of sights and fire control equipment. General instruments comprise by far the largest group of different instruments; however, many of these are of similar design and serve similar purposes.

In our discussion of general instruments, we shall consider the purposes for which the various instruments have been designed and the part which each plays in solving the fire control problem for the various weapons. Before considering these instruments, however, we must understand the two general methods by which laying of a weapon may be accomplished: namely through the use of either direct fire, or indirect fire.

DIRECT FIRE

If a target is visible from the gun, then the weapon is aimed by the use of sighting equipment mounted on the gun. This form of fire control is called direct fire, and, in order to use this method, we must establish a line of sight from the gun to the target.

One of several types of sights may be used for this purpose. The crudest form is the *open sight* containing no optical elements. This type is used on small arms and consists of a front sight and a rear peep or notch sight. When the two sights are lined up on the target the weapon is aimed. The principal shortcoming of this type of sight is the inaccuracy introduced because the human eye can not at the same time see clearly the rear sight, the front sight, and the target. Two of these elements will appear blurred when the third is viewed; the eye cannot accommodate itself for objects at different distances at the same time. A second drawback of open sights is the necessity of placing the eye at a very definite position behind the rear sight.

The *Collimating Sight* obviates these two limitations. A simple lens is used in

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place of the rear sight and a reticle is used for the front sight. When looking through the lens, the reticle appears to be magnified and at a great distance from the eye. It appears, therefore, to be superimposed over the target, and can be lined up accurately with the target to establish the line of sight. Many old panoramic telescopes and the M4 mortar sight use this form of sight. By employing a partially reflecting mirror in conjunction with the collimating sight, the reticle and the target can be observed through the same aperture. Many aircraft weapons and the antiaircraft multiple gun motor carriages use sights of this nature.

Telescope Sights are mounted parallel to the gun tube and enable the observer to look through the sight and see the reticle apparently superimposed over the target, which itself may be magnified. A reticle pattern which is graduated for various ranges enables the gunner to give the proper amount of elevation to the weapon. He places the target on the graduation corresponding to the estimated range.

Lateral graduations may be provided to enable the gunner to estimate more accurately the proper amount of "lead" to give a moving target. Telescopic sights are used for direct fire on many tank weapons, antitank guns, and artillery pieces. Antiaircraft guns can be employed against ground targets and are therefore provided with telescopic sights.

In the control of direct fire, no effort is made to compensate for factors other than range and lead. Errors resulting from wind, muzzle velocity, drift, etc., are adjusted after the first round is fired and the effect of fire observed.

INDIRECT FIRE

It is frequently necessary to lay a weapon so as to hit a target which is invisible from the position of the gun. Such may be the case with a field howitzer shooting over a mountain or a large seacoast gun firing at a target at sea. It is necessary to establish an observation post from which the target can be seen and at which the fire control data is gathered and computed for the gun. Such a procedure is called indirect fire.

The data needed for the direction of the gun is the azimuth, or direction of the target, and the elevation at which the gun shall point. If the azimuth of the target is measured at the observation post, a correction must be applied to compensate for the difference in position between the observation post and the gun. The determination of this correction is the primary consideration in computing the azimuth for the gun. In more precise firing, correction is made for windage, drift, and even the rotation of the earth.

In order to lay a gun in elevation, it is necessary to determine the difference in altitude between the gun and the target and the range to the target. Firing tables show the range elevation for all possible ranges. Knowing the elevation of the target and the additional elevation for range, we can lay the gun at the proper angle from the horizontal. In more accurate computations, such as for heavy field artillery or coast artillery, certain ballistic corrections must be applied to the elevation. Change in muzzle velocity due to wear, temperature of the powder, and the weight of the projectile must be taken into consideration. Also, ballistic corrections for air density, wind, air temperature, and rotation of the earth enter into the problem.

Regardless of the accuracy of the fire control procedures, we cannot expect a hit with every round that is fired. Due to dispersion, we can expect only a certain number of hits within a given area according to the laws of probability. It is the purpose of fire control to place the center of dispersion on the target.

In many fire control methods, particularly those used with smaller weapons, it is neither necessary nor advisable to take the time to compute the firing data accurately. Minor errors are corrected by observing the bursts relative to the target. Thus, by the use of observation instruments we can make corrections for errors regardless of what causes them. In observing the effect of fire, we must be able to detect 'overs' and 'shorts,' as well as 'lefts' and 'rights.' The latter are easily discernible, but it is very difficult to detect an 'over' or a 'short,' especially at the longer ranges. For this reason, observation instruments are made binocular so that both eyes may be used to observe stereoscopically. This stereoscopic effect is increased by magnification of the telescopes and also by having the objective lenses of the telescopes separated more than the distance between the eyes.

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THE ANTIAIRCRAFT PROBLEM

Just as there exists a wide variety of general instruments designed to meet specific needs, so there are many distinct pieces of antiaircraft fire control equipment. While these may be grouped under the single heading Antiaircraft Fire Control Materiel, a discussion of them as an entity is not feasible; therefore, in the following pages, distinct types have been chosen for separate consideration.

Providing defense against aerial attack the basic mission of antiaircraft artillery, presents problems unique in the fire control picture. The most obvious problem is anticipation of a target's position, because the target may move a very considerable distance after a shell has been fired. The problem is comparable to that

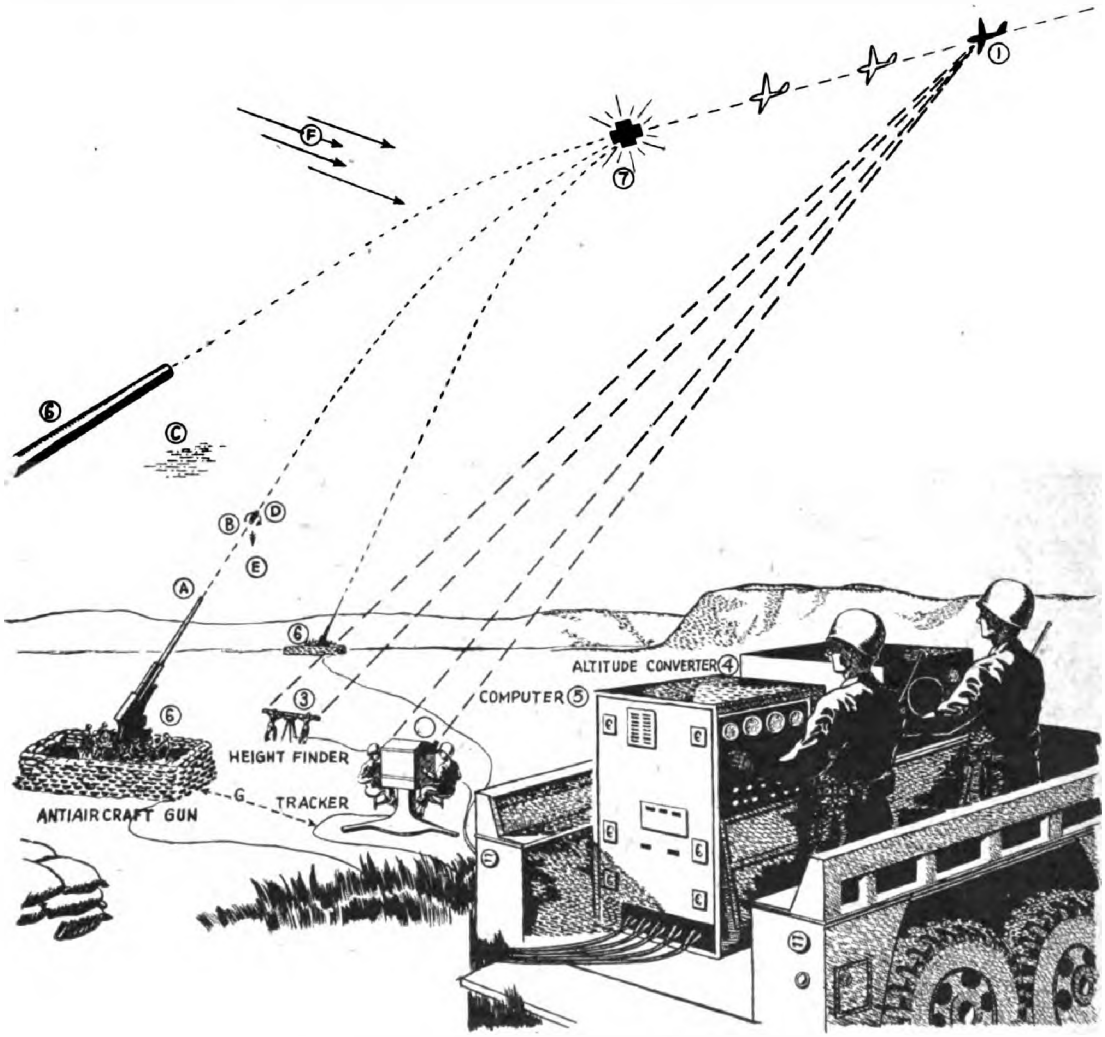

Figure 1. The Antiaircraft Fire Control Problem.

HOW TO HIT AN ENEMY PLANE AT 5 MILES—Solved Instantly By the Electical Gun Director

THE PROBLEM

An enemy bomber is sighted 5 miles away, 3 miles high, flying fast. He's within range of your 90 mm. anti-aircraft battery. A shell will take perhaps 20 seconds to reach him, but meanwhile he'll have flown nearly 2 miles. How could you possibly tell where to aim to hit such a speeding target?

HOW THE GUN DIRECTOR SOLVES IT

Enemy plane ① is spotted and followed by Tracker ② and Height Finder ③, which feed information into Altitude Converter ④ and Computer ⑤. Swiftly the Computer plots the plane's distance, course and speed—aims the gun ⑥ and sets the fuse of the shell to burst at a calculated point ⑦ for a hit.

This electrical brain—the Computer—thinks of everything. It figures on: A, muzzle velocity of gun; B, shell drift to the right due to its spin; C, air density; D, time of shell's flight; E, downward pull of gravity; F, direction and velocity of wind; G. even the distance between Tracker and gun!

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confronting a duck hunter who must be able to 'lead' his target accurately if he is to return with a full bag of game. Antiaircraft gunners, however, must be capable of firing against targets whose speeds may vary from roughly 175 miles an hour to 400 miles an hour and which may be at ranges varying from 400 yards to perhaps 10,000 or 12,000 yards.

Determination of the future position by means of adding 'lead' (or prediction) to present position does not, by any means, complete the solution.

With future position determined, it may yet be necessary to correct for many errors and considerations. Were the gun fired directly at the future position, the shell, because of the pull of gravity on it, would pass below the target. A means must be found, therefore, to compensate for trajectory drop. Drift, the shift of the shell to the right caused by the rotation of the shell, may also cause an error large enough to require compensation. Changes in muzzle velocity, variations in air temperature and pressure, humidity and wind—all these may have such effects that corrections for them need to be inserted.

In short, then, the problem is to determine firing data, the elements of which are the angles of azimuth and elevation to be used, and, in some instances, the fuze setting required to have the burst occur at the proper time. This firing data must be appropriate for a given future position and take into consideration the various sources of error. The determination of future position requires a knowledge of the present position, for to this the prediction will be added. Prediction itself will, in turn, depend upon the rate at which the target is flying and the length of time that the target will have an opportunity to fly while the shell is in flight.

Of far-reaching importance is the fact that not just one set of firing data is to be computed, but rather that firing data appropriate for any instant must be available during the entire period of time that the target is flying a constant path within the range of the weapon being employed. This period may vary from as little as two or three seconds to more than half a minute, and so firing data must be produced simultaneously, instantaneously, and continuously throughout that interval.

EQUIPMENT

It should be obvious that the antiaircraft fire control problem is so complicated that its solution reaches far beyond the ability of individuals. Several types of directors are available, however, which will accomplish the desired results with amazing accuracy. Subsequent sections of this chapter will deal with them in some detail and will, in addition, offer information on instruments designed to supplement the directors.

Production of firing data must be coupled with a use of that firing data if it is to be of value. Little would be gained, however, if that data were not used with as much speed and accuracy as that with which the firing data was produced. It is necessary, therefore, to provide other pieces of fire control equipment for such purpose.

Cable systems are employed to transmit the information electrically to the guns. The weapons then must be continuously and instantly positioned in azimuth and elevation in accordance with this information. A manual control could be used, but it would tend to introduce both erratic motion and a certain amount of lag. Remote control systems have been provided, however, to bring the weapons to the desired positions. Provision must be also made, in some instances, to set fuzes at calculated values. These devices, too, fall within the antiaircraft fire control classification, as do also the generating units which supply power to operate the entire systems. Representative types of each of these elements will be discussed in some detail in the following pages.

GENERAL INSTRUMENTS

Principles of Optical Sights. General instruments are, for the most part, optical instruments. To understand optical instruments, however, it is necessary to be familiar with the most elementary aspects of optical science, and so it follows that in order to understand the optical principles underlying the construction of military optical instruments, we first need to know a few facts about a simple lens.

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Table of Equipment Ratings

Gen. Unit	Eng. Model	SAE Rated H. P. at 1200 RPM	Bore & Stroke	Alternator Ratings at 80° P. F.						References		Use		
				Phase	Voltage	Amp.	KVA	K. W.	Frequency Cycles/Sec	T.M.	SNL	Gun	Director	RCS
M5	Hercu- les Model XZB	11	2⅝ x 3	3	125 130	13.9 13.3	3	2.4	60 50	9-616 9-1616 9-2616	F- 227	37mm M3A1 Carr. 40mm M1, M2 M2A1 M5 Carr.	M5, M5A1 M5A2 M6	M1 M5 M9 M10 M15 M3 M4
M6	Hercu- les Model ZXB	11	2⅝ x 3	1 3	 125 	20 13.9	2.5 3 	2 2.4	60	9-616 9-1616	F- 227	90mm M1 Carr. 37mm 40mm	M4 M5 M5A1 M5A2	DTS M4, M4A1, M6 M1 M10M5 M15M9
M7 & M17A1	Hercu- les Model WXLC-3	 43.3	4¼ x 4¾	3	125	162	35	28	60	9-618 9-1618	F- 226	90mm M1A1 Carr. 90mm M2 Carr.	M4, M7 M7A1B1 M7A1B2 M9	M2 M12
M15 & M15A1	Hercu- les Model WXLC-3	 43.3 67	4¼ x 4¾	 3 	125 250	162 81	 35	 28	 60		 F- 226	 120mm M1 Carr.	 M10	 M6
M18	Hercu- les Model WXLC-3	 43.3	4¼ x 4¾	 3	125 250	162 81	 35	 28	 60	 9-617	 F- 291			

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The Converging Lens. The only kind of lens which concerns us is the so-called converging lens—thickest in the center and thinner toward the edge. This is the only kind of lens used to any extent in military instruments.

There are two facts about such lenses which we must remember:

(1) When light from a distant object passes through the lens, it forms a real image in the focal plane of the lens. A common example of this principle is the 'burning spot' found by holding a lens to the sun. The burning spot is formed at only one point behind the lens and is a real image of the sun; it appears round because the sun is round. The distance of the focal plane from the lens is termed the focal length of the lens and is the most important constant to know in connection with the lens. See Figure 2. The camera further illustrates this principle.

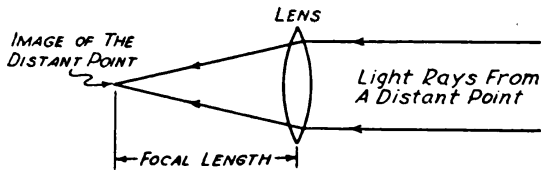

Figure 2. A Simple Lens.

The film is placed a distance behind the lens equal to the focal length so that a real image is formed on the film. A characteristic feature of all real images is the fact that they are inverted relative to the object which forms the image.

(2) The second principle is a little more difficult to understand because we have difficulty believing our eyes. When the normal eye looks upon a distant object, it is at perfect rest and without strain. However, as the object comes closer to the eye, it is necessary to strain or accommodate the eye in order to view the closer object. When the object approaches closer than a few inches, the eye cannot accommodate for it and therefore cannot see the object clearly, except with optical aid. By inserting a lens such as we have been discussing between the eye and the close object, we have no longer to strain the eye to see the object clearly because the lens aids the eye in seeing the object.

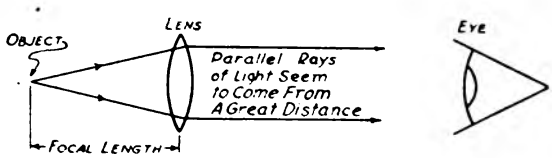

Figure 3. How a Lens Aids the Eye.

If the distance from the lens to the object is equal to the focal length of the lens, then the eye is at perfect rest and is viewing the object as if it were at a great distance. We thus have two desirable characteristics: the object looks clear and apparently at a great distance from the eye, and the object also looks large because it is actually close to the eye. The object looks large and far away at the same time, which is paradoxical but pleasing to the eye.

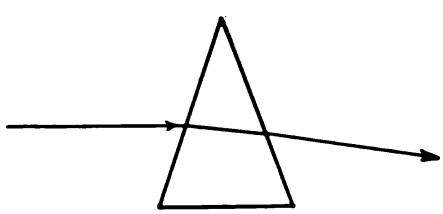

Figure 4. A 90° Prism.

To summarize, then, the two points which we must know in order to understand the use of lenses in optical instruments are:

(1) A lens forms a real image in its focal plane.

(2) An object placed at the focal plane and viewed by the eye through the lens appears large and distant, and the eye is at rest.

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The Prism. Another type of optical element found in instruments is the prism. The primary use made of prisms is to deviate rays of light from their original direction by simple refraction or by total internal reflection. Simple refraction takes place whenever light strikes an air-glass surface. A wedge of glass, for instance, causes the light to be bent at each surface, as shown in figure 4. Total internal reflection occurs whenever a ray of light in glass strikes the surface of the glass so that the angle between the ray and the surface is less than about 48°. Under this condition, the ray of light will not pass out into the air at all, but will be totally reflected back into the glass again just as if the surface were a perfect mirror. The 90° prism illustrates this phenomena well.

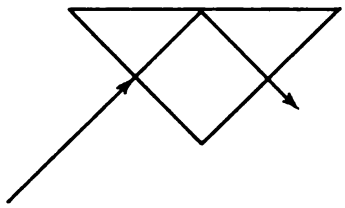

Figure 5. A Prism.

Collimating Sights. A collimating sight utilizes a single lens as the rear sight and a luminous object called the reticle for the front sight. The reticle is placed in the focal plane of the lens so that when viewed through the lens it appears to be at a great distance and is sharp and clear. This is an application of the second principle discussed in the preceding section. In order to view the target simultaneously, it is necessary to move the eye slightly to one side so as to see outside the sight towards the target and also through the sight to see the reticle. In other words, the eye is placed in such a piston that it can see both the target and the reticle which seems to be superimposed over the target.

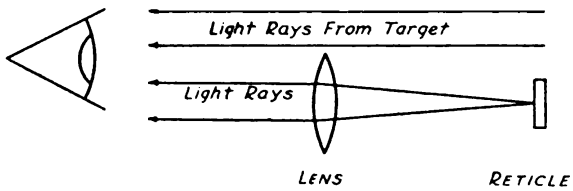

Figure 6. Principle of the Collimating Sight.

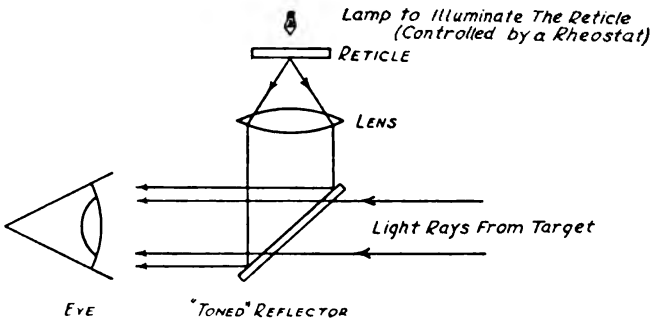

Figure 7. A More Advanced Type of Collimating Sight.

An alternative method is to look through the collimating sight with one eye and directly at the target with the other eye. The brain superimposes the images formed in each eye and the reticle therefore appears superimposed over the target. More recently, collimating sights have been developed for use in aircraft turrets and fighter planes and also for use in antiaircraft multiple gun mounts. These employ a toned reflector which is a mirror that both reflects and transmits light. It is arranged so that the observer can look through the mirror at the target and also receive a reflection of the reticle seen through the colli-

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mating sight. The various components are arranged as shown in figure 7.

The important advantage gained by the use of collimating sights is the fact that the position of the head behind the sight makes little difference as long as the reticle is visible, and a slight shift of the head introduces no error in the line of sight.

Telescopic Sights. It has been seen that the limitation of collimating sights lies in the fact that the target cannot be seen through the sight. This difficulty has been obviated by the use of telescopic sights. The simplest kind of telescope is the astronomical telescope. It consists of (1) an objective lens which forms a real image of the target in the focal plane of the objective lens, (2) a reticle which is placed in the same focal plane and is nothing more than a flat piece of

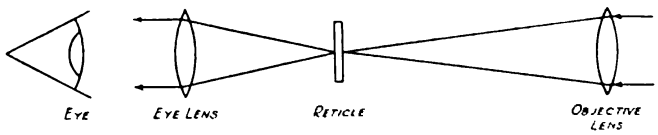

Figure 8. A Simple Astronomical Telescope.

glass with black lines etched on one surface, and (3) an eyelens placed a distance behind the reticle equal to the focal length of the eyepiece. With this arrangement, both the reticle and the image of the target are sharp and clear when viewed through the eyepiece, and both seem to be a great distance from the eye—in other words, the reticle seems to be superimposed over the target.

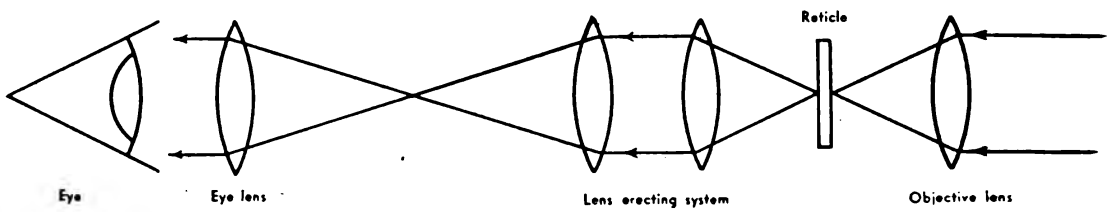

Figure 9. Simple Military Telescope.

Since all real images are upside down or inverted, it is evident that the target would appear inverted when viewed through an astronomical telescope. Consequently, military telescopes must be made to cause the target to appear erect. To do this we merely use two astronomical telescopes, one behind the other. Whereas the first telescope causes the target to appear upside down, the second telescope causes it to appear right side up again. Both telescopes are mounted in the same tube and we have military telescopes.

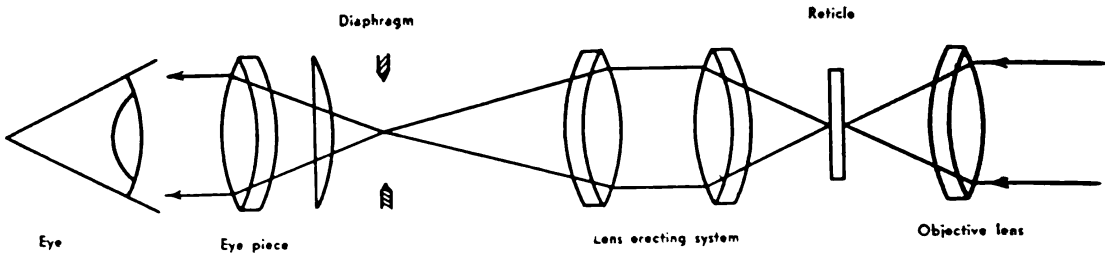

Figure 10. Practical Military Telescope.

It is evident that the two center lenses shown in figure 9 serve no other purpose than to erect the image. These lenses, therefore, constitute a lens erecting system. Other types of erecting systems may be used by combining various types of prisms in a telescope. In such systems the principle of total internal reflection is used to invert the image.

In some fire control operations it is desirable to use telescopes which magnify the target so that it appears closer or larger. Magnification is gained by the

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choice of lenses with suitable focal lengths, and thus any desired degree of magnification may be obtained in the design of a given instrument. In general, however, increases in magnification decreases the field of view.

There are certain lens aberations and distortions, particularly near the edge of the field of view, which the manufacturer must eliminate in the actual design of telescopes. He improves the clarity of images by combining lenses of various kinds of glass and mounting several lenses close together to perform the function of a single lens, but in a much more efficient manner. In many cases lenses

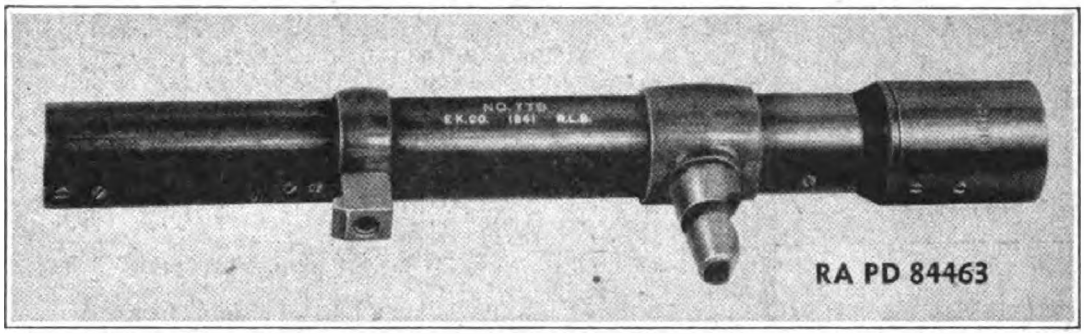

Figure 11. Telescope M6.

are cemented together and serve the purpose of a single lens. In a military telescope, we find the objective lens is a compound cemented doublet. Each lens of the erecting system is also a cemented doublet, and the eyepiece consists of two lenses mounted close together, either or both of which may be a cemented doublet. By combining lenses in this fashion we are assured of having a telescope which will give us a sharp and clear image over as wide a field of view as possible. A diaphragm also is usually inserted in the telescope at a point where a real image is formed, so that the edges of the field of view may be sharp and well defined and the visible part of the image sharp and clear.

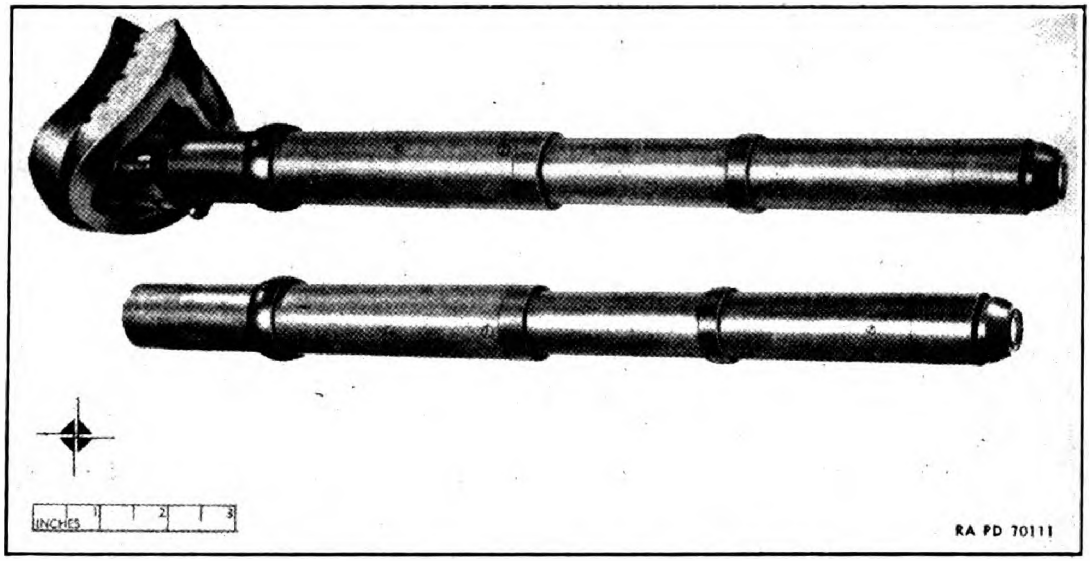

Figure 12. Telescope M51.

Sighting Equipment Used for Direct Fire. Straight telescopes are designed for sighting small caliber weapons and are the most accurate type of visual sight used in conducting direct fire. The reticle patterns found in various types of telescopic sights vary in design and depend upon the purpose for which the weapon is intended. Sighting telescopes must be mounted parallel to the bore of the gun. The process of obtaining this relation is called bore sighting. The

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sniper's sight (telescope M73) used on cal. .30 rifles has a magnification of 2.5x, and the reticle can be adjusted for range and windage. A similar type telescope (M6) is mounted on the 37mm AT gun. The magnification in this case, however, is 1x, and the reticle is fixed. The pattern of the reticle is designed so that the gunner can properly allow for various range and leads.

The telescopes used for aiming various types of tank weapons are somewhat longer, but have low magnifications so as not to limit the field of view. The reticles used in tank machine gun telescopic sights (telescope M15) is a simple cross-line reticle. The telescope (M51) used to aim the 3-inch gun on the M10 tank destroyer has a reticle which is graduated up to 3,000 yards range.

Tank sights are frequently combined with the periscope so as to give the instrument and the observer some degree of protection. Such telescopes are mounted vertically between the upper and lower mirrors of the periscopes, so as to provide a means of periscopic sighting. Similar periscopes without the telescope are used for observation only.

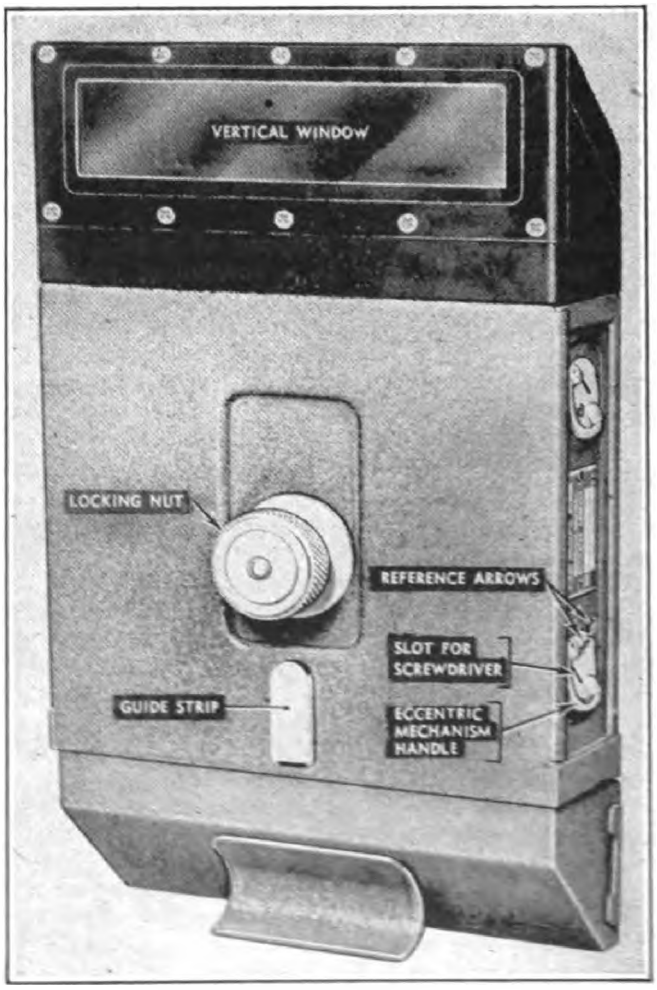

Figure 13. Periscope M4.

The upper ends of periscopes project above the armor plate of tanks and are made of some plastic material so that a lucky hit would shatter the entire head—window, mirror, and body. If this happens, the observer merely pulls the instrument from its holder and replaces the damaged head with a spare which he always carries with him.

Provision is made for adjusting the telescope in the periscope, so that the optical line of sight may be adjusted in deflection and elevation when boresighting the weapon.

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ARMY ORDNANCE PERISCOPES

ARMY ORDNANCE PERISCOPES

MODEL	GUN	CARRIAGE, GUN MOUNT OR VEHICLE	CONTAINED TELESCOPE	INSTR LIGHT	ALTERNATE PERISCOPE	STATUS	DRG. NO.	SNL & TM	OCM	SPEC	MISCELLANEOUS
M1 [T1]	37mm M6	[L] T9E1	M46	M15	M8	LIMITED STANDARD	22-303	F-217 9-1608	16654 18418 18877	FXS 418	18" x 6"—11 LBS.
	3" M7	[M] M6, M6A1, T1E1	M39A1, M39								
M2 [T2]	75mm M2	[M] M3	M19A1, M19	M15		[M] M3 IS NOW OBSOLETE	22-304	F-218 9-1608	16654 18418	FXS 394	8½" x 6½"
M3	37mm M6	[L] M5A1, M5, M3A1, M3A3	M19A1, M19	NONE		OBSOLETE	22-324	F-236 9-1608	18418 22172	FXS 473	SIMILAR TO M2. 10½" x 6½"
		37mm MED. ARM. CAR, T17E1									
	75mm M3	[M] M4 SERIES	M38 M32A1								
M4	37mm M6	37mm MED. ARM. CAR, T17E1	M40A1, M40, M19A1	NONE	M4A1	LIMITED STANDARD	22-325	F-235 9-731A 9-1608	18230 18418 18542 18861 22172	FXS 519	MODIFIED M3 11" x 6½"
		[L] M5A1, M5, M3A1, M3A3									
	57mm M1	57mm HEAVY ARM. CAR, T18E2	T42								
	75mm T13E1	[L] T24	M38A1, M38								
	75mm M3	[M] M4 & VARI. T20E1, T23E1									
	76mm M1	76mm G. M. C., M18	M47A1, M47								
		[M] M4 [SERIES], T20, E3, T23, E3									
M4A1	37mm M6	[L] M5A1, M5, M3A1, M3A3	M40A2	M10	M4	STANDARD FOR LT. TANKS SUBSTITUTE STANDARD FOR THE OTHERS	22-325	F-235 9-1608	22172 22405	FXS 519	MODIFIED M4 PROVIDES FOR RETICLE ILLUMINATION.
	75mm M3	[M] M4 & VARI.	M38A2								
	76mm M1	[M] M4 [SERIES] T21, T23E3	M47A2								
	105mm M4	[M] M4, M4A3 [105mm HOW.]	M77C								
M5	37mm M6	[L] M5A1, M5, M3A1, M3A3	NONE	NONE	M6	OBSOLETE	22-330	F-235 9-1608	18418 22172	FXS 474	M3 TYPE—WITHOUT TELESCOPE FOR OBSERVATION ONLY
	75mm M3	[M] M4 & VARI.									
	3" M7	[H] M6, M6A1									
M6	.30 cal M2	MED. ARM. CAR, T17E2	NONE	NONE	M5	STANDARD	22-331	F-235 9-1608	18418 22818 18542 18069 18313 19945 21113 22172	FXS 523	MODIFIED M4 WITHOUT TELESCOPE. FOR OBSERVATION ONLY REPLACES M5
	37mm M6	37mm LT. ARM. CAR, T24, T28									
		37mm MED. ARM. CAR, T17E1									
		[L] M5A1, M5, M3A1, M3A3									
	57mm M1	57mm HEAVY ARM. CAR, T18E2									
	75mm T13E1	[L] T24									
	75mm M3	[M] M47 & VARI. T20E1, T23E1									
	76mm M1	[M] M4 & VARI. T20, E3, T23, E3									
		76mm G. M. C., M18									
	3" M7	[H] M6, M6A1									
		3" G. M. C. M10, M10A1									
	90mm M3	[M] T25, T26									
		90mm G. M. C. T71, T71E1									
	105mm H. M4	[M] M4, M4A3 [105mm HOW.]									
		105mm H. M. C. T76									
M7 [T3]	3" M7	[H] M6, M6A1	M39	NONE		STANDARDIZATION RESCINDED	NONE	NONE	18418 18877	NONE	MODIFIED M1
M8 [T3]	37mm M6	[L] T9E1	M46A1	NONE	M8A1 M1	LIMITED STANDARD	22-343	F-235 9-1608	18877 21113 22172	FXS 566	REPLACES M1 18" x 6½"
	3" M7	[H] M6, M6A1, T1E1	M39A1								
	105mm M4	[M] M4, M4A3 [105mm HOW.]	M77C								
M8A1	37mm M6	[L] T9E1	M46A2	M10	M8 M1	STANDARD	22-343	F-235 9-1608	22172 22405	FXS 566	MODIFIED M8 TO PROVIDE FOR RETICLE ILLUMINATION.
	3" M7	[H] M6, M6A1, T1E1	M39A2								
	90mm M3	[M] T25, T26	T121								
M9 [T6]	75mm How. M3	75mm H. M. C. M8	NONE	NONE		STANDARD	22-344	F-235 9-1608	18877 21487	FXS 567	MODIFIED M8 FOR OBSERVATION ONLY
M10C	75mm T13E1	[L] T24 WITH PERIS. MT. T107	BUILT-IN	M10	M4, M4A1 M8A1 WITH ADAPTERS	STANDARD	22-401		22064 22172	FXS 864	T8 MODIFIED FOR PRODUCTION DUAL POWER OPTICAL SYSTEM—1x and 4x
	75mm M3	[M] M4 & VARI WITH PERIS. MT. T106									
M10D	105mm M4	[M] M4 [105mm HOW] [M] M14A3 [105mm. HOW] WITH PERIS. MT. T112									
M10F	90mm M3	[M] T25, T26 WITH PERIS. MT. T113									
M10G	76mm M1	[M] M4 & VARI. T23, T23E3 WITH PERIS. MT. T110									
M1910		USED ON AZ. PERISCOPIC INSTRUMENT, M1910				LIMITED STANDARD	22-108	F-85			RETAINED FOR STABILIZED WARFARE ONLY INACTIVE REQUIREMENT
M1922		14" GUN TURRET, M1909 (HIGH)				LIMITED STANDARD	91-12	F-94			INACTIVE REQUIREMENT
M1922		14" GUN TURRET, M1909 (LOW)				LIMITED STANDARD	91-11	F-94			INACTIVE REQUIREMENT
E. C. M1918		WAS USED IN TRENCH WARFARE NOW USED IN TANK WARFARE				STANDARD	22-62	F-41	22531		HAND HELD 12 LBS. 20" OFFSET TRIPOD—TYPE G
T7	75mm M3	[M] M4 & VARI.				SUPERSEDED BY T8			19472		FITS IN M4 PERIS. HOLDER 1X AND 10X
T8	75mm M3	[M] M4 & VARI. WITH PERIS. MT. T105	BUILT-IN	T9	M4 WITH ADAPTER, OR M10	LIMITED PROCUREMENT	22-375		20471 21665		SUPERSEDED M4 PERI. IN [M] M4 1X AND 4X OPT. SYSTEMS
T9	75mm M3		BUILT-IN			EXPERIMENTAL	22-384		20331		BINOCULAR TYPE 7X109
T9E1			BUILT-IN	M10		EXPERIMENTAL	22-384		20331		MODIFIED T9 1X OPT. SYS. ADDED TO THE 7X
T10						EXPERIMENTAL			21429		HAND HELD 4 x 5" 30" LONG 12—15 LBS.
T13						EXPERIMENTAL	22-404				
T14						EXPERIMENTAL	22-405				
T15	90mm M3	[M] T25, T26	BUILT-IN			EXPERIMENTAL					MODIFIED T8 OBJ. PRISM RAISED 2"
T16		LANDING V., TRACKED, ARM., MK1 LANDING V., TRACTOR, ARM., MK2	NONE			EXPERIMENTAL	22-413				SOLID GLASS—TO AVOID LEAKAGE OF WATER INTO BODY. USED IN PLACE OF M6 IN L.V.

PERISCOPE CHART
10 MAY 1944

[L] [M] [H] INDICATE LIGHT, MEDIUM AND HEAVY TANKS

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Field Artillery guns use elbow telescopes for direct sighting. Elbow telescopes give the observer a convenient observing position out of the way of the gun crew. They also provide protection to the observer as the gun is fired; upon recoil, the telescope moves across his face instead of into his eye.

These telescopes are four power and contain reticles graduated in various ranges, usually in hundreds of yards. Heavy antiaircraft guns are also provided with similar telescopic sights for use against possible ground targets.

The interesting part of the optical system in elbow telescopes is the roof prism located at the elbow.

This prism allows the light to be reflected twice inside the prism so that the prism not only deviates the light through 90°, but also serves as a prism erecting system for the telescope. Elbow telescopes are used extensively with antiaircraft equipment for tracking the target in azimuth and in elevation.

Aiming Circle. In conducting indirect fire, it is necessary that firing data be obtained at a point other than at the gun, and from which the target can be seen. This initial measurement of angles is accomplished by the use of certain instruments which are essentially angle measuring instruments. The most important of these is the aiming circle M1.

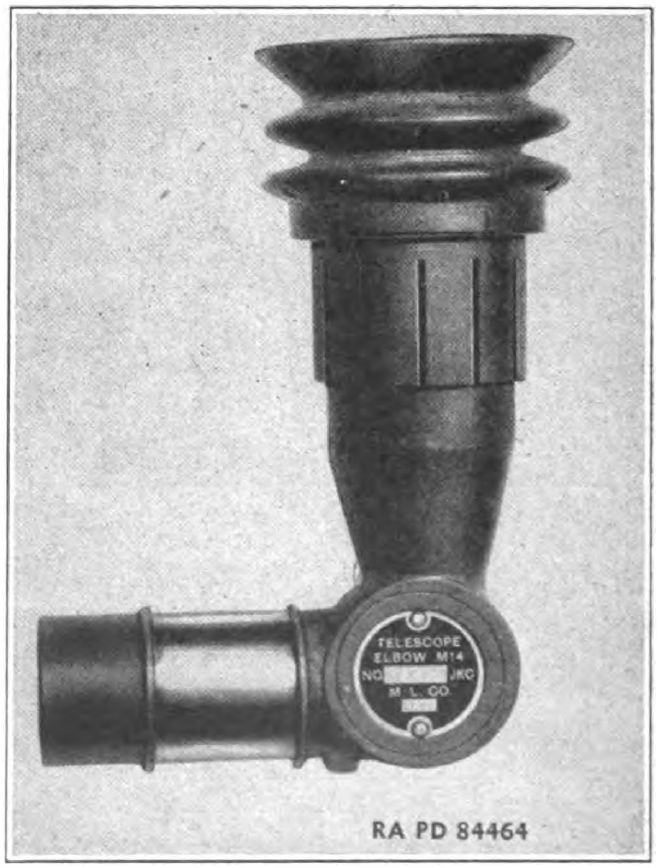

Figure 14. Telescope Elbow M14.

The first step in directing the gun in azimuth is to measure an azimuth angle of the target. This azimuth is measured by the aiming circle which is supported by a tripod and located at the observation post. The azimuth is measured from magnetic North or from any convenient aiming point.

The instrument rotates through 6,400 mils in a horizontal plane. The aiming circle, like most angle measuring instruments, has two scales to measure an angle—a coarse scale and a fine or micrometer scale. As the telescope rotates clockwise, the index moves around the azimuth scale which is calibrated every

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hundred mils. The micrometer drum is calibrated every mil from 0 to 100 mils. Thus precision to the nearest mil can be attained.

The telescope is rotated in azimuth by turning the knurled azimuth knob. This knob is mounted on a worm shaft which is in mesh with a worm gear. On the same worm shaft the micrometer is mounted. The entire instrument can be oriented by turning the lower knurled orienting knob. The telescope may be elevated and depressed by the knurled elevating knob. The instrument also contains a spherical spirit level vial for initially leveling the instruments, a tubular level vial on the telescope for pointing it horizontally, a sensitive magnetic meedle for orienting on magnetic north, and a night lighting device for illuminating the reticle and external scales when using the instrument at night.

When the instrument is set up, it must be leveled by loosening the ball-and-socket joint clamp and bringing the bubble in the spherical level vial to the center of the vial, after which the clamp is tightened and the instrument is made level in all positions.

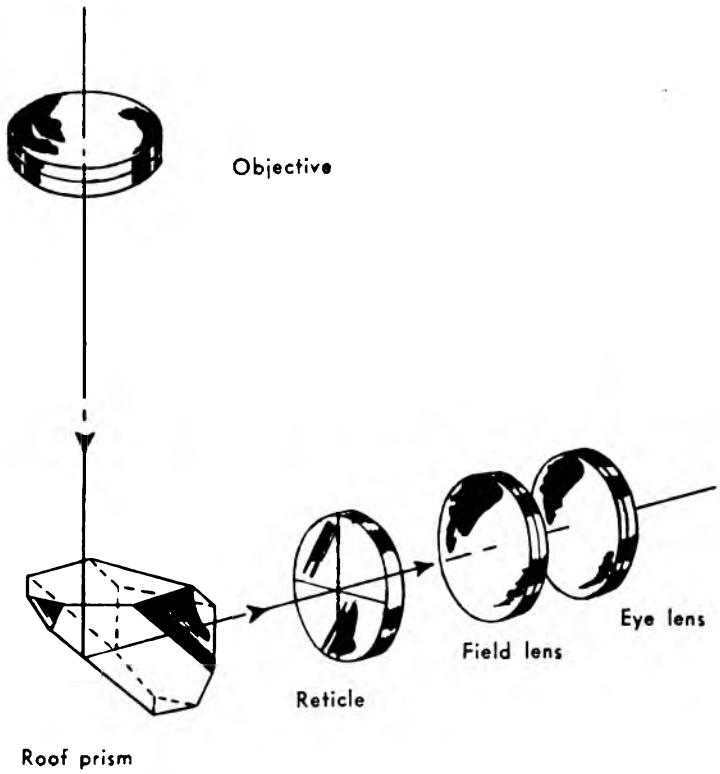

Figure 15. Optical System of Elbow Telescope.

In order to measure an azimuth angle, the index is first set to zero on the azimuth scale. The micrometer, of course, must also read zero. Next, by turning the orienting knob (or, for rapid motions, loosening the spindle clamp and rotating the entire instrument) the telescope is pointed in the direction from which the azimuth is to be measured, and the vertical cross hair of the reticle lined up on the reference point. Then, by turning the azimuth knob (or, for rapid motions, unmeshing the azimuth worm with the throwout lever and turning the telescope) the telescope is brought to bear on the target the azimuth of which is desired. Then, by reading the azimuth scale (to the nearest hundred mils) and the micrometer (to the nearest mil), the azimuth is determined.

When measuring magnetic azimuth, the needle is released by pressing the green plunger on the side of the instrument, and the instrument oriented by observing the south-seeking end of the needle through the magnetic needle eye-lens. The reticle of this eye lens enables the operator to orient accurately by

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lining up the end of the needle with the vertical reticle mark. Thus, magnetic azimuths to the nearest mil can be measured. The needle is locked in position by pressing the red plunger in the side of the instrument.

A small amount of vertical movement is provided on the telescope so that an aiming point or target above or below the horizontal may be brought into the field of view by elevating or depressing the telescope. The tubular level vial built into the telescope body indicates when the telescope is pointed horizontal, in which case, the horizontal cross hair would intersect all objects that are level with the instrument, and the instrument could therefore be used as an engineer's level.

The cross-lines of the reticle are graduated in mils so that small angles of azimuth and elevation may be measured directly on the reticle.

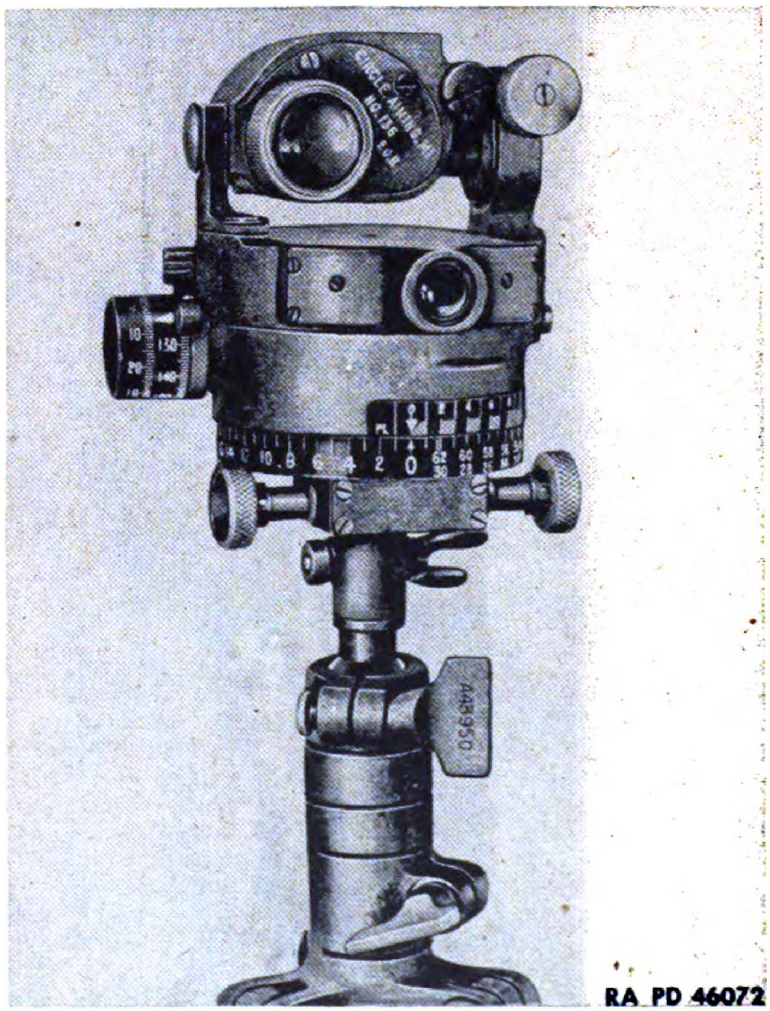

Figure 16. Circle, Aiming, M1.

The optical system of the telescope is the same as that found in binoculars. In the telescope is an objective lens, two porro prisms, a reticle, and the eyepiece. The objective lens collects the light and forms an image of the target. The porro prisms serve as a prism erecting system; the light undergoes four total internal reflections in the prism system. The reticle graduations give us the required reference for measurements, and the eyepiece can be focused for the individual eye by rotating the knurled portion which moves the eye-lens in and out.

The night lighting device consists of a battery case and switch which is clamped to one leg of the tripod. One electrical connection furnishes power to a lamp bracket which is clamped to the telescope by a dove-tail joint. This

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illuminates the reticle in the telescope. The other electrical connection provides power to a small finger light, so that external scales on the instrument may be read at night.

Azimuth instruments, used by the Coast Artillery are similar in nature to the aiming circle, but are much more elaborate so that angles may be measured with a greater degree of precision.

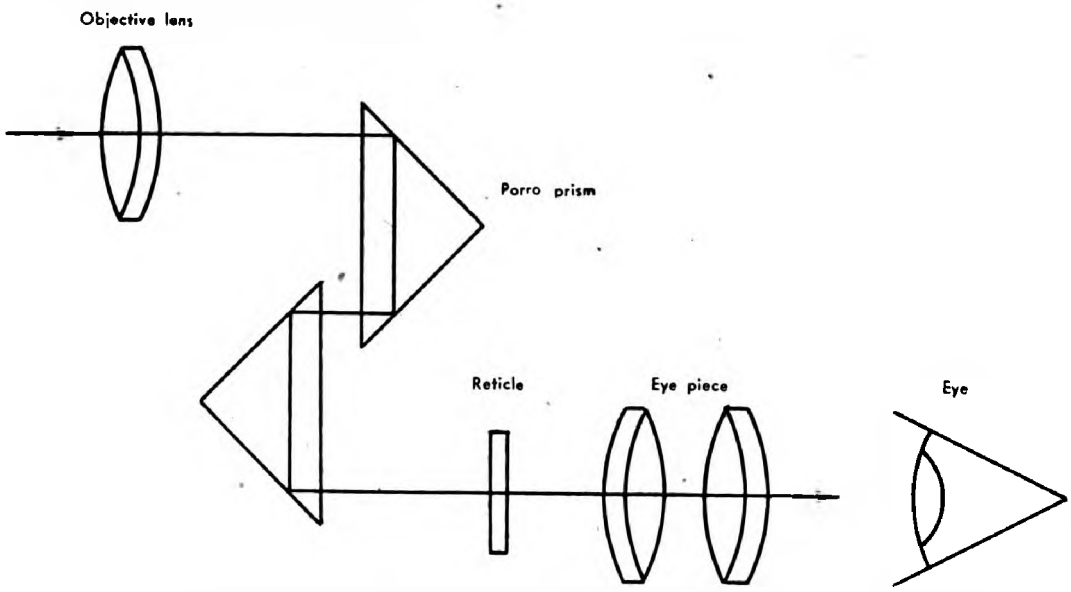

Figure 17. Optical System of Aiming Circle Telescope.

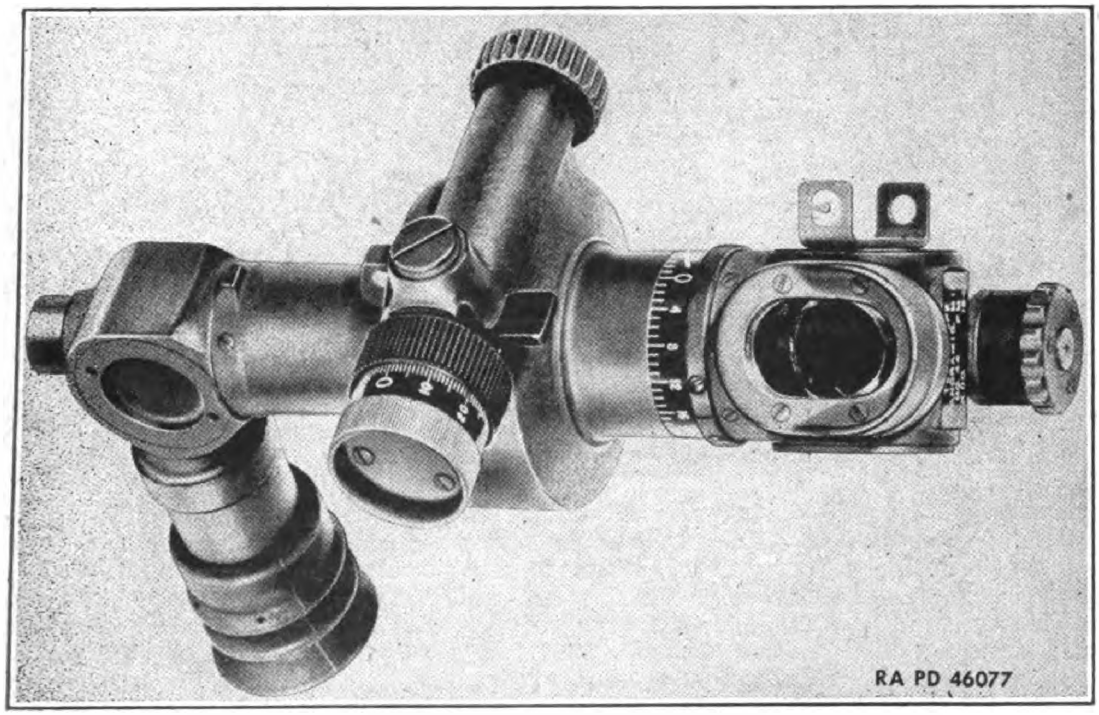

Figure 18. Panoromic Telescope M12.

Panoramic Telescope. Once the firing data in azimuth has been determined, the panoramic telescope mounted on the gun is used to point the gun in the desired direction. When the gunner looks through the eyepiece of the panoramic telescope he is able to sight in any direction by rotating the head of the instrument.

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The head rotates through 6,400 mils and its angular rotation is measured on the instrument by the use of the two scales, the azimuth scale and the micrometer scale. In using the instrument, the gunner first sets the computed azimuth of the target on the scales, and then traverses the weapon (on which is mounted the panoramic telescope) until the aiming point is on the vertical cross hair of the telescope. The aiming point may be aiming stakes, a distant well-defined point, or an aiming circle if magnetic azimuth is being used.

Panoramic telescopes have a knob at the top for elevating or depressing the line of sight, a throw-out mechanism for rapid movements in azimuth, and a 'gunner's aid' on the micrometer scale for automatically applying small corrections to the initial setting.

The instrument is supported by a cross-leveling mount and is provided with a night lighting device for night operations.

The optical system of the instrument is shown in figure 19. The window

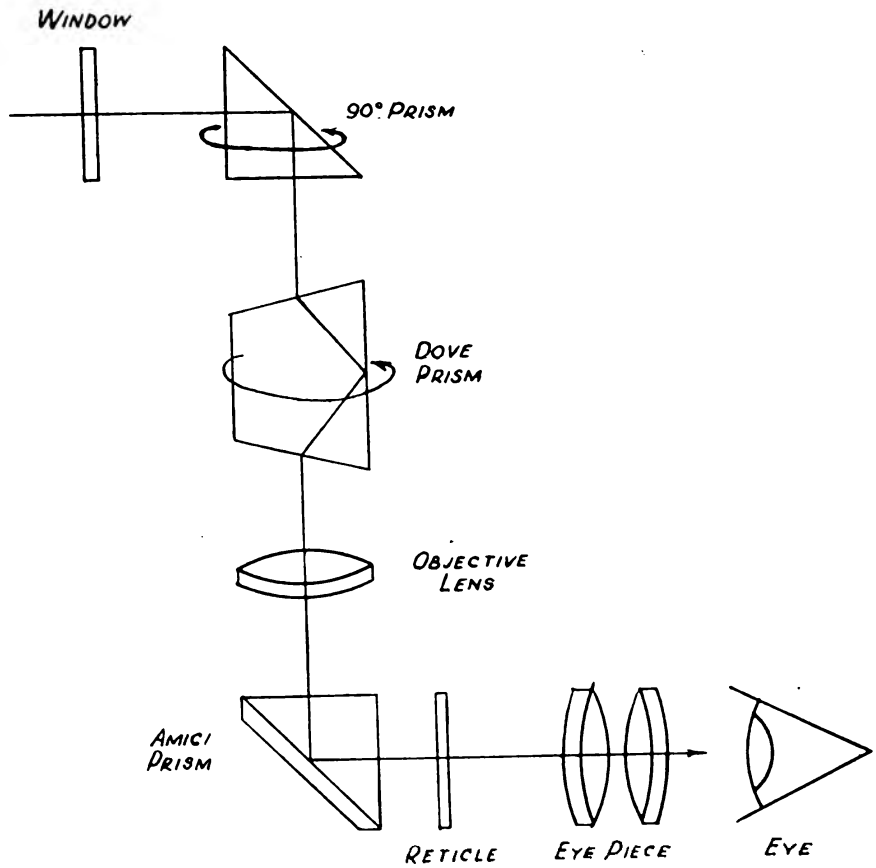

Figure 19. System of Panoramic Telescope.

seals the instrument and prevents foreign material from entering the mechanical or optical elements. The 90° prism in the upper head directs the light downward and enables the observer to look in any direction he wishes by rotating the upper head containing the 90° prism and window. The dove prism is inserted so that the image will always remain erect no matter which direction the line of sight is pointed. Consequently, the dove prism must be geared up to the rotating head, so that the dove prism rotates only half as fast as the 90° prism. This insures the image remaining upright for all directions of sight. Below the dove prism is an elbow telescope containing the objective lens, an amici prism which serves as a prism erecting system, a reticle, and the eyepiece.

A night lighting device clamps to the instruments and contains a battery, switch, and lamps so that the external scales and the reticle can be seen when using the instrument at night.

Some instruments, known as telescope mounts, combine the panoramic tele-

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scope with the range quadrant so that the complete sighting equipment of a weapon is contained in one instrument.

QUADRANTS

The various types of quadrants are provided for laying weapons in elevation when conducting indirect fire. They are constructed with scales which measure angles in a vertical plane.

The *Gunner's Quadrant* M1 has a movable arm containing a spirit level, and this arm pivots about one end; the other end rides around an arc of a circle which is graduated into mils. When using the instruments, the quadrant elevation, which has been determined by the firing officer, is set on the scale by pivoting the movable arm until it reads the proper angle; then the instrument is placed on top of the bore of the gun and the gun elevated until the spirit bubble on the instrument is centered. The gun is then pointed at the proper elevation above the horizontal.

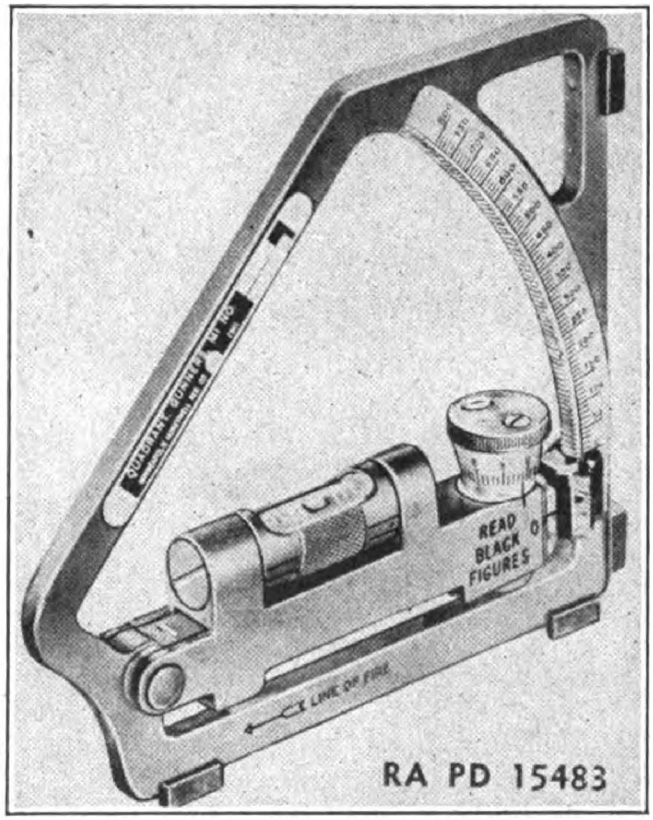

Figure 20. Gunner's Quadrant M1.

The graduations on one side of the arc are from 0 to 800 mils. If the angle lies between these limits, the horizontal base of the instrument is placed against the bore of the gun. However, for angles between 800 and 1,600 mils, the other side of the arc must be used, and the vertical base of the instrument placed against the bore of the gun. The smaller angle scales are calibrated in black figures, and the larger angles show as red figures.

The micrometer, mounted on the movable arm, is graduated to 1/5 mil so that great accuracy may be obtained with the gunner's quadrant. This instrument is used to check the accuracy of other quadrants.

Elevation Quadrants accomplish the same purpose as the gunners quadrant except that they are mounted integral with the weapon and are not unattached as gunners quadrants are.

Elevation Quadrants have a single angle mechanism on which is set the quadrant elevation at which the weapon is to be fired. The weapon is then elevated until the bubble on the instrument is centered.

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Range Quadrants are also on-carriage instruments for laying a gun in elevation, but these have two angle scales, both of which position the bubble of the spirit level.

One scale is used to set the angular height of the target above the horizontal

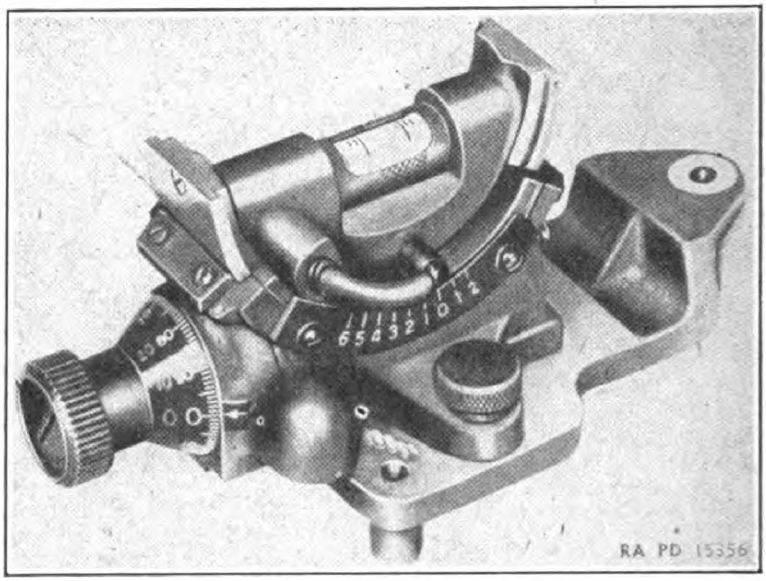

Figure 21. Elevation Quadrant M9.

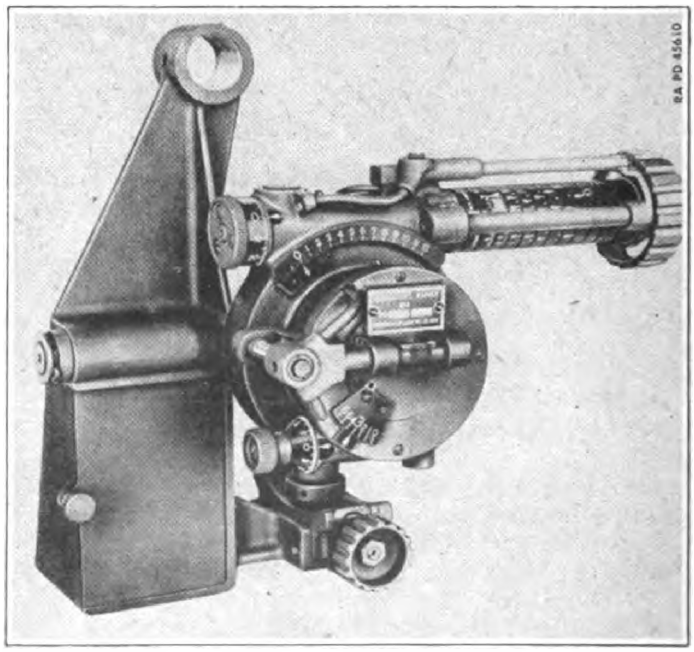

Figure 22. Range Quadrant M4.

(angle of site), and the other scale is used to set the range elevation according to firing table data. The mechanism automatically adds algebraically these two angles to give quadrant elevation, which is the angle between the bore of the gun and horizontal. Since there is a definite relation between range (in yards) and range elevation (in mils), a range scale may be found on the same shaft

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RANGE QUADRANTS									
MODEL	DRG. NO.	SNL & TN	OCM	SPEC.	CARRIAGE, GUN MOUNT OR VEHICLE	INSTR. LIGHT	TELESCOPE	STATUS	MISCELLANEOUS
M1 (T2)	92-21	F-166 9-1549	11129 18381	FXS 194	75mm G.C. M2,M2A1,M2A2	M6		Limited Standard	
M2 (T1)	92-18	F-169 9-320	11141		75mm H.C. M2 & M2A1			Not Required	
M3 (T3)	92-20	F-169 9-1547	18724	FXS 198	75mm H.C. M2A1,M3,M3A1, M3A2,M3A3	M18	Elb.Tel. M5	Standard	
M4 (T4)	92-24	F-197 9-1551	18559 19327 20766	FXS 291	105mm H.C. M2,M2A1,M2A2 105mm H.M.C. M7 & M7B1	Built In		Standard	Canvas Cover,M411 Carrying Case,M41 for the Range Drums
M5 (T5)	92-25	F-199 9-1552	15709 15942	FXS 307	75mm G.C. M2A3	Built In		Standard	Similar to M4; Mounting brackets slightly modified
M6 (T6)	92-26	F-197 9-1540	16517 20278 17407	FXS 420	3" G.C. M1	Built In		Rescinded	Similar to M4 - Graduated for 3" Gun
M7 (T7)	92-27		16341	FXS 420	3" G.C. M1			Never Mfg.	M6 & M7 are identical except for mounting bracket. M7 never manufactured
M8	92-28	F-169 9-326	19684	FXS 602	105mm H.C. M3,M3A1	M18	Elb.Tel. M61	Standard	Similar to M3 - Graduated for 105mm Howitzer
M10C	92-33			FXS 771	3" G.C. M1A1,M6	Built In	Elb.Tel.M29 Mt.Tel.,M23	Standard	Similar to M4 - Graduated for 3" Gun
M10D	92-33			FXS 771	76mm G.C.	Built In			Similar to M4 - Graduated for 76mm Gun
M10E1	92-33				105mm H.M.C. T76	Built In		Dropped	See Range Quadrant, T14
T8	92-29				90mm G.M.C. T53E1			Project Cancelled	
T9					105mm H.C. T7			Project Cancelled	
T14	92-35				105mm H.M.C. T76			Experimental	Similar to M3 - Graduated for 105mm Howitzer
ELEVATION QUADRANTS									
M1917	15-12F	F-87			12" Mortar Carr. M1918 8" Barbette Carr. M1				
M1	92-23	F-204 9-1674 9-2674	17240 17241	FXS 305	8", 16", 240mm Materiel			Standard	Quadrant Adapter,M8 used with 155mm Gun, M1,M1A1
M9 (T10)	92-31	F-281	20095 20838 21113	FXS 705	(M) M4, (M) M4,A3 (105mm How.) 3" GMC,M10 - 76mm GMC,T70 .	M30		Standard	Used with Azimuth Indicator for laying artillery in elevation for indirect firing
T12,T12E1	92-32				3" G.M.C. M10 76mm G.M.C. T70			Experimental	Will accompany Cant Corrector,T10,T10E1
T13	92-34				10" Mortars		Elb.Tel. M62	Experimental	To provide more satisfactory sight. Carrying Case,T14

QUADRANT CHART
8 January 1944

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as the range elevation scale, so that if the range is known, it may be set directly on the instrument and the use of firing tables is obviated.

It is obvious that a given range drum can be used only for one type of ammunition in the given weapon. This range drum is calibrated in yards according to the firing table for the given ammunition. However, these drums are interchangeable so that one drum can be slipped off and replaced by another upon changing the ammunition in the gun.

Range Quadrants, since they are on-carriage instruments, must be constructed as sturdily as possible, so that the shock of firing the gun will not affect the accuracy of the instrument. The angle mechanisms have ball or roller bearings, so that close fits can be obtained and smooth functioning assured.

Quadrants are mounted so that they can be cross-leveled, using a cross-level vial to indicate this adjustment. Night lighting equipment is built into the instrument so that the level vials and external scales can be observed at night.

OBSERVATION INSTRUMENTS

In many fire control procedures, it is neither advisable nor necessary to compensate for the various factors which contribute to errors in directing the weapon. Certain ballistic effects such as wind, drift, and non-standard conditions of the atmosphere, as well as changes in the muzzle velocity of the gun and non-standard conditions of the ammunition, all contribute to error. With larger caliber weapons, these factors are reckoned with, and compensation for them is considered in the initial laying of the gun in azimuth and elevation. However, with most smaller caliber weapons, such small errors are disregarded in the initial laying on the target, and all such errors are corrected by observing the effect of fire on the target.

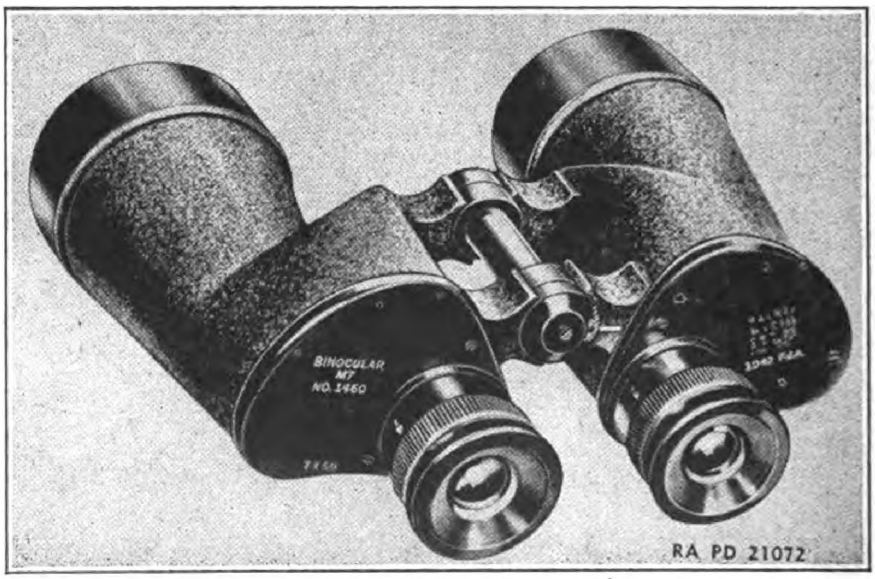

Figure 23. Binocular M3.

Observation instruments, therefore, are provided to enable the observer to correct for errors. It is of primary importance that the observer be able to see stereoscopically so that he may observe 'overs' and 'shorts' as well as 'lefts' and 'rights'. For this reason most observation instruments are made binocular so that two eyes may be used instead of only one. With no optical aid, an individual has stereoscopic vision to a maximum range of 500 yards. At greater ranges, relative distance in depth cannot be judged. However, we may increase this maximum stereoscopic range by optically moving the eyes farther apart, or by increasing the magnification. The binoculars utilize both of these principles to give the observer increased stereoscopic range.

Binocular, M3. The binoculars are two telescopes mounted parallel to each other. The telescopes use prism erecting systems which serve to shorten the

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ARMY ORDNANCE BINOCULARS AND FIELD GLASSES

Instrument	S.N.L.	Power	Aperture	Field of View	Method of Collimating	Carrying Case	Weight With Case	Weight Without Case	Manufactured By	Similar To	Reticle	Miscellaneous
Binocular, M1	F-238	8X	56MM	6°	Eccentric cell & Ecc.Bushing				Keuffel & Esser. Used with Height Finder T9E1			OCM 10313 (12-1-32) authorized Ht. Finder, T9E1 for Limited Procurement. (Never procured)
Binocular, M2	F-238	8X	56MM	6°15'	Eccentric cell & Ecc.Bushing				Bausch & Lomb		None	Discontinued
Binocular, M3	F-210	6X	30MM	8°30'	Eccentric cell & Ecc.Bushing	M17	39 oz 41 oz	22 oz 25 oz	Nash Kelvinator Westinghouse	Basic Design	Left Eye	Substitute Standard See M13
Binocular, M4	Cancelled											
Binocular, M5	F-210	6X	30MM	7°10	Eccentric cell & Ecc.Bushing	M30	35 oz	18 oz	Wollensak Optical	M3	Right Eye	British
Binocular, M6		6X	30MM	8°16'	Eccentric cell & Ecc.Bushing	M17	42 oz	22½ oz	Universal Camera	M3	Right Eye	For Lease Lend Purposes
Binocular, M7	F-238	7X	50MM	7°16'	Eccentric cell & Ecc.Bushing	M24	67 oz	41 oz	Bausch & Lomb	Basic Design	None	Substitute Standard Same as Navy MK 13 See M14
Binocular, M8	F-210	6X	30MM	8°30'	Eccentric cell & Ecc.Bushing	M17	39 oz	22 oz	Bausch & Lomb	M3	Reticle in Left Eye	Substitute Standard. Parts 90% interchangeable with M3
Binocular, M9	F-210	6X	30MM	8°16'	Eccentric cell & Ecc.Bushing	M17	42 oz	22½ oz	Universal Camera	M3	Left Eye	
Binocular, M10		7X	50MM	7°	Eccentric cell & Ecc.Bushing	M24	67 oz	41 oz	Optical & Film Supply Company	M7		Cancelled
11	Number 11 - not used in Ordnance "M" Series											
Binocular, M12		6X	30MM	8°15'	Eccentric cell & Ecc.Bushing		42½oz	21 3/4oz	War Supplies Ltd. Ottawa, Canada	M3		Canadian Mfg., for Lease Lend Purposes only
Binocular, M13		6X	30MM	9°5'	Eccentric cell & Ecc.Bushing	M43	41 oz	25 oz	Nash Kelvinator Universal Camera	M3	Left Eye	Waterproof Body To replace M3, M8 & M9
Binocular, M14		7X	50MM	7°16'	Eccentric cell & Ecc.Bushing	M44	67 oz	41 oz	Hamilton Watch Westinghouse	M7	None	Waterproof Body To replace M7
Binocular, M15		7X	50MM	7°16'	Eccentric cell & Ecc.Bushing	M44			Hamilton Watch Westinghouse	M7	None	M14-with soft rubber eyepiece and addition of filters
OLDER TYPES STILL IN USE												
Field Glass Type E	F-146	6X	30MM	8°	Tilting and Adjusting Screw		41 oz	24 oz	Bausch & Lomb		Left Eye	Obsolete
Field Glass Type EE	F-34	6X	30MM	8°	Tilting and Adjusting Screw	Type EE Carrying Case	42 oz	25 oz	Bausch & Lomb		Left Eye	Substitute Standard. Large number still in field
Field Glass Type EE	F-146	6X	30MM	8°	Tilting and Adjusting Screw	Type EE Carrying Case	48 oz	32 oz	U.S. Naval Gun Factory		Left Eye	Obsolete
Field Glass (Huet & Long)	F-146	8X	1.06"	5°48'	Tilting and Adjusting Screw		40 oz	24 oz	Huet and Long		Right Eye	Obsolete. Has adjusting ring for reticle
Field Glass (Huet Type)	F-146	12X	1.22"	3°42'	Tilting and Adjusting Screw		44 oz	28 oz	Huet and Long		Right Eye	Obsolete. Has adjusting ring for reticle

Note 1: Binoculars, M3, M6, M8, M9, M12, M13 are similar, but all parts are not interchangeable.
Note 2: Instruction and maintenance manuals pertinent to any one type of Binoculars may be considered applicable to all types.

Binocular Chart
June 25, 1943

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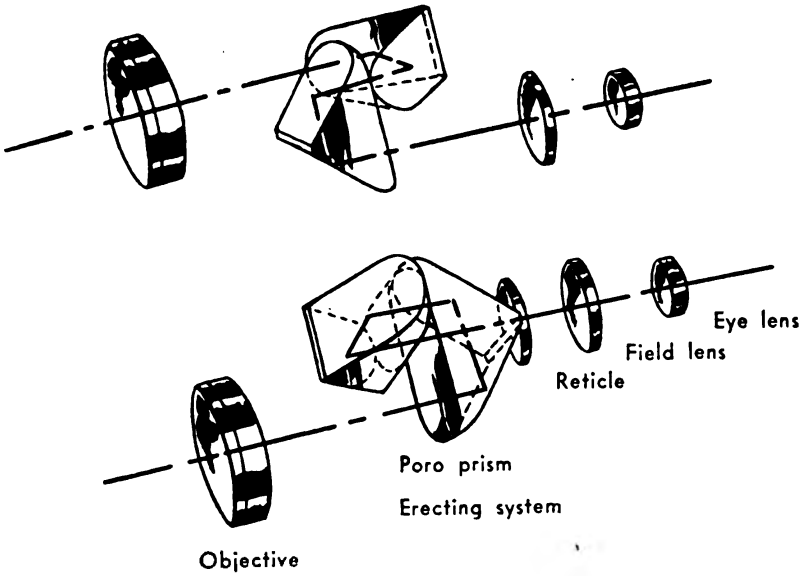

Figure 24. Optical System of Binoculars.

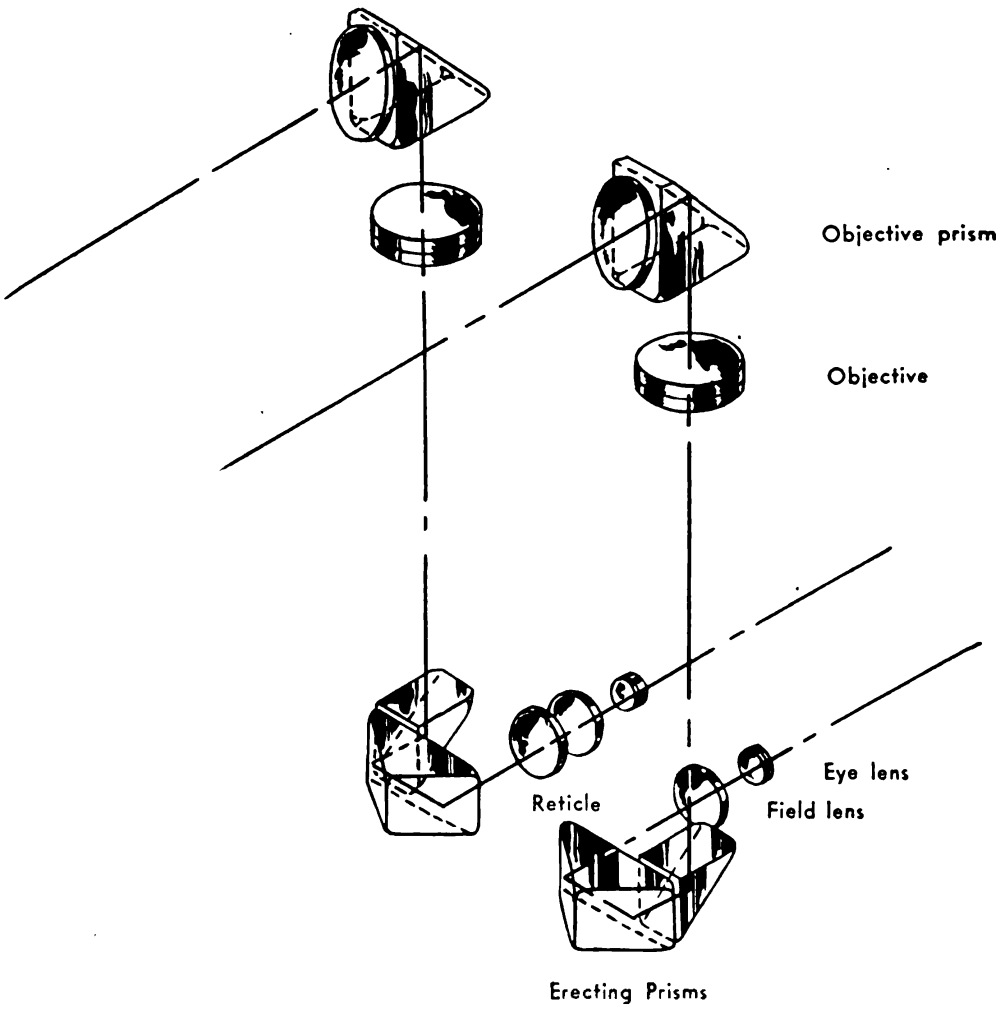

Figure 25. Optical System of B.C. Telescope.

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tubes and also to cause tthe objective lenses to be 5 inches apart instead of the interpupillary distance of only 2½ inches between the eyes. This doubles the stereoscopic range. By using 6-power telescopes the stereoscopic range is increased six more times, giving a net increase in stereoscopic range of 6,000 yards. On the hinge pivot of the instrument is the interpupillary scale which is graduated in millimeters and measures the linear distance between the two eyepieces. Each telescope has a focusing eyepiece with a diopter scale for setting the proper focus for each eye. A normal eye requires a zero diopter setting; a near-sighted individual would require a minus setting, and a far-sighted person would require a plus correction setting. The reticle is graduated in mils so that small horizontal angles may be measured. The vertical scale on the reticle is used in connection with 30 caliber weapons for indirect fire.

Magnification of military binoculars is not made greater than 7x because these instruments are held in the hands. Greater magnification would cause the target to move around so rapidly in the field of view due to slight movements of the instrument that observation or measurement would be impracticable.

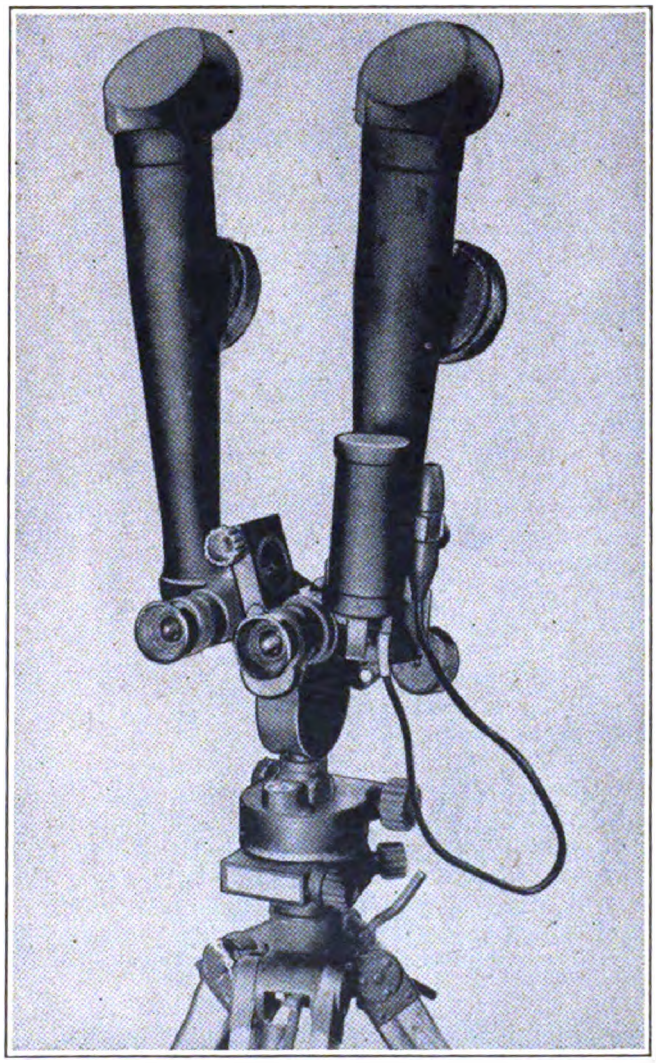

Figure 26. Telescope B.C. M1915A1.

The telescopes utilize porro prisms for a prism erecting system. This arrangement of prisms causes the light to be reflected four times back and forth in the prisms giving an erect image, a shorter telescope for compactness, and a wider separation of the objective lenses for greater stereoscopic range.

Telescope, B.C. M1915A1. The battery commander's telescope is a binocular observation instrument of greater magnification and greater stereoscopic range

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and is mounted on a tripod. The mount is designed similar to the aiming circle tubes and also to cause the objective lenses to be 5 inches apart instead of the it is both an observation instrument and an angle measuring instrument. The mount contains a spherical spirit level, an orienting mechanism, and an azimuth mechanism similar to that of the aiming circle. On the telescope is mounted the angle of site mechanism and the telescopes contain the usual diopter scale and interpupillary scale.

The optical system used for the telescopes has been designed so that observation may be made from behind a bush or rock or from a trench or foxhole. The telescopes look somewhat like a periscope. The objective prism at the top and the erecting prisms in the lower part of the telescope act together as a prism erecting system to give an erect image.

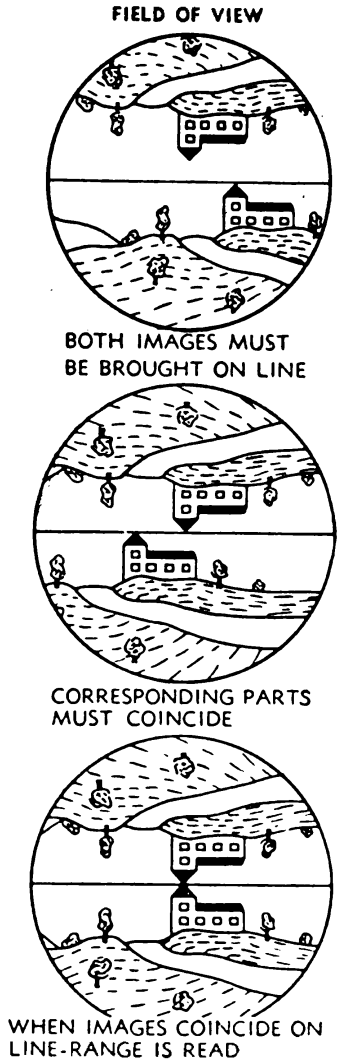

Figure 27.

Some observation instruments used on very distant targets are high magnification instruments and monocular, since stereoscopic vision would be of no advantage. Such observation instruments resemble an ordinary observing telescope, and some have a selection of magnification obtained by use of one of several eyepieces mounted in turret fashion, or by shifting the lens erecting system in the telescope. The AA battery commander's observation instrument is an elbow telescope mounted also for measuring angles in elevation and azimuth, and contains a smaller elbow telescope for tracking purposes. Elbow telescopes provide a convenient observing position for all elevations of the airplane.

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RANGE FINDERS

Range Finders are of two types—stereoscopic range finders and coincident range finders. The stereoscopic instruments have two eyepieces so that the observer's sense of stereoscopic vision is utilized in determining the range of the target. The height finder, which is to be discussed later, illustrates this type of instrument.

The coincident type of range finder has only one eyepiece through which two images of the distant target are observed. The field of view is usually divided in half, so that one image is seen in half of the field and the same image is reproduced in the other half of the field of view. In operation, the range drum is turned until both images are made to coincide on the halving line. When coincidence is obtained, the range is read directly in yards on the range scale.

The light which enters the left end window of the range finder forms one of the images, and the light which enters the right end window forms the other image, which may be inverted. The position of each image along the halving line depends upon the direction from which the target is viewed from each end window.

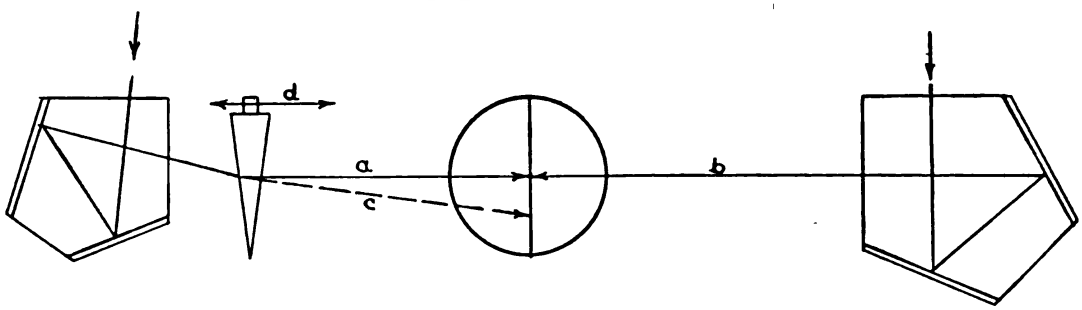

Figure 28. Schematic of Coincident Range Finder.

At each end of the instrument, see figure 28, is located a penta prism which contains two reflecting surfaces so that no matter how the light strikes the prism, it will be deviated through exactly 90°. Light which comes straight into the right prism will therefore be reflected straight down the tube of the instrument indicated by the light ray 'b'. This will pass through the optical system and form an image in the center of the field of view. However, the light which comes from the same target and passes into the left prism will not come in straight, but at a small angle depending upon the range because the target is at some finite distance. It is reflected through 90°, so that it passes down the tube of the instrument at the same small angle. In the left hand optical system is placed a wedge of glass which bends the light so that it passes straight down the tube 'a', instead of in the direction 'c'. This brings the image into coincidence with the other image on the halving line. Now by moving the wedge along the tube as shown by 'd', the ray of light 'a' will move up and down so that the image is moved along the halving line. The amount of translation required of the wedge depends upon the angle at which the ray enters the left window and consequently upon the range. The range drum rotates as the wedge translates and is calibrated for all the possible ranges, so that when the drum rotates, the wedge translates to cause 'a' to be coincident with 'b' on the halving line.

In addition to the telescope, on each side there are certain optical elements inserted for adjustment purposes and a complex ocular prism in the center of the instrument to bring the light out of the instrument, through the eyepiece, and into the eye.

MISCELLANEOUS INSTRUMENTS

There is a wide variety of instruments used by the Coast Artillery in their more accurate methods of determining firing data in azimuth and elevation. Depression position finders and azimuth instruments are used to locate a target accurately. Deflection and spotting boards and other computing devices are used for applying ballistic and adjustment corrections to the observed data; and plotting boards are used for following the path of the target in the process of firing. In firing a 16-inch Seacoast Artillery gun where each round costs about a thousand

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dollars, it is advisable to take the time and trouble to accomplish the fire direction problem as accurately as is possible, so that all possible factors which may introduce errors are compensated for in the computation of the azimuth and elevation at which we lay the gun.

Clocks and watches are listed as fire control materiel. These are supplied and maintained by Ordnance, and their proper functioning is of prime importance in modern warfare where operations are scheduled and many require close timing. Slide rules, graphical firing tables, now used widely in Field Artillery, fuze setters of various kinds, aiming posts, and both vehicle and hand types of compasses are all maintained by Ordnance, and are classified as fire control materiel.

In addition there are certain auxiliary items used in connection with instruments. Various types of instrument lights must be provided so that fire control may proceed at night as well as in daytime; mounts must be provided to support the instruments on weapons or tripods, and to provide for leveling adjustments. Carrying cases of leather, metal, or wood are provided to protect the instruments in transportation or storing. Cleaning and preserving materials are necessary to perform maintenance of these instruments.

FIELD INSPECTION AND FORMS

Telescope Inspection. Most fire control instruments and sighting equipment incorporate some type of telescope. Certain optical checks may be made without special tools or equipment to determine the serviceability of a telescope. They are as follows:

Conditions of the optics. The optical elements of a telescope may be examined by looking at them rather than through them. Look into the eyepiece end, then the objective end, and examine the lenses. The various lenses and prisms making up the telescope can be examined from either end. Optics should be free from dirt, finger prints, moisture, scratches, chips, and fungus growth. Blotches or haze in a compound lens may be caused by a breakdown of the cement holding the components together. Such a condition should be corrected. The glass surfaces should be so clean as to be apparently invisible upon inspection.

Clearly defined reticle and image. Sight a distant target through the telescope with the right eye. Look directly at the target with the left. Two targets should appear, one superimposed upon the other. If the telescope has a power greater than one, magnification will cause the image of the target seen through the telescope to appear larger. Both images should be clear. Slightly closing first one eye, then the other, will aid in seeing both images. The image seen through the telescope should be as clearly defined as the image seen with the unaided eye. The reticle should appear clearly defined and superimposed upon the target.

A more accurate check may be made by using any well adjusted magnifying telescope between the eye and the instrument undergoing test. If the image of the target and reticle still appear clearly defined, one is assured that the instrument being checked is well adjusted as far as image and reticle are concerned.

Parallax. Place the telescope in a stationary position and sight a distant target. Moving the eye from side to side across the eyepiece should produce no apparent movement between the target and the reticle. Movement of the reticle relative to the target indicates parallax, a condition which should be corrected by a repairman.

Aiming Circle Inspection. The telescope of the aiming circle may be checked by the method described for telescopes. Other adjustments are as follows:

Tilt of reticle. Sight a target and place the horizontal cross hair of the reticle on a well-defined reference point. When the azimuth knob is rotated the reference point should not move above or below the horizontal line.

Circular level vial. With the instrument mounted on its tripod, center the bubble of the level vial, tighten the clamp on the ball and socket joint, and rotate the instrument slowly. The bubble should not move outside the circular center index.

Vertical travel. Sight a target and place the vertical cross hair of the reticle on a well-defined reference point. Elevate the telescope and note that the reference point does not move to the right or left of the vertical cross hair.

Tubular level vial. On fairly flat terrain choose two stations, A and B, sepa-

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rated by a distance of 50 yards or more. Set up the aiming circle at station A and hold a stick at station B. The top of the stick must be the same height above the ground as the telescope of the instrument. Center the bubble and measure the angle of site of the top of the stick by using the mil scale on the vertical cross hair. Next, move the instrument to station B and the stick to station A. Again measure the angle of site of the top of the stick. The two angles of site should be the same numerically but of the opposite sign. If they do not agree, the level vial is out of adjustment.

Magnetic needle. The needle should have a lively oscillatory motion when released.

Scales. With the azimuth scale index exactly opposite a graduation, check to see that the micrometer reads zero. This may be set by loosening the three screws on the micrometer and rotating the scale to zero.

Backlash. Sight the telescope on a distant target so that the reticle is lined up on some well-defined point. Turn the azimuth knob back and forth one mil. The reticle should leave the target point. One should also check to see that the telescope moves simultaneously with the turning of the orienting knob.

Tripod Inspection. Remove the instrument from the spindle and loosen the ball-and-socket joint clamp. The spindle should support itself in any position when the clamp is loose.

Panoramic Telescope Inspection. The optical system of the panoramic telescope may be checked according to the method described for telescopes. Scales and backlash may be checked in the manner described for the aiming circle. Other checks may be made as follows:

Horizontal travel. Sight a reference target and align the horizontal cross hair on a well-defined point of the target. Rotate the azimuth knob and check to see that the reference point does not move off the horizontal cross hair.

Vertical travel. Place the target reference point on the vertical cross hair and rotate the elevating knob. Check to see that the reference point does not move off the vertical cross hair.

Vertical movement. Check to see that the elevating knob has six full turns between stops.

Binocular Inspection. Since the binocular consists of two parallel telescopes, each may be checked according to the method described for the telescope. For these checks the diopter scale should be set to zero. Other checks are as follows:

Diopter scale. Turn the eyepiece all the way out and sight a distant target. Slowly turn the eyepiece in until the target is just clear and sharp with the eye at rest. When it first becomes clear, stop turning. The eyepiece is now focused properly. If the observer's eyes are normal, the diopter should now read zero. While making this check, the eyes may be forced into a rested position by observing the distant target with the unaided eye as the other views the target through the telescope. Both telescopes of the binocular must be checked in this manner.

A more accurate test may be made if a well adjusted binocular is available. Set the diopter scale of the master instrument to zero and look through it into the eyepiece of the instrument under test. Adjust the diopter scale of the test instrument until the target comes clear. The diopter scale of the test instrument should then read zero. This diopter movement should cover the entire diopter scale.

Double vision. Place the instrument on a stable support and sight a distant, well-defined object. Look through first one telescope, then the other. Each should show the same field of view and the object should occupy the same position in the field of view of each telescope. Repeat the test for several positions of the interpupillary scale setting.

Interpupillary scale. Measure the distance between the eyepiece with a millimeter scale. This value should agree with the reading on the interpupillary scale. If a millimeter scale is not available, the observer's interpupillary distance must be known. With this known value set on the instrument, check to see that each eye looks squarely through its telescope simultaneously. Each eye should see a full, clear field of view.

Hinge movement. Check to see that the hinge pivot is tight enough to support the weight of each telescope in any position.

Battery Commander Telescope Inspection. The B.C. telescope may be inspected

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for optical condition, parallax, diopter scale movement, double vision, interpupillary scale movement, and hinge movement in the same manner as that described for the binocular. The tests for interpupillary scale and double vision must be made with the telescopes in both the horizontal and vertical positions.

Circular level vials, scales, angle of sight mechanisms, and backlash are checked in the same manner as for aiming circles. Other checks may be made as follows:

Backlash in the angle of site mechanism. Rotating the angle of site micrometer scale one mil. should cause the bubble to move.

Extent of elevating movement. Check to see if the telescope will elevate 300 mils above and depress 300 mils below the horizontal. Use the angle of site scale to make this check.

Fit of the angle of site housing to the telescopes. The housing must support its own weight in any position.

Fit of telescopes to eccentric. The telescopes when moved together about the eccentric should remain in position.

Fit between telescopes. Each telescope should support its own weight in any position.

Ball-and-socket joint. With the clamp loose, the weight of the mount should be supported in any position. With the clamp tight, the weight of the mount and telescopes should be supported in any position. The clamp lever must not come above the horizontal position when tight.

Tripod hinge and clamp. With the lower leg extended and the clamp tight, the tripod must support its own weight in a horizontal position.

Tripod wing nut clamp. When tightened the lower leg must be held firmly.

GLOSSARY OF TERMS FOR FIRE CONTROL INSTRUMENTS

Angle of site: The vertical angle between the horizontal and the target.

Azimuth knob: The knob which, when turned, causes the telescopes to rotate in azimuth.

Azimuth mechanism: The worm and worm gear mechanism which enables the telescope to be moved in azimuth.

Azimuth scale: The horizontal scale calibrated every 100 mils.

Backlash: Play, or lost motion, between the worm and worm wheel gear teeth.

Binocular: An instrument containing two telescopes which allow the use of both eyes for observing.

Circular level vial: A spherical glass vial containing fluid with a bubble which is free to move in all directions. Horizontal may be established for all directions in one setting.

Diopter movement: The full extent of movement of the diopter scale.

Diopter scale: The set of graduations which indicate the focus setting of the eyepiece.

Double vision: A malfunction of a binocular instrument existing where the telescopes are not paralleled and the eyes therefore see two images superimposed one upon the other.

Eccentric: A bushing containing an off-centered bearing surface used for adjustment purposes.

Elevating knob: A knob which, when turned, causes the telescope to move in a vertical plane.

Elevating mechanism: The mechanical components which enable the telescope to be elevated.

Eyepiece: The mounted optical elements nearest the observer's eye, which give him a clear view of the reticle and image.

Field-of-view: The angular diameter of clear vision seen when looking into the eyepiece of an instrument.

Fire Control Instrument: Off-carriage instruments used to control the fire direction of weapons.

Focus: The adjustment of the eyepiece to give a clear and sharp image to the observer.

Image: The apparent target when seen through a telescope.

Interpupillary scale: The scale provided on the instrument to indicate the distance between the eyepieces in millimeters.

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Magnification: The increase in the apparent angular size of the target when viewed through a telescope. This results in the target appearing either larger or closer to the observer.

Micrometer: A graduated scale which provides the finest readings which can be made on an instrument. These scales are usually graduated in mils.

Mil: An angular unit of measurement, 1/6400 part of a circle. It is also the angle subtended by one yard at a distance of one thousand yards.

Objective: The lens in the telescope which is nearest the target.

Optic: An optical element in a telescope.

Orienting knob: The knob which, when turned, causes the entire instrument to rotate in azimuth with no change in the azimuth scale readings.

Orienting mechanism: The mechanical components which enable an instrument to be oriented in azimuth.

Parallax: An apparent shift between the reticle and the image as the eye is moved from side to side behind the eyepiece.

Reticle: A set of reference marks built into an instrument. It is usually a flat piece of glass with black lines etched thereon.

Sighting equipment: On-carriage instruments used for fire control direction of the weapon on which it is mounted.

Spindle: A vertical projection on top of the tripod on which the instrument is mounted.

Target: A distant object viewed through a telescope.

Tubular level vial: A curved glass tube containing fluid and a bubble for establishing the horizontal in one direction only.

MECHANICAL DIRECTORS

Introduction. Mechanical directors, though of a very specialized nature, have as their sole purpose the production of firing data. As has already been pointed out (see Introduction), the firing data produced must be proper for future positions of the target and must, therefore, be continually changing. The firing data will be based on several considerations, principal among which are the present position of the target, the rate at which and the manner in which this present position is changing, and the several ballistic factors. Ballistic factors may have appreciable effect on the firing data.

Types of Directors. Directors may be classified in several ways, one important classification being with respect to the basic principle of operation. Thus some directors are referred to as 'angular travel' directors while others are termed 'linear speed' directors. As the name implies, the angular travel type uses angular rates as the basis of prediction or determination of lead. Linear speed directors, on the other hand, first resolve target flight into linear components of speed in the usual three-dimensional rectangular coordinates, and produce linear predictions on the basis of these component rates. Ultimately, both types produce comparable elements of firing data, but the methods of arriving at the data are very different.

Directors may again be classified with respect to the number of ballistic factors for which compensation is made. Under this classification we have 'non-ballistic' directors, or those which make practically no ballistic compensations. 'Semi-ballistic' and 'ballistic' directors are those which make some corrections and those which make most corrections, respectively.

To provide firing data for guns to be used against fast-moving targets at relatively short ranges, a non-ballistic, angular travel director is normally employed. Such a mechanism is very fast in operation and is of suitable accuracy for its purpose. Heavier guns, however, require more accurate information than can easily be produced by an angular travel nonballistic director, so the semi-ballistic or ballistic type director of the linear speed type is used to obtain firing data on targets engaged by such guns.

LIGHT AA DIRECTORS—OPERATION AND FUNCTIONING

As has already been pointed out, mechanical directors of the non-ballistic angular travel type are employed to direct the fire of automatic, rapid-fire cannon against fast, low-flying, hostile aircraft. Such directors enable the initial rounds

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fired by the gun to be placed in proximity to the target and the observed error to be corrected by quick adjustments at the director.

Ammunition characteristics affect the fire control problem. In this case, the 40mm gun fires a high-explosive fixed shell with a point-detonating, supersensitive fuze. The shell is considered bore-safe, being armed in flight at about 400 yards from the gun. Each shell also has a tracer element which destroys the shell after seven seconds of flight, equivalent to approximately 3,500 yards range.

The angular travel method of computation can be understood by imagining an airplane flying at constant speed in a circular course around a gun position located at the center of the path of flight. Under these conditions, the number of degrees traversed by the plane per unit of time is constant and may be expressed as the angular rate of travel. The range to the target is also constant throughout the circular course. The time-of-flight factor is thereby determined, since range is a direct expression of the time-of-flight of the projectile. If these factors are known, it is possible to predict the position of the plane at any future instant by multiplying the angular rate of travel by the time factor involved and then adding the product obtained to the angle of the present position. Reduced to a word equation, then, this means that the future position equals the present position plus angular rate times time.

Normally, the course of a plane will be rectilinear rather than circular. Therefore the angular rate will change with the target's range as viewed from the gun position, even though the speed of the plane remains constant. This can be illustrated by observing a train. As it approaches, a person watching the train first turns his head very slowly. As the distance to the train, or the range, decreases, he has to turn his head more rapidly since the angular rate of travel increases, although the train speed remains constant. This increase in angular rate reaches a maximum when the train passes a point directly opposite the observer and decreases as the train recedes into the distance.

The above example is analagous to the rate changes encountered when tracking a target on a rectilinear course. At any given instant the angular rate introduced into the calculation will be correct for that instant only and will not reflect the average rate of change for any period of time. Since an instantaneous rather than an average rate is used, an error is produced which is inherent to the angular travel method of computation. The effect of this error is relatively unimportant because of the short range of the target engaged, because of the target's large area, and because the use of an estimated range results in a fictitious time-of-flight. A fictitious time-of-flight is the time of flight necessary to obtain a hit, and is secured by adjusting the range according to the observed error.

The rectilinear course of a target may be resolved into horizontal and vertical travel. It is therefore necessary to calculate the future position of the target in both the vertical and the horizontal plane. Each is derived in practically the same manner, differing only in that compensation for the effect of gravity must be introduced into the calculation of elevation.

The basic formulae used are:

(1) Future Azimuth = Present Azimuth plus Lateral Deflection (Lead);

(2) Lateral Deflection = Angular Rate in Azimuth × Time-of-Flight of Projectile;

(3) Future Elevation = Present Elevation plus Vertical Deflection;

(4) Vertical Deflection = Angular Rate in Elevation × Time-of-Flight of Projectile.

The angle of elevation necessary to compensate for the force of gravity, or trajectory drop, which must be added to the future elevation is known as the angle of superelevation. So the complete elevation data, known as quadrant elevation, includes future elevation plus superelevation.

(5) Quadrant Elevation-Future Elevation plus Superelevation.

Types of data involved in the solution of the above problems can be classified for simplicity of explanation into three groups: input data, calculated data, and output data. The individual items of data falling within these groups are shown in the following table:

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Input Data	*Calculated Data*	*Output Data*
Present Azimuth	Lateral Deflection	Firing or Future Azimuth
Present Elevation	Vertical Deflection	Quadrant Elevation
Angular Rate in Azimuth	Superelevation	
Angular Rate in Elevation		
Range or Time of Flight		

Director M5. Our first example of an instrument operating on the angular travel principle is the director M5. Its mechanisms are contained in an aluminum case approximately 25 inches wide, 30 inches long, and 20 inches high. The director weighs 490 pounds. It is mounted on a tripod (M7 or M19) in such a manner as to permit continuous traverse of the instrument.

The director is kept sighted on the target by two operators who follow, or track,

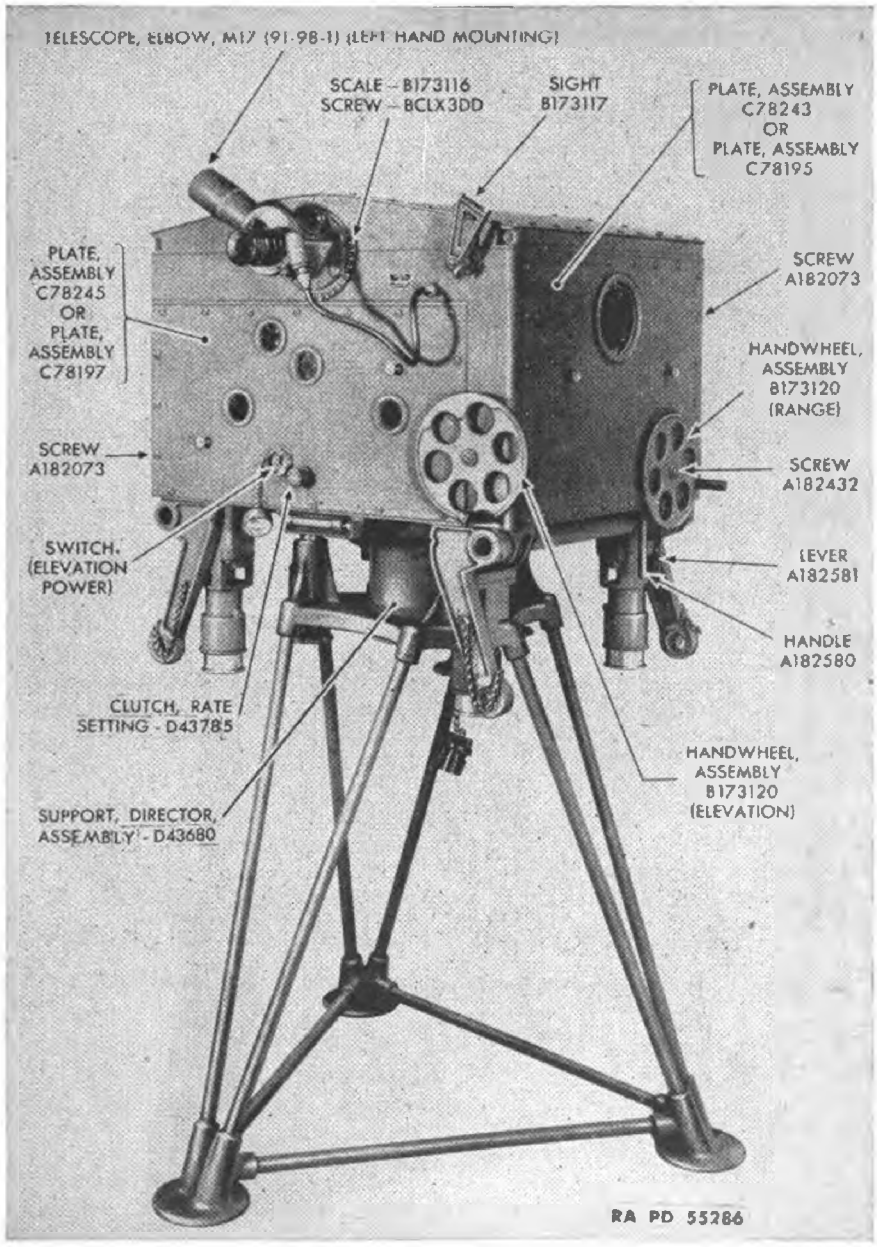

Figure 29. Director M5, M5A1, Left Rear View.

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the target through two telescopes (type M17) by operating the azimuth and elevation handwheels. The handwheels controlling director operation in azimuth and elevation are located on the right and left sides of the director respectively. The telescopes are connected by means of an internal shaft and rotate simultaneously in the vertical plane according to the angle of elevation. The line of sight of the telescopes in the horizontal plane is determined by the director's position in azimuth.

Range is introduced to the instrument by means of a handwheel located in the rear. A stop on the handwheel shaft limits the selection of range values from 375 yards to 2,800 yards for a 40mm gun. A visual indication of the amount of range set into the director is provided by a dial and index mounted above the range handwheel.

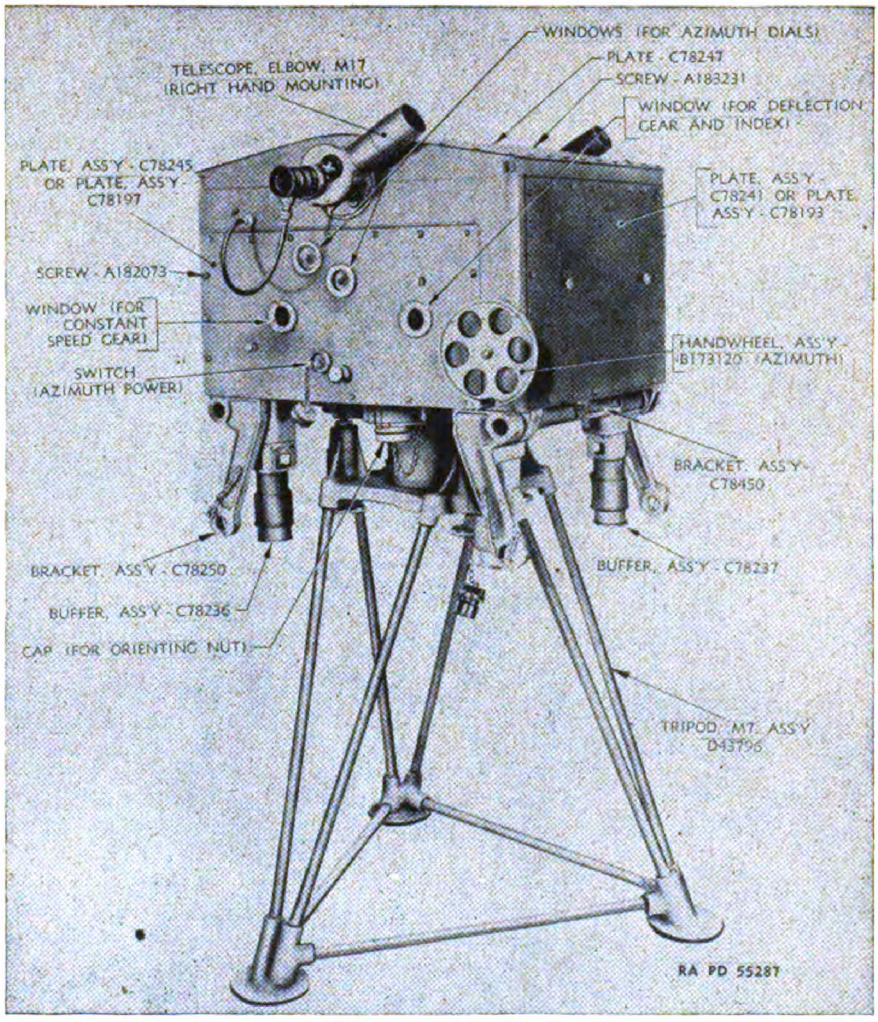

Figure 30. Director M5, M5A1, Right Front View.

From the above discussion it becomes apparent that three men are required to operate the director, namely, the azimuth tracker, the elevation tracker, and the range setter. Let us now see what happens as each of these men performs his function.

The azimuth tracker, standing on the right-hand side of the director, introduces present azimuth to the instrument by keeping his tracking telescope aligned on the target. This he accomplishes by turning his handwheel, causing the entire director to rotate according to present azimuth. However, a steady tracking rate is not obtained by this procedure because of the human element involved. To

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assure steady tracking, a variable speed drive is used indirectly to rotate the director at the desired rate for keeping the telescope aligned on the target. When the variable speed drive is used, only slight handwheel adjustments are required to modify the tracking rate according to the angular rate of change of the azimuth to the target. This mechanism is capable of producing an infinite and variable number of speeds in either direction between zero and the maximum tracking rate of 20° per second.

The variable speed drive consists of a polished circular disc, a ball carriage which houses two polished steel balls, and an output cylinder. The axis of rotation of the cylinder is perpendicular to the axis of rotation of the disc, which is rotated at 20 r.p.m. by a three-phase induction motor. A centrifugal type governor mounted on the motor shaft maintains the disc speed at the proper rate. Motion is imparted from the disc through the balls to the output cylinder by means of frictional contact. The ball carriage can be shifted in the horizontal plane across the face of the disc, giving the output cylinder a continuous rotary motion in a direction and at a rate directly proportional to the direction and distance of the balls from the center of the disc. Movement of the ball carriage from the center of the disc, or zero rate position, is accomplished by manipulation of the azimuth tracker's handwheel and the displacement is equivalent to a linear measurement of the angular rate. Therefore, since the disc is turned at a constant speed, for each increment of ball carriage displacement a definite rate results at the output cylinder. This rate value is equal to the tracking rate of the director and also equals the angular speed of the target. The motion from the handwheel which positions the ball carriage can be stopped by disengaging the clutch. The ball carriage also contains a stop to prevent moving the balls off the face of the disc.

In order that the torque, or twisting force, of the motion supplied by the output cylinder of the azimuth variable speed drive may be sufficient for proper operation of director mechanisms, a torque amplifier is used. This device consists of two carbon drums which are rotated at equal speeds in opposite directions by a three-phase induction motor. Wrapped around each drum in the direction of rotation is a steel band which can be tightened on the drum. One end of the band is connected to the cylinder of the azimuth variable speed drive; the other end is connected to the load, which in this case is the director mechanism. As an input is received from the variable speed drive, the steel band tightens about one of the drums and transmits the power of the drum to the director mechanism through kinetic friction developed between the rotating drum and the tightened band. The torque amplification thus obtained may vary from 50 to 220 times the input; however, the output rate remains the same as the input rate.

Motion from both the torque amplifier and the azimuth tracker's handwheel are combined in a tracking mechanism which positions the director according to the present azimuth of the target. The output of the tracking mechanism meshes with a stationary main azimuth gear, which is located beneath the base of the director, and this tracking motion serves to pull the director around this gear.

The multiplying mechanism shown in figure 31 calculates the product of two factors which are rate of change and time-of-flight by comparison of similar triangles. In two similar triangles, the base of one is proportional to the base of the other in the same ratio as that existing between the altitudes of the triangles. When the azimuth tracker moved his handwheel to displace the ball carriage of the variable speed drive, the lower end of a link on the multiplying mechanism was simultaneously positioned according to the linear measurement of the angular rate.

As previously stated, the range operator, stationed at the rear of the director, sets an estimated slant range on the range dial by means of a handwheel, and thus introduces the time-of-flight factor into this multiplier by positioning a time nut on a time screw. The position of the time nut determines the ratio of the altitudes of the two similar triangles.

Had the time nut been positioned at the center point of the time screw, the altitudes of both triangles would be equal. The displacement of the upper end of the link, then, would be the same as that of the lower end. Under this condition, the position of the time nut would represent a time-of-flight of one second; and the displacement of the upper arm would represent an angular lead equal to the

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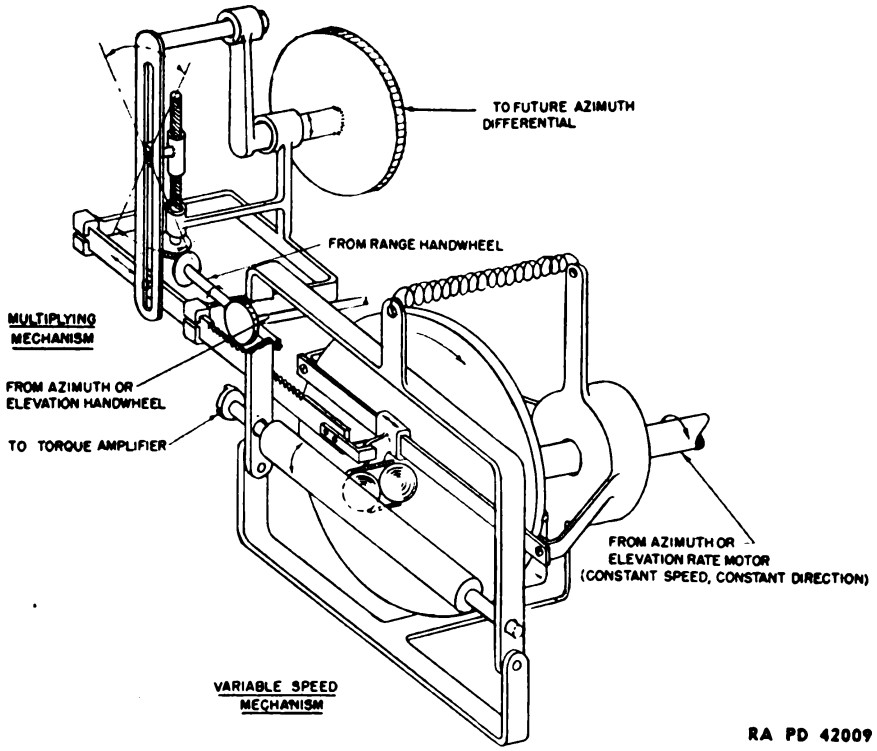

Figure 31. Azimuth Computing Mechanism. Schematic Diagram.

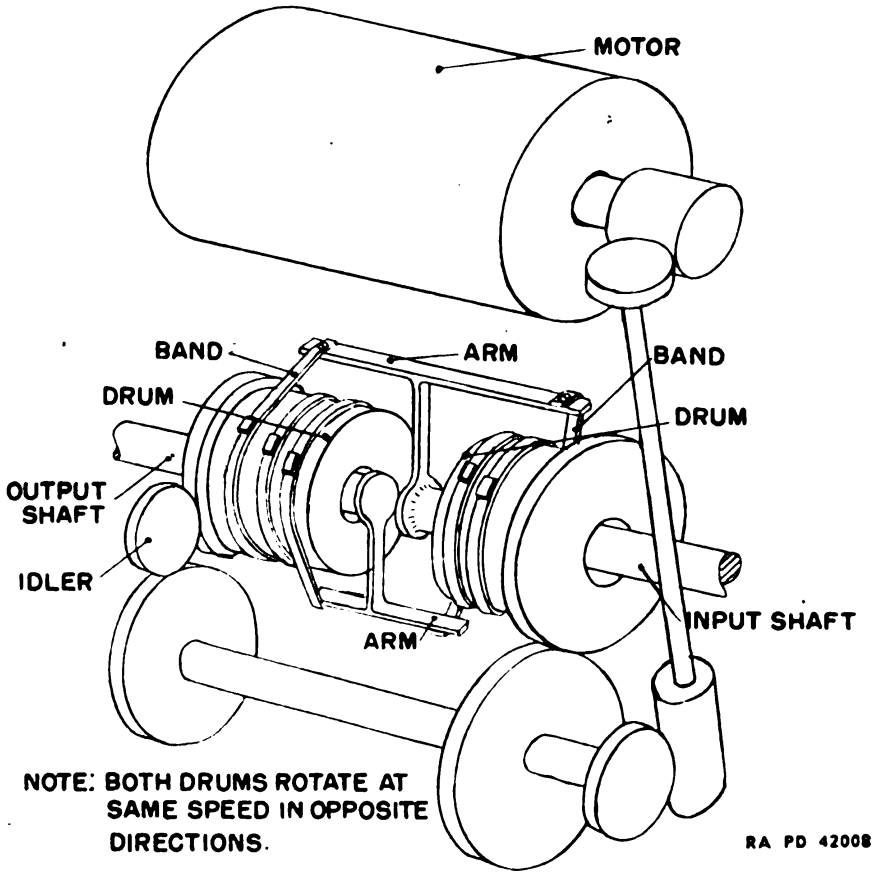

Figure 32. Torque Amplifier. Schematic Diagram.

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angular rate. If the time nut were to move upward, the displacement of the upper arm would be less and represent an angular lead proper for a lesser time-of-flight. Conversely, if the nut had been moved downward, the upper displacement would have been greater, thus representing the greater angular lead required by a greater time-of-flight.

It follows, then, that the product of azimuth rate times time is given as movement of the upper end of the multiplying linkage. This movement is converted into rotary motion by means of a crank arm attached to a deflection gear. This computed lead, or lateral deflection, is introduced as an input to the firing azimuth mechanism. At this point, the present azimuth, or director position, is added, resulting in an output value of firing azimuth. This motion positions the rotor of the azimuth fine synchro-transmitter, accordingly, at the ratio of one revolution of the rotor for each 20° of firing azimuth. Discussion of data transmission and the use of data will be found in the section of this chapter which deals with cable systems and remote control systems.

Solution of the problem for quadrant elevation is accomplished in a manner similar to that described for firing azimuth by employing another variable speed drive, torque amplifier, multiplier, and associated mechanisms.

The value of present elevation is introduced to the director by the elevation tracker who, through operating his handwheel, keeps his telescope aligned on the target. By engaging a clutch, the motion from the handwheel is utilized to position the ball carriage of the elevation variable speed drive according to the angular rate of target travel in elevation. This motion is transmitted through the elevation torque amplifier to the elevation tracking mechanism where it is added to the motion of the handwheel resulting in an output value of present elevation. This output serves to rotate the telescope shaft, thereby positioning both tracking telescopes according to present elevation.

The principal difference between the azimuth and elevation solutions lies in the calculation of the superelevation. An eccentric cylinder, which is rotated according to present elevation, displaces, through a lever arrangement, the ball carriage of the elevation variable speed drive according to a value proportional to the angle of superelevation. Since this will result in a false elevation rate and consequently erroneous tracking, the elevation tracker must adjust his handwheel to obtain the correct results. In so doing, the lower end of the vertical multiplier is positioned according to the linear measurement of angular rate in elevation plus the superelevation factor. The element of time is introduced into the vertical multiplier in the same manner described for the azimuth calculation, since the value of range involved will be the same for both azimuth and elevation. The output of the multiplier is the sum of vertical deflection and superelevation. The total is added to the present elevation, or telescope position, at the quadrant elevation mechanism, resulting in an output of quadrant elevation. This motion positions the rotor of the elevation fine synchro-transmitter accordingly.

Operational limits of the director in the vertical plane are from a depression of 10° below horizontal to an elevation of 92° above. At these points mechanical stops are engaged to prevent unmeshing of the elevation gear train. Protection to the mechanical stops is afforded by an electrical limit switch which cuts off electrical power to the elevation motor approximately 5° before the mechanical stops are met. Operation in the horizontal plane is unlimited. Electrical connections for power and data are made to a cable through an assembly of slip rings located in the base of the director.

Director M5A1. In outward appearance the director M5A1 is similar to the M5. However, it incorporates two major engineering changes, namely the addition of another synchronous transmitter and the elimination of the torque amplifier. In the past, torque amplifiers have been the most common source of director malfunctions and their removal means greatly reduced field maintenance.

Each torque amplifier is replaced by a compound gear reduction unit, and each of these occupies the same position in the director as did the torque amplifier. The input to each gear reduction unit is connected to the cylinder of a variable speed drive, while its output is connected to its respective tracking mechanism. The input motion is reduced in speed and consequently increased in torque to the magnitude required to operate the director mechanisms. In order that there be

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no alteration in the over-all tracking rate of the director for any given ball carriage displacement, the speed of the variable speed drive disc and consequently the speed of the output cylinder is increased in the same ratio as that of the reduction obtained in the gear reduction box.

By means of a solenoid brake, the elevation variable speed drive is brought to a positive stop whenever the electrical limit switch is contacted, thereby preventing coasting of the telescope gear into the mechanical stops. The electromagnetic coil of the brake is wired in parallel with the elevation rate motor in such a manner that breaking of the power lines to the motor by the elevation limit switch results in the collapse of the magnetic field in the solenoid. This allows a spring loaded brake shoe to ride against the rear of the disc of the elevation variable speed drive. Whenever the rate motor is operating, the electromagnetic coil of the solenoid is energized and the brake shoe is withdrawn from the disc.

The additional synchro-transmitter is utilized to obtain an electrical signal indicative of the calculated quadrant elevation throughout 360°. This coarse quadrant elevation transmitter is geared to the fine transmitter at an 18 to 1 ratio. Thus, in the M5A1 director, the azimuth and elevation transmitter assemblies are identical, each consisting of a coarse and fine transmitter whose rotors are geared at the 18 to 1 ratio. This feature is necessary in order to use effectively the self-synchronous features of the oil gear M3 (see remote control systems) which enables the gun to remain oriented with the director at all times during normal operation.

Director M5A2. In the operation of directors M5 and M5A1, it becomes evident that a means of basing calculations upon true target range would improve director accuracy and decrease crew training time. This consideration led to the development of the director M5A2, which is an M5A1 with a range finder M10 added. Also incorporated are devices to cause range to be automatically and continuously set into the director and to adjust true present range to that variation of future range (previously referred to as 'fictitious range') which will result in proper firing data.

The M10 range finder determines ranges by triangulation on a base of 30 inches, using superimposition of two full-field images to allow the eye to judge exact range settings. Two mirrors, 30 inches apart, are set parallel to each other and at an angle of 45° to the line of sight to the target. If the target is at an infinite distance, light rays to both mirrors follow parallel paths and the reflections of the target image from the mirrors will also be parallel. If the target is at some finite range, the reflection from one mirror follows a path diverging from the other by an angle which is the same as the one subtended at the target by the lines of sight from each mirror. The left mirror can then be turned through half that angle and cause the two reflections to follow the same path. Because of this, the angle through which the left mirror is moved from its 45° position is directly proportional to the slant range of the target, and any mechanical motion needed to set the mirror's angle can be so calibrated.

The right mirror is used both as a reflector of one image and also a transmitter of the other image. To allow this, a special optical coating is applied to the right-hand mirror. This coating reflects light of blue wavelength and transmits light of orange wavelength. The range finder telescope (8X, 8° field of view) thus receives two colored images, a blue image from the right mirror and an orange image from the left or range measuring mirror. When these two images are superimposed by a correct range setting, the original target color is obtained. Positioning of the left mirror is accomplished by a motor which drives a cam pivoting the left mirror. Operation of the motor is governed by an electro-mechanical device which is brought into play by means of a manual control knob. The left mirror is allowed to continue to move until superimposition of the images is obtained. When this superimposition takes place, the correct range has been determined and also has been fed into the director electrically. The manner in which this latter action is accomplished will be touched upon briefly later in this section.

Since the blue light from the right mirror and orange from the left mirror is used in the ranging telescope, the orange light from the right and blue from the left can be used in another telescope (6X, 8° field of view) for spotting. The images are seen here in the same relationship as in the telescope previously described. When the gun is fired, a tracer appears in the spotting scope as a

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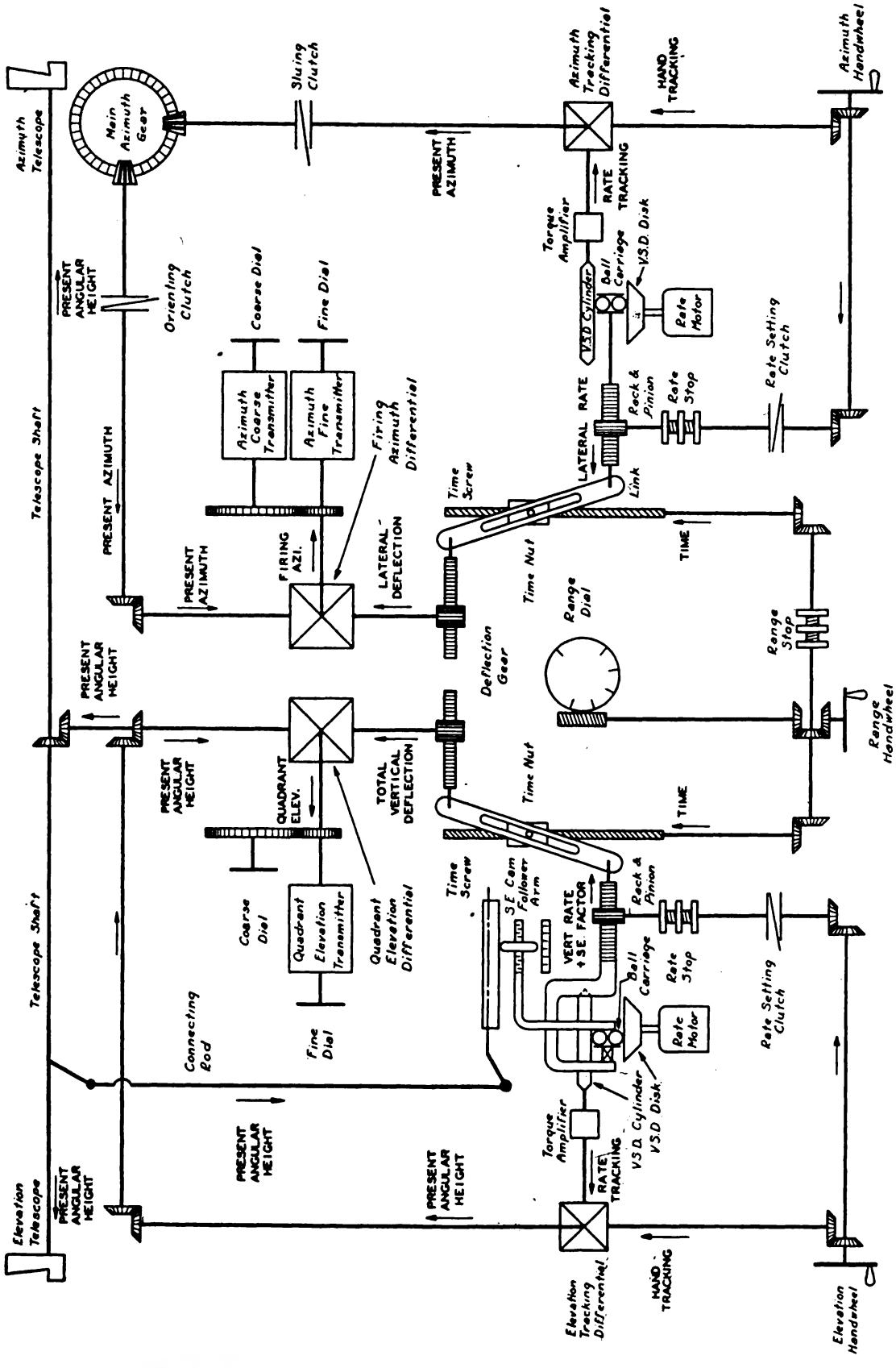

Figure 33. Flow of Data, Director M5. Schematic Diagram.

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double image until it reaches that range which has been set in the range finder. There the two images merge into one and then split again as the tracer's range increases. The crossover point of tracer path is viewed in relation to the target; and the range, set into the director from the range finder, is adjusted until the crossover point meets the target. In addition to the mirrors and two telescopes, an internal adjustment system is included among the optical parts. This permits quick calibration without an infinite target or an adjusting lathe.

Because the range finder is mounted on the director, it is pointed in azimuth as the azimuth tracker controls movement of the director. It is elevated through a linkage with the director's telescope shaft. A crew of four is required for the

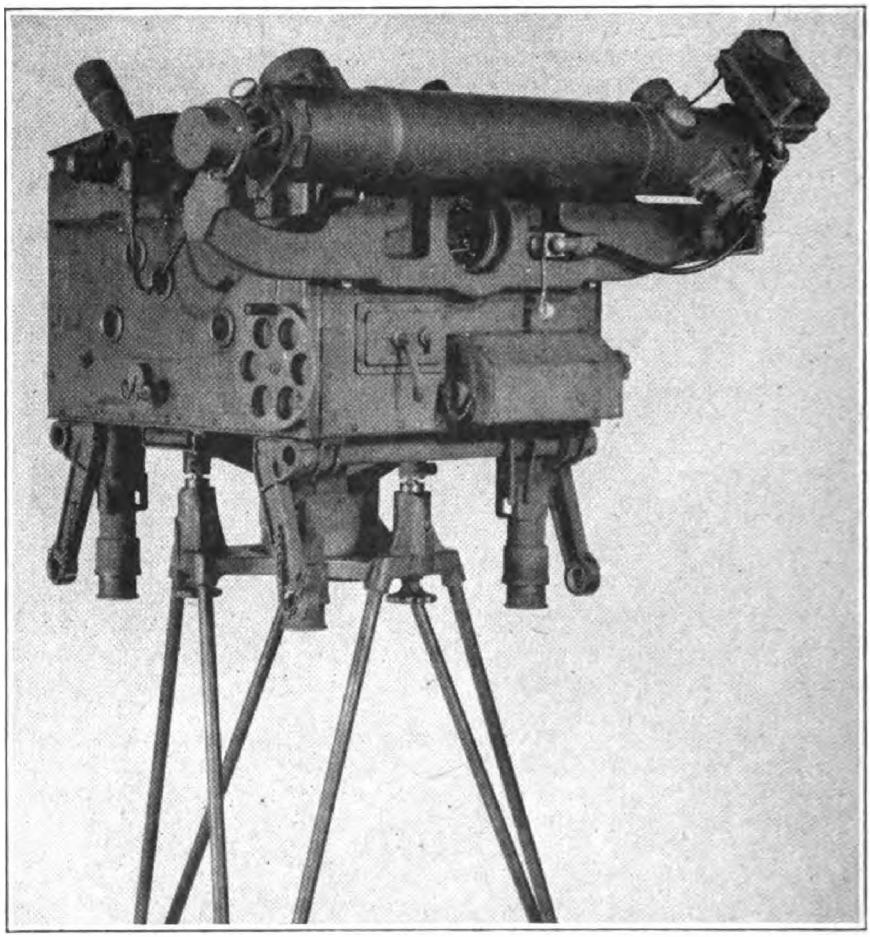

Figure 33A. Director, M5A2, Right Front View.

M5A2, the same azimuth and elevation trackers, and in addition, a range finder operator, and a spotter. Range may be determined from 385 to 2,500 yards. The range finder, being a tube about 45 inches long and 6 inches in diameter and mounted at the rear of the director, requires provisions for greater stability of the director. A new tripod (M21), having large, duck feet, is provided and the director is locked to the tripod by spring catches. The range finder and its mounting bracket are easily removed and carried in their own packing chest. The range handwheel may still be used for the director M5A1 in case of failure of the automatic mechanism.

Let us now examine briefly the manner in which the proper value of range is automatically fed into the director. As the range operator moved his control knob to position the left mirror, he upset an electric balance which had existed prior to the moment he turned his control knob. Then, in order that this balance could be reobtained, changes within the electrical element had to take place. These changes occurred when the motor driving the cam went into operation; in fact,

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the unbalanced condition started that motor operating. This unbalanced condition also upset another electrical system. This, in turn, caused a second motor to operate which rotated the range shaft (within the director proper) and repositioned the time nuts of the multipliers. This action continued until the range man, obtaining superimposition of the images, no longer moved his control knob. When movement of the control knob ceased, balances in the electrical systems were immediately regained, the motors ceased running, and the proper value of range was set into the director.

Slight corrections may be introduced into the director by means of effecting only the electric balance in the second electric system mentioned. To accomplish this, the spotter has a control lever to introduce this unbalance which causes slight repositioning of the time nuts. Thus the correct present range is adjusted to produce the firing data needed. It should be noted, too, that these adjustments effect only the director proper and not the range finder, which will still be set in accordance with the present range.

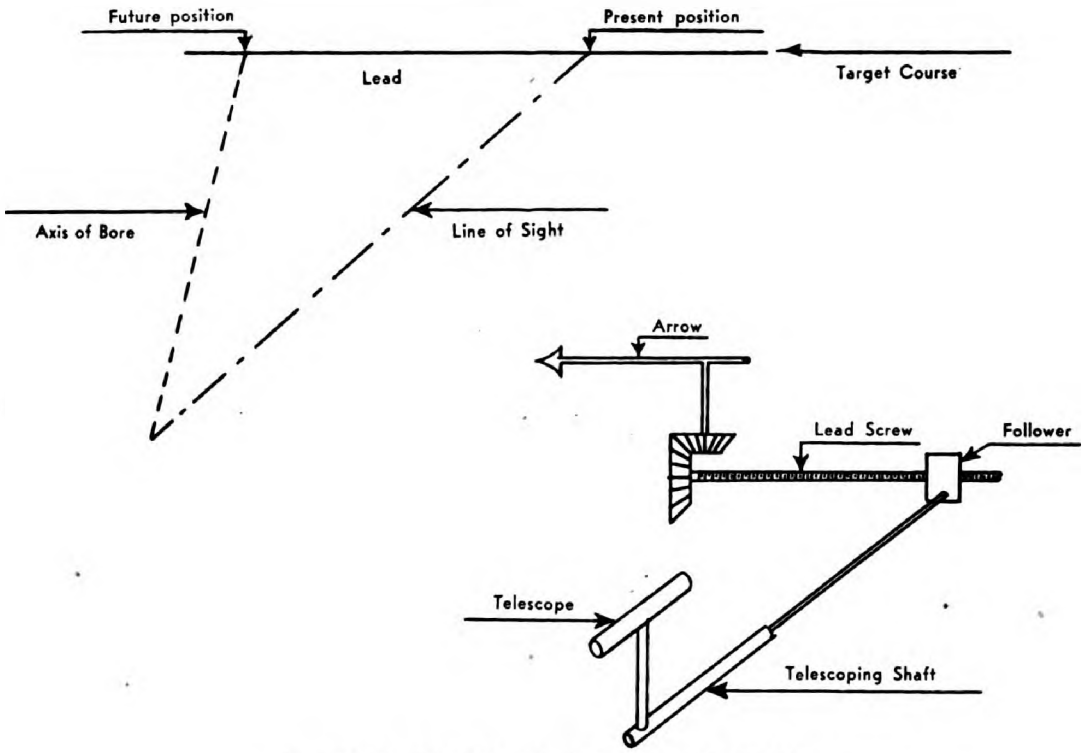

Figure 34. Principle of Computing Sight, M7.

Computing Sight M7. In certain situations it is necessary to use the 40mm gun against aircraft when the light director is not available or cannot be put to use quickly enough. For such an emergency, the computing sight M7, an on-carriage fire control system, computes the necessary leads by simpler means than the director does, though not as accurately. The sight consists basically of two telescopes (M7 or M74) and a computing mechanism. When the telescopes are trained on the target by the azimuth and elevation gun trackers, the operation of the computing mechanism results in causing the gun to lead the target properly in azimuth and elevation.

Two elements of data are necessary for the computation: speed of the target and direction of target flight. These are set in by an operator who rides on the gun carriage behind the azimuth tracker. To set in the target course, the operator moves an arrow so that it points in the direction of the target course. As he does this, he is pivoting a lead screw to such a position that it, too, is parallel to the target course. Next, he must make a dial register, his estimation of the target's speed and as he does his he moves a traveler nut on the lead screw in a direction opposite to the direction of flight of the target. This movement of the traveler is

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actually away from the pivot point of the lead screw, and the amount of the movement, of course, is proportional to the speed of the target.

As is shown in figure 34, a telescoping shaft connects the traveler to the telescope pivot point and is so connected to the telescope that the line of sight and the shaft will always be parallel. Further, a line from the pivot point of the telescope through the pivot point of the lead screw will point in the direction in which the gun barrel should be trained. Thus, with the telescopes offset as indicated, the process of tracking with these telescopes will necessarily cause the gun barrel to lead the position of the telescopes. Because the pivot point of the azimuth telescope is set lower than the pivot point of the lead screw, the lead determined in the slant plane is resolved into component azimuth and elevation leads.

The two telescopes are mounted on a sight bar which is fixed across the breech casting of the gun. This bar also supports the computing mechanism on the right side. All motions of the azimuth telescope are repeated by the elevation telescope on the left by means of linkages which carry the motion through the supporting bar. The speed set in is registered on a dial graduated from 0 to 500 miles an hour. It should also be noted that after the arrow has been positioned to point in a certain direction, it is maintained there by motion from azimuth tracking. Thus the arrow is stationary with respect to the ground although it has an opposite turning with respect to gun movement.

Superelevation is obtained by lowering the computing mechanism, and therefore the telescopes, below a line parallel to gun bore. By thus having the telescopes lower, a vertical lead of 9 mils at zero elevation is permanently set into the sight. The angle is varied from this value to zero mils at 90° elevation. Such variation comes from a link between the gun trunnion and an eccentric in the computing mechanism support. The same link also keeps the computing mechanism housing absolutely level at all elevations. The superelevation thus determined is correct for a range of 1,180 yards; and, being fixed at values which are correct for the average of the expected target ranges, results in but small errors when other ranges are used.

The above description of obtaining a lead was predicated on the assumption of a static position. For a moving target on a crossing course, we find that the sight computes a lead which starts at minimum value on the approaching leg, increases to a maximum value at the midpoint, and returns to minimum on the receding leg. On an incoming course, vertical lead increases until the target is directly overhead. As with the director, fire of the 40mm gun is adjusted by tracer observation. So here, when tracking has started and shells are fired, the arrow's position is adjusted until the tracer path crosses the line of sight to the target. Then the speed set in at the speed dial is adjusted until the proper lead results in a hit.

The sight operator is usually the range setter of the director crew, for the successful use of the sight depends upon the quick and accurate judgement of the man who sets in the target course and speed.

LIST OF TERMS AND SYMBOLS FOR LIGHT DIRECTORS

Symbol	*Name*	*Term*	*Definition*
A	Alpha	Azimuth	A horizontal angle measured clockwise from zero (north) to a line joining the target and observer.
A_f	Alpha sub-f	Firing azimuth	The azimuth at which the gun is laid in order to hit the target at its future position.
A_o	Alpha sub-zero	Present azimuth	The azimuth of the target at the instant the gun is fired.
None	None	Angular travel method	A method of determining firing data based upon the rate of angular travel of the target in azimuth and elevation.
D	D	Slant range	The linear distance from an observer to the target, measured along the line of sight.

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Symbol	*Name*	*Term*	*Definition*
δ	Delta	Lateral deflection angle	The horizontal angle representing the difference between present azimuth and firing azimuth.
None	None	Drift	The divergence of a projectile from the plane of departure due to the rotation of the projectile and the resistanc of the air.
ϵ	Epsilon	Angular height	The angle measured in a vertical plane between the horizontal and a line joining the target and observer.
ϵ_0	Epsilon sub-zero	Present angular height	The angular height of the target at the instant the gun is fired.
ϵ_p	Epsilon sub-p	Future angular height	The angular height of the target at its future position.
Φ	Phi	Quadrant elevation	The angle measured in a vertical plane between the horizontal and the axis of the bore when the gun is fired.
Φ_{sa}	Phi sub-s-a	Super-elevation	That part of the quadrant elevation which allows for the curvature of trajectory during the time-of-flight.
Σ_1	Sigma sub-1	Principal vertical deflection angle	The vertical angle due to change in angular height of the target during the time-of-flight.
Σ_a	Sigma sub-a	Angular velocity in azimuth	The rate of change in azimuth.
Σ_e	Sigma sub-e	Angular velocity in elevation	The rate of change in elevation.
T	t	Time-of-flight	The time required for a projectile to reach the future position of the target.
t′	t prime	Fictitious time-of-flight	The estimated time-of-flight.
None	None	Trajectory	The curved path of a projectile due to the influence of gravity.
None	None	Line of position (or line of sight)	A straight line from the observer (director) to the target.
None	None	Prediction	Forecasting the position of the target at some future time based upon its past behavior.

HEAVY AA DIRECTORS—OPERATION AND FUNCTIONING

General. The determination of firing data for the heavier antiaircraft weapons, the 90mm and 120mm guns, presents problems beyond those met in the computation of this data for the lighter equipment. Because of the relatively long ranges at which the targets to be engaged by these weapons will be flying, ballistic effects upon shell travel become great enough to require compensation. For instance, at an altitude of 7,000 yards, and a range of 6,000 yards the shell will drift to the right about 40 yards, while a 10 mile an hour rear wind at an altitude of 1,000 yards and a range of 8,000 yards will blow the shell an additional 35 yards in range. It is therefore, plainly evident that since the effective bursting radius of a 90mm shell is only about 30 yards, neglect of errors of this magnitude can result only in very inaccurate fire.

It should further be recognized that the angular travel method of solution employed in the M5 and M6 directors contains inherent errors which render it unsuitable for proper solutions when the target is at a considerable range from the director. These errors will become evident if the reader will visualize an aerial target approaching him at a constant altitude and speed. When such a target is a long way off it appears to be moving quite slowly, but as it approaches the observer it seems to be gaining speed. In particular, its rate of change of angle of elevation increases as it approaches, even though its ground speed remains constant. The same effect takes place in azimuth.

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It should now be clear that if prediction in angular elevation is to be based upon the target's instantaneous rate of change of angle of elevation times the time of flight of the projectile to the target, the predicted future angular elevation will be inaccurate, because the rate will be changing continuously. In actual fact, calculated prediction will be too small for an approaching target and too large for one flying away. In the case of light antiaircraft fire control, the errors introduced by this method of solution are not of sufficient magnitude to be of much consequence, particularly since the tracer element in the shells will make their course visible. Subsequent corrections may be made on the basis of this observed flight.

In the case of heavy antiaircraft guns, fire must be accurate enough to hit, or at least drive away, aerial targets which will be flying at ranges greater than 3,000 yards. For this mission, the error introduced by assuming a non-constant rate to be constant will be multiplied by time factors ranging from as little as two to as much as thirty seconds. This error will become prohibitively large. Furthermore, since no tracer stream will be emitted by the shells in flight, it is necessary to wait until the burst of each shell occurs before the accuracy of the fire may be checked. Moreover, if an error could be corrected on the basis of the observed burst, a period of time equal to the time-of-flight of the next shell *must* elapse before that correction can become effective. Consequently, no predictable errors whatsoever can be left uncompensated for before the gun is fired.

Determination of firing data must, therefore, be attacked from a new direction in order to provide a more accurate solution of the basic problem; and, at the same time, some ballistic corrections must be incorporated therein. Thus we find that the heavy directors employed with the 90mm and 120mm guns are classified as 'semiballistic' directors because they take into account some ballistic effects. The directors used with the 90mm guns, for instance, have provision for corrections for wind effect and lateral drift on the flight of the shell. Parallax, the physical displacement of the director from the center point (battery directing point) of the group of guns, is also compensated for automatically in the director

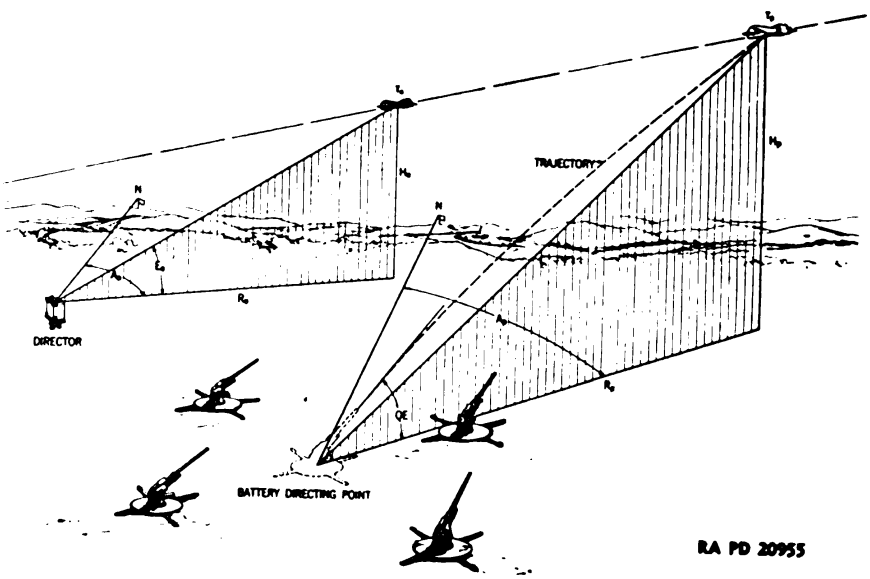

Figure 35. Battery Hook-Up, Indicating Symbols.

The effect of muzzle velocity variations, and similar ballistic errors which are variations from standard must be precalculated and set into the director manually during trial firing. This will be discussed later.

The classification 'linear speed director' is also applied to this equipment to convey the idea that it expresses the target speed in linear distance per second rather than degrees per second as do the 'angular speed directors.' This latter classification is applied to the light directors M5 and M6. The target may be

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visualized as traveling simultaneously in east or west, north or south, and up or down directions. That is to say, we break the motion of the plane down into motions in three directions mutually perpendicular. Furthermore, the speed in each of these directions will be constant if the target continues to fly in the same direction and at the same speed. The use of these constant linear rates as the basis for prediction therefore eliminates the objection involved in the use of varying angular rates subtended by a target moving at a constant speed.

Firing data used by the heavy antiaircraft guns must be provided in terms resembling spherical coordinates. Thus they require a firing azimuth, a firing elevation, and a fuze setting to make the shell burst at the target's range from the guns (A_p, Q.E., and trajectory length in Figure 35). The target's present position (T_o, Figure 35) is also determined in terms of two angles and one distance, A_o, E_o and H_o or present slant range, since this method for locating it is the easiest to accomplish from a single fixed observation point. It is now apparent that the director must include elements which will receive these angular measurements, determine from them linear rates, and produce as an end product the required firing angles and fuze setting. Thus the reader may anticipate that the heavy directors have incorporated within them mechanisms which will make the necessary conversions from angles to linear distances, and back again to angles.

Firing elevation usually referred to as quadrant elevation, Q.E. and fuze setting could be determined from a firing table if the future position of the target were known. Examination of a firing table, however, will reveal that the position of the target therein must be described in terms of future range, R_p and future altitude, H_p. Since the director makes use of a 'mechanical firing table,' it will be necessary that mechanical motions representing the future values of range and altitude be present in the director. The easiest way to get these values is to start from their corresponding present values.

Present altitude is introduced as information from a height finder or a radar installation. Present angular height, E_o, is introduced by tracking the target. These two values are two elements of a right triangle and from them the present horizontal range, R_o, may be determined. Thus the director must have a mechanical solver for this trigonometric problem. Present azimuth, A_o, is determined by tracking the target. It is used in conjunction with the calculated horizontal range to produce north-south and east-west components of present position, direction of movement, and speed of the target in the horizontal plane. Similar up-down components are received directly as changes in altitude from the height finding instrument used in conjunction with the director.

Thus we have converted present horizontal range, present azimuth, and present altitude into three mutually perpendicular components from which we may determine the three corresponding rates of change of these components. These rates, when multiplied by the time-of-flight provided by the mechanical firing table, determine how far the plane will move (i.e. prediction) in the three directions during the interval which elapses from the time the shell leaves the gun until it reaches the target. These predictions must then be reconverted into corresponding changes in altitude, azimuth, and range, and added algebraically to the present values. The future azimuth, altitude, and range are then used as a basis for determination of suitable firing data to hit the point so described. In addition, facilities are provided for making arbitrary corrections to the data thus transmitted to the guns.

There are four mechanical directors in this class, any one of which may be used with a heavy antiaircraft battery of four guns merely by installing the proper mechanical firing table for the particular type of gun and ammunition being used. Basically they are similar, and the discussion which will follow will apply to them all, but will be more detailed than heretofore. These directors are designated the M4, the M7, the M7A1B1, and the M7A1B2. Distinctions between these directors will be described later.

Director M4. The several simultaneous operations going on within the director which lead to a solution of the firing problem will not be discussed. One of the director operators is assigned the task of tracking the target in elevation by observing it through a telescope (elbow telescope M17). In order to keep the

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target on the center of the reticle in the telescope he must control its angular elevation with a handwheel. This motion also positions a dial which indicates the present angular height, E_o, of the target.

At the same time, the height finder has transmitted to the director the altitude of the target in yards by electrical means. This value appears on a dial in the director. The actual transmitting mechanism will be described later in the section on cable and remote control systems. Since, however, this signal system which transmits the altitude cannot be used to transmit enough power to function the altitude mechanism in the director, an operator must set into the director, with the aid of a hand wheel, the same value as appears on the dial receiving altitude. This operator is usually called the altitude tracker.

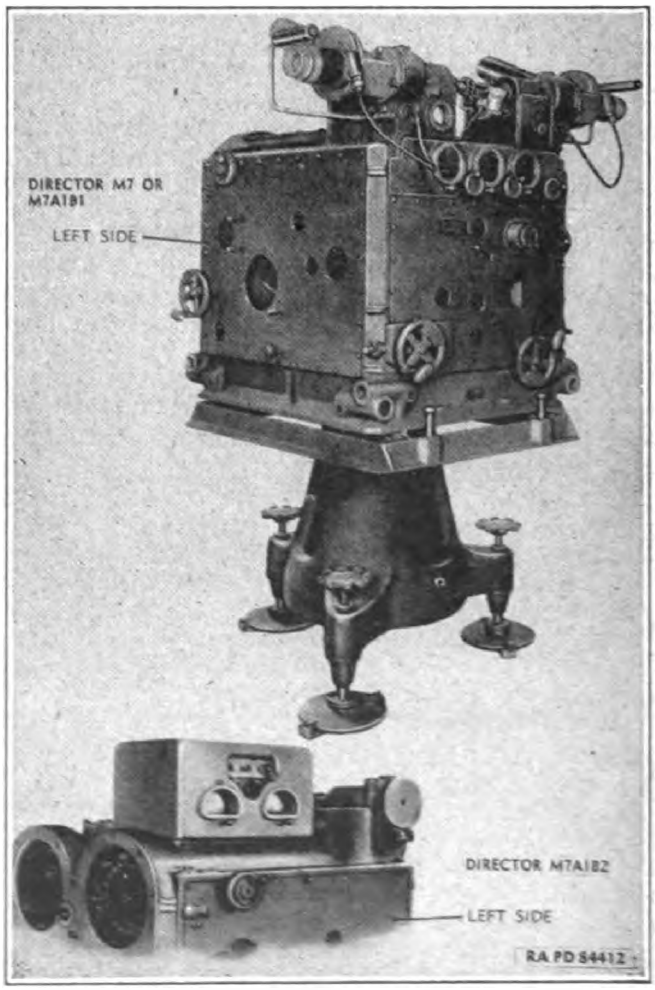

Figure 36. Director, AA, M7, M7A1B1, M7A1B2.

At this point, the present altitude and the angular elevation of the target have been introduced into the director. As has already been called to the reader's attention, these two values are one side and one angle of a right triangle. The second side is the horizontal range of the target from the director. This value may be determined by solving the relation:

$$R_o = H_o \text{ Cot } E_o \text{ (see figure 34).}$$

A mechanism must, therefore, be described which will solve this equation.

Visualize a graph whereon the various values of angular height are plotted against the corresponding values of horizontal range for a constant altitude (See figures 37A and 37B). Instead of drawing this curve on paper, let it be cut out of a thin piece of sheet metal (figure 37C). This curve is then supported rigidly so that we may rest one end of a vertical rod (a 'follower') on its curved edge.

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This follower is constrained to move only up and down, and will do so as it follows the curve on the metal graph if the graph is moved laterally on a line along which the range axis lies. Thus if the target were flying at the altitude for which this graph was cut, we could find the proper range for this altitude and the observed angular height if we put an index on the follower and made it run against a scale which was graduated in degrees (See figure 37C). The procedure would be as follows: An observer would move the graph laterally along the range axis until the follower recorded on its scale the same value for angular height as the one observed by tracking the target with the elevation telescope. When the observed angle and the angle produced from the graph are the same, the range below the position of the follower would be the correct range for this particular altitude and angular height. The operator who is responsible for producing an angle of elvation off the graph, which is the same as the observed angular height by translating the graph, is called the range tracker.

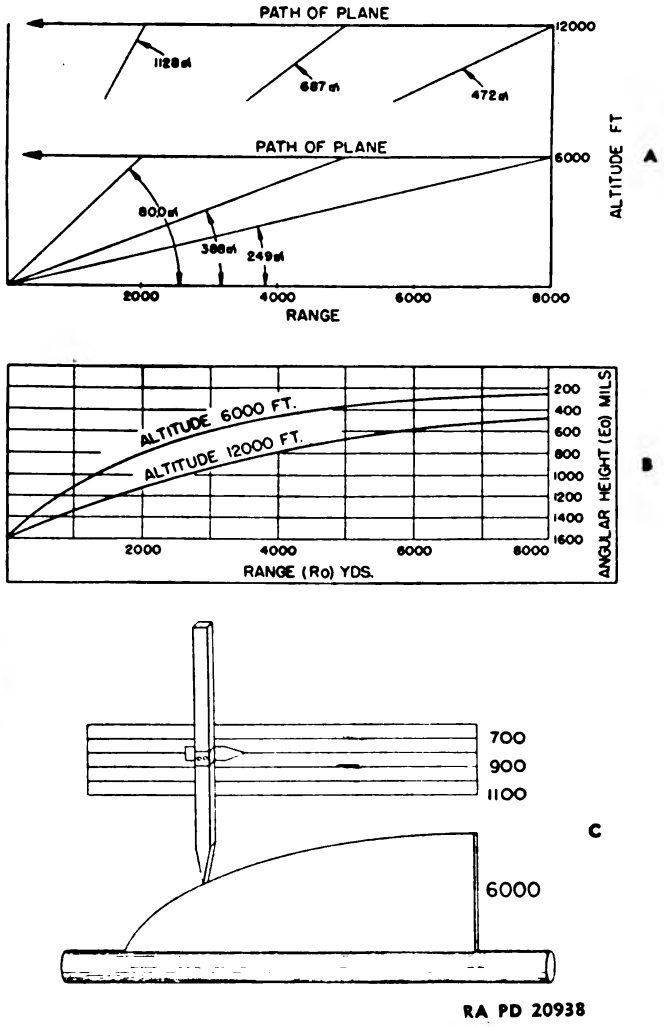

Figure 37. Build-Up of the 3-Dimensional Cam.

The mechanism which we have described is good, however, for only one altitude. But we can make similar graphs for all altitudes within the operating range of the director. Each one of these graphs may be mounted onto a shaft so that the range axis falls along the length of the shaft and the angular height axis extends out radially from the shaft.

If the graphs are arranged in the order of increasing altitude, then by turning the shaft we can cause each graph to come under the follower in its turn. Moreover, when we have mounted all the altitudes onto the shaft we shall have built up a

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solid of continuously varying cross-section (see figure 38C). This mechanism is called a 3-dimensional cam. We can make the follower read the correct angular elevation for any range and altitude merely by turning the cam on its axis until the desired altitude is under the follower, and then by translating the cam, obtain the required range for the given angular height. This mechanism is called the 'present angular height cam.'

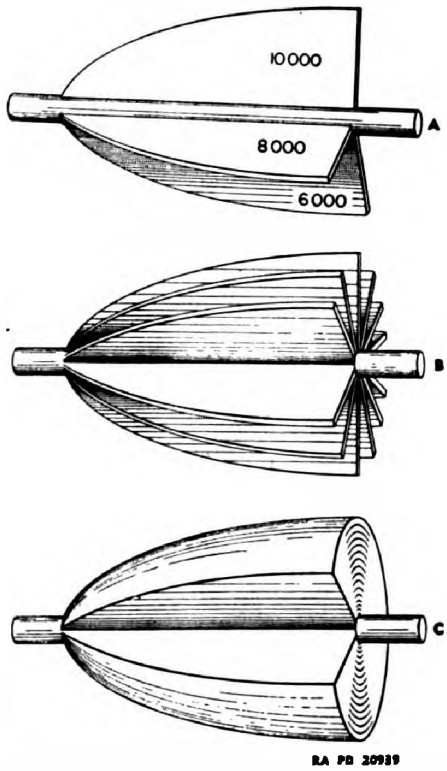

Figure 38. Build-Up of the 3-Dimensional Cam.

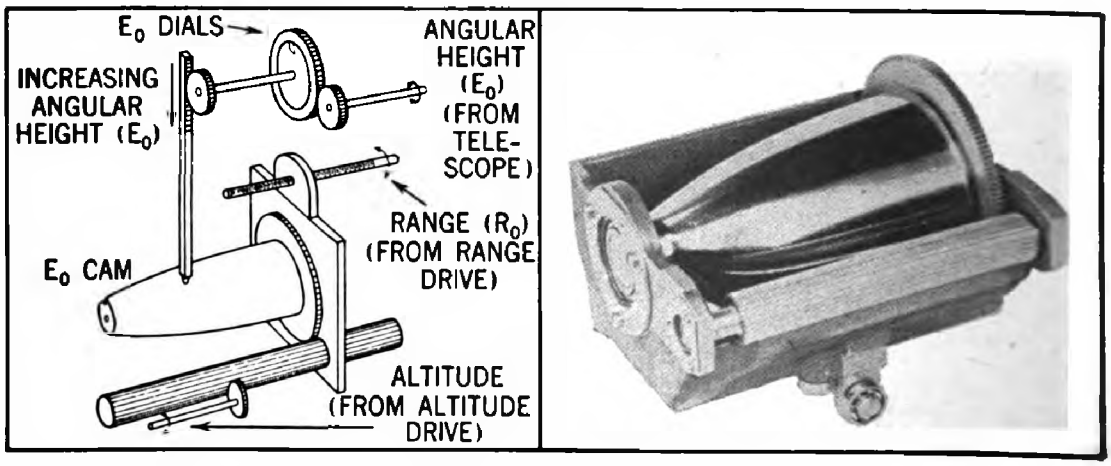

Figure 39. Angular Height Cam and Schematic of Operation.

In the director, the altitude tracker causes the cam to rotate about its axis as he sets in the altitude received from the height finder. The range tracker translates the cam. The follower has a gear rack cut in its upper end which engages a small pinion geared directly to a dial mounted concentrically with the dial which records the angular height measured by the elevation tracker. These two

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dials each have an index on them. All the range tracker must do in order to obtain the proper value of range for the settings of altitude and angular height is to keep these two indexes lined up.

A fourth operator, the azimuth tracker, is setting in the present azimuth of the target at the same time as the angular height, altitude and range trackers are setting in their respective values. This operator observes the target through another telescope of the same type, and mounted on the same shaft as that of the elevation operator. By this means the azimuth telescope is kept pointed at the target in elevation. As the azimuth operator observes the target, he endeavors to keep the vertical retical line in his field of view bisecting the target. As he tracks the target he slews the entire director around its vertical axis.

Summarizing, we find that the operators have set into the director motions describing the present position of the target with respect to the director. These values must now be converted into corresponding rectangular coordinates, and in addition, the rates of changes of the coordinates must be determined from the continuous change in the original values as the target moves in the sky.

In order to proceed further, it is necessary to plot the present position of the target on a 'map'. In the director, the 'disc mechanism' serves as the map on which the present position of the target is automatically plotted.

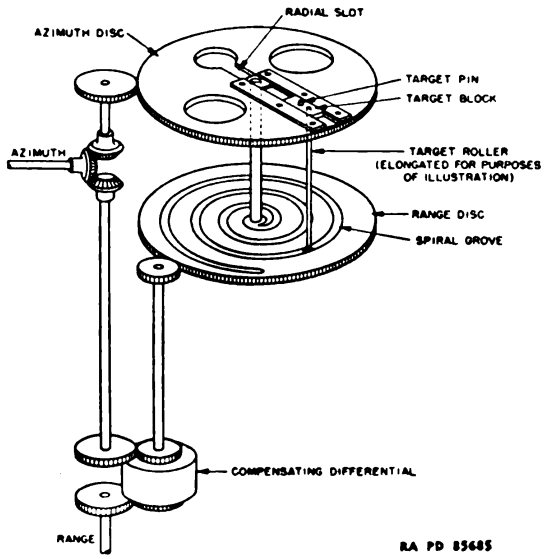

Figure 40. Schematic Diagram of a Disc and Slide.

This device consists of two discs about 12 inches in diameter mounted on the same shaft. Each has gear teeth cut in its circumference. One of them is rotated by azimuth, and the other by range. The former rotates once every 6,400 mils, and the latter once every 6,000 yards of change in horizontal range.

The azimuth disc has a radial slot cut in it, the direction of which represents the present azimuth of the target. The target block is free to ride radially in this slot. The small pin, called the target pin, which is fitted into the block represents the exact position of the target. Thus as the disc is rotated the target pin will be carried around in azimuth by the slot. On the opposite side of the block from the target pin we find the target roller. This roller engages the continuous equi-angular groove cut in the range disc. As the range disc is rotated, therefore, the target pin is forced in or out along the slot on the azimuth disc. Thus by rotation of the azimuth and range discs, the target pin may be made to assume a representation of the actual position of the target in the horizontal plane.

From this description, it will be seen that the center of the discs represents the position of the director on the ground, and that the greatest displacement of the target pin from center is, to scale, the maximum range at which the

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director can follow a target. The discs themselves are geared directly from the range and azimuth handwheels respectively.

A careful examination of these discs will show, however, that if the azimuth disc is turned alone, then a simultaneous range change will be set in because the target pin is constrained to follow the groove in the range disc. It is for this reason that azimuth is made actually to turn both discs, while range is used to turn only one of them. In order for this to be done mechanically, azimuth to the range disc is fed through the 'compensating' differential where its change is added algebraically to the range change. The net result is that both discs turn for an azimuth change. But that only the range disc will turn for range changes.

Not only does the position of the target pin represent to scale the position of the target with respect to the director; but as tracking goes on, the target pin is continuously repositioned. Its movement then represents the course which the target is flying in the horizontal plane in direction and speed.

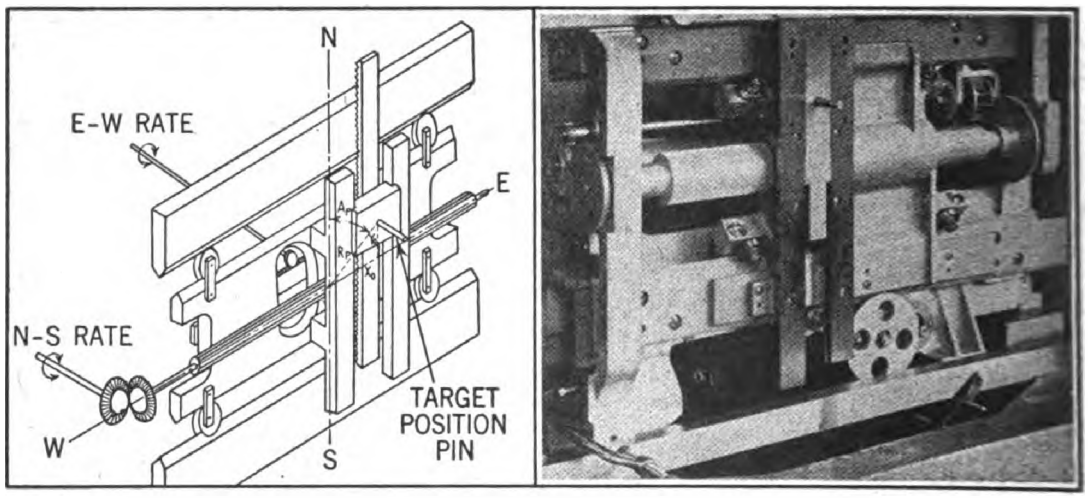

Figure 41. The Slide Mechanism.

The target pin is set into a small hole in a metal bar with a gear rack cut in it. This bar is permitted to move only up and down by a pair of rails, which themselves may move sidewise only.

Thus movement of the target pin due to tracking will drag the rails sidewise and the bar up or down. This bar and these rails will then follow the movement of the target pin and hence, to scale, the target. The lateral movement of the rails will be proportional to the amount the target has moved in the east or west direction, while the up and down movement of the bar will be proportional to the north or south motion of the target. Thus the disc and slide (bar and rails) mechanism has plotted to scale the course of flight of the target in the horizontal plane, and has broken it down into two components, one of these being in the north-south and the other in the east-west direction.

More than this has been accomplished, however. The positions which the bar and rails take up at any instant are the exact distances to scale that the target is away from the director in the north-south and east-west directions. In addition, and of even greater importance, is the fact that the speed with which the bar and rails change their position is proportional to the speed of the plane in these same two directions. The speed with which altitude is changing is represented by the change in altitude received by the director from the height finding device.

Thus, to this point in the director, we have received the present position of the target as an azimuth angle, an angular elevation, and a linear altitude. By combining the two latter values, we have determined the present horizontal range, which, with the present azimuth, has been used to find the distance the plane is away from us, in yards, in the cardinal compass directions. Further-

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more, we have motions in the director to represent the speed of the plane in these three directions, namely north-south, east-west, and up or down.

In order to convert these present values into future values, prediction must be calculated and then added to the present values. Essentially, we must compute how far the plane will fly in the north-south, east-west, and up-down directions in the time it takes the shell to reach the line of flight of the target. Let us consider only the north-south direction, for its prediction computation is characteristic of all three.

A pinion engages the bar which is moved by the north-south component of the flight of the target. Thus as this bar is moved, the pinion turns at a speed proportional to the observed speed of the target in this direction. This speed serves as the rate input to the 'equating differential.'

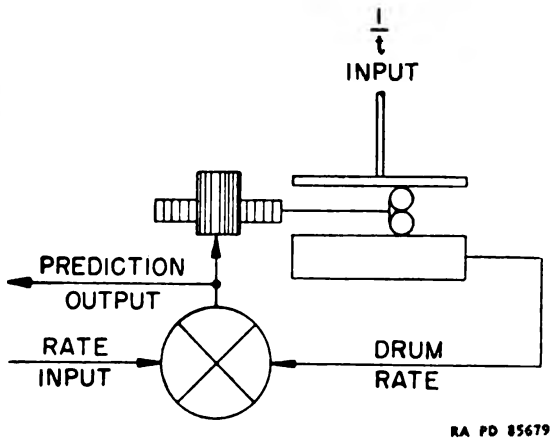

Figure 42. Prediction Multiplier Schematic.

Initially it will pass through this differential and displace the balls of the variable speed drive (prediction multiplier). The disc of this multiplier is driven at a rate proportional to the reciprocal of the time-of-flight obtained from the mechanical firing table to be described later. As soon as the balls of the variable speed drive are displaced from the center, the cylinder begins to turn. This turning is fed back into the equating differential in such a direction that its effect is to be opposite to rate input; and thus, the output of the differential is the difference between this cylinder rate and the input rate from the disc and slide mechanism. This difference continues to displace the ball carriage of the multiplier. It will be noted that displacement will continue until the cylinder rate is just equal to, and hence just cancels out the input rate in the equating differential. When this condition arises, the ball carriage will cease to be further displaced. It will actually retain its position until either the input changes (target north-south speed changes), or until the time-of-flight changes (target at different range). A property of this mechanism is that the distance the ball carriage is displaced is proportional directly to the product of the time-of-flight of the shell times the north-south speed of the target. This displacement, then, in turn, is proportional to the distance the target will move in that direction during the time-of-flight of the shell, that is, it is the calculated prediction in the north-south direction.

The output from the equating differential goes not only to the ball carriage of the prediction multiplier, but also to operate the 'contact control,' a device which will initiate the reconversion of the rectangular prediction to polar coordinates. This device is essentially a single pole, double-throw electric switch. It makes contact in one direction for a northward prediction, and in the other direction for a southward prediction. When the contact control is closed by the output from the equating differential, one of two 'difference' motors will run. Selection of the motor which will run for a north or south prediction is controlled by the 'quadrant switch,' which will be described below. The output of one of these motors is sent into the azimuth 'difference' differential where it is added

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to present azimuth to produce future azimuth. The other motor output goes to the range 'difference' differential where it and present range lead to future range.

These future values of azimuth and range position the 'future disc and slide mechanism.' This unit is identical with the present disc and slide mechanism already described. From this mechanism we obtain future east-west and north-south components. Again confining our discussion to the north-south direction we shall continue.

The north-south future component is fed into the north-south 'component difference differential,' where it is subtracted from the present north-south component. This difference is the actual north-south prediction already set into the director by the running of either the range or azimuth difference motors. This prediction is then run back to the contact control. When the actual prediction set into the director is equal to that calculated in the prediction multiplier, then the contact control will open. At this point, whichever difference motor is running will stop.

By way of summary, we see that on the basis of time-of-flight and observed rate a prediction is calculated. This prediction then starts the range or azimuth difference motor running. The future component thus generated is compared with the present; and when the difference between them is equal to the calculated prediction, the motors stop running. The future target pin is then set to scale in the position the target will reach when the shell gets to it.

As far as altitude is concerned, the observed rate is fed into the altitude prediction multiplier as in the case of the north-south component. Once again the calculated prediction operates a contact control which causes the altitude motor to run. When the motor output equals the calculated prediction, the contact control turns it off.

However, there is a complicating factor in the north-south and east-west mechanisms. Let us presume that we have a target flying radially away from the director in an northerly direction. In this case, the only prediction will be in the north direction, and is in fact a range change. Thus the north-south contact control will have to make the range difference motor run. However, if the same target were flying in an easterly direction, again prediction would be a range change, but in this case the east-west contact control must function the range motor. The reader will see now that the signals from the east-west and north-south contact controls must be routed to either the range or azimuth difference motors depending upon the azimuth of the target.

The 'quadrant switch' is the device which directs a given signal from a contact control to the proper motor. Essentially it operates like a telephone switchboard which receives calls from two sources and must route them to two other destinations. The 'sources' in the director are the north-south and east-west contact controls, while the 'destinations' are the azimuth and range difference motors. The 'operator' at the quadrant switch is future azimuth.

To this point in the director, we have received present azimuth, altitude and angular height. The quantities have been used to calculate the rates of change of altitude and north-south and east-west components. Each of these rates has been multiplied by time-of-flight of the projectile to obtain prediction in three mutually perpendicular directions. With the aid of three difference motors, these predictions have been added to altitude, azimuth and range. By this means, the future values have been obtained.

Not previously mentioned, but of importance, are corrections needed because of wind effects on the projectile and the difference in position on the ground between the guns and the director (i.e. parallax). Factors to take care of these corrections are added in at the prediction multipliers and contact controls respectively. Thus, the center of the future discs is caused to be the position of the battery directing point and not that of the director. Also the position of the future target pin will become not the actual position that the target will have taken up when the shell reaches it, but the position at which we must fire in order that the wind will blow the shell into the target's actual position.

The future azimuth which we have obtained need only be corrected for right lateral drift of the projectile in the air before we send this value to the guns.

An approximate average angular drift is used in this director and is put in

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as an angular correction to future azimuth before it reaches the azimuth transmitter. This corrected azimuth is now called the 'angle of train' and is transmitted to the guns by a self-synchronous motor. Angle-of-train rotates the armature of this transmitter.

The values of future range and altitude could now be read off dials and plotted on the trajectory chart in a firing table. From this chart, a suitable quadrant elevation and fuze setting could be determined. These firing values might then be transmitted to the guns. This procedure is slow and inaccurate, however; so it is necessary to develop a mechanical 'firing table' which will automatically determine fuze and quadrant elevation on the basis of calculated future range and altitude.

It is possible for us to make a graph of quadrant elevation versus altitude at constant range. This graph may be cut out of metal and fixed to a shaft with the altitude axis along the length of the shaft and the quadrant elevation axis extending radially from the center of the shaft. Then just as was done in the case of the present angular height cam, we may mount many of these metal graphs, each for a different range, around the central shaft. Ultimately, we will obtain a solid three-dimensional cam. If we put a follower on the surface of this cam, then we could obtain the quadrant elevation for any given point by rotating the cam to the proper range and translating the cam for the correct altitude. Thus the follower would be displaced an amount from the center of the cam equivalent to the necessary quadrant elevation.

By a similar procedure, cams may be made for fuze and the reciprocal of the time-of-flight. In the director the three cams are mounted rigidly together, the entire unit being called the 'ballistic cam.'

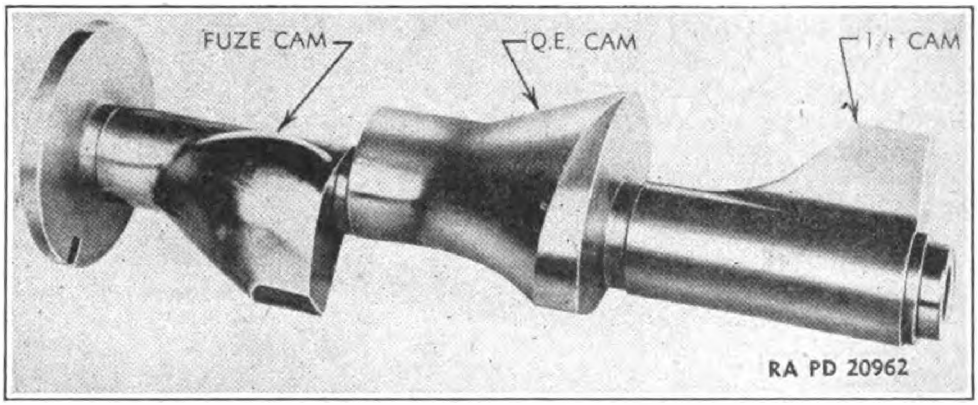

Figure 43. Ballistic Cam.

Each lobe (*i.e.*, the Q.E., F., and 1/t cams) has its own follower. The 1/t follower translates the ball carriage of a variable speed drive whose disc is run by a canstant speed motor. The cylinder speed will then be directly proportional to the displacement of the ball carriage which, in turn, is proportional to 1/t produced by ballistic cam. This cylinder speed is used to turn the disc of the prediction multipliers.

The followers for the quadrant elevation and fuze lobes each have a gear rack cut in them. As they move in and out over the cam surface they cause a pinion engaged with each rack to turn. These pinions are on shafts which turn the armatures of transmitting self-synchronous motors. These transmitters send the data directly to the guns.

By way of recapitulation, we see that the director has located the present position of the target, that it has calculated the future position of the target, that it has converted this future position into firing data to enable the shell to burst at this point, but that we have no facilities as yet for making arbitrary corrections to the firing data.

It will be asked why facilities for arbitrary corrections to the firing data are incorporated in the director. Many reasons come to mind, of which the most important are: minor maladjustments in the director, unknown wind effects,

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gun wear and other causes for muzzle velocity changes, and non-standard ammunition. In short, any deviation from perfection in the director, guns, or projectiles will cause us to miss the target. Errors in the trajectory of the shell cause misses because the data obtained from the ballistic cam is for a round fired from a perfect gun.

It is necessary, therefore, that we be able arbitrarily to observe the burst of the shell and correct it if it is not at the target. For this purpose, a small spotting telescope (elbow telescope M1A1) is mounted on the same shaft as the tracking telescopes. The operator who views the target through this scope is concerned only with making 'spot' corrections to the observed fire. For this purpose he has easy access to four handwheels. These control small corrections to fuze (fuze spot), quadrant elevation (vertical spot), angle-of-train (lateral spot), and the present altitude (altitude spot). These small corrections are added to the values being calculated in the director by passing each of them into a differential, to which is run the corresponding calculated value in the director. The resulting corrected data is then sent to the transmitters or to the present angular height cam in the case of the altitude spot. A vertical spot will raise or lower the burst in a vertical plane perpendicular to the line of sight. A lateral spot moves the point of burst in a horizontal plane perpendicular to the line of sight. In order to move the burst along the trajectory a fuze spot is used, whereas a correction along the line of sight is obtained by using an altitude spot.

During actual fire, the lateral and altitude spots are the only ones used. If flank observers are available, it would then be possible to use the other two spots. However, when the observer can only view the target and burst through the spotting telescope, he is unable to tell when he sees the burst appear below the target, for instance, whether quadrant elevation is too small or fuze too short. In this case he would make an altitude spot and hope for the best.

All four spots are used when a battery is being set up. Because of minor variations from standard in the director, guns, ammunition and other equipment, it becomes necessary arbitrarily to adjust by spot corrections the data produced by the director. In order to do this, a point is selected in the sky which is assumed to be the median range and altitude of targets to be fired on. The director is set with azimuth, range and elevation for this point. Since the point is fixed there are no rates set in the director so that no prediction is calculated. For this reason, future values of azimuth, range and altitude are the same as the present values. The firing data, therefore, which is transmitted from the director, is such that the guns will be trained on this point in the sky. A few rounds are fired (trial shots); and the variations in the bursts from the determined point in the sky are observed through the height finder, battery commander telescope, or by other means; and the necessary corrections which must be applied to the firing data to make the shells burst at this point are calculated. These corrections are then applied by necessary spot adjustments.

This method of adjustment of the battery fire makes the director produce correct firing data for this one point only; and as the target moves farther away from this point, firing data is slightly less accurate. However, since there are no facilities for correcting the firing data for variations in shell weight, non-standard muzzle velocities, humidity, etc., this arbitrary method makes the director produce data which is more nearly correct than would be the case if such corrections were not applied.

When the director is put into operation, the spotter will set the director on the desired target. He views the target over the collimating sight and, using an azimuth slewing handwheel and the present angular height handwheel, he brings the director to bear on the target. As soon as he is near the target he will turn control of the director over to the azimuth and elevation trackers. These two operators observe the target through their respective scopes. Present azimuth and angular height are transmitted from the director to the height finder or radar installation where the operators there can bring their instrument to bear on the same target.

As soon as the altitude value has been correctly determined, the altitude tracker will set the altitude in with his handwheel. The range tracker may now adjust range so that the two angular height dial indexes will be alined. A few seconds

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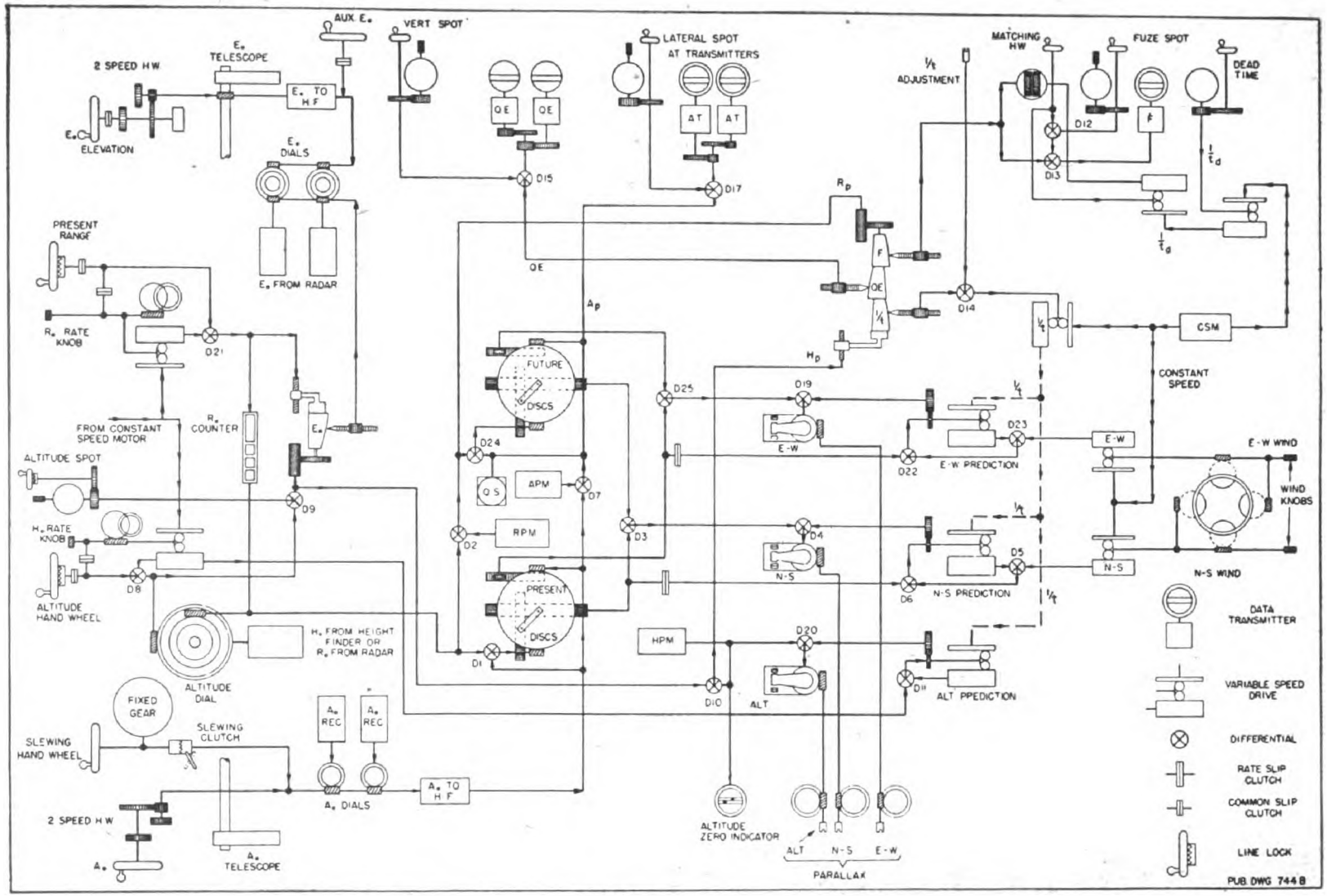

Figure 44. Schematic Flow of Data for Director M7.

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later, the director will be transmitting accurate firing data to the guns. On the basis of the resulting observed fire the spotter will make necessary spot corrections to this data.

Sometimes, the actual tracking of the target will be done by a tracking instrument away from the director proper. In this case, present azimuth and angular height will be transmitted to the director in the same way as present altitude is transmitted from the height finder. Dials are provided with double indexes (one for received value and one for value already in the director) and the azimuth and range trackers must line these indexes up by turning their respective handwheels. In all other respects, operation of the director with an external tracker will be the same as if the director were used as both tracker and computor.

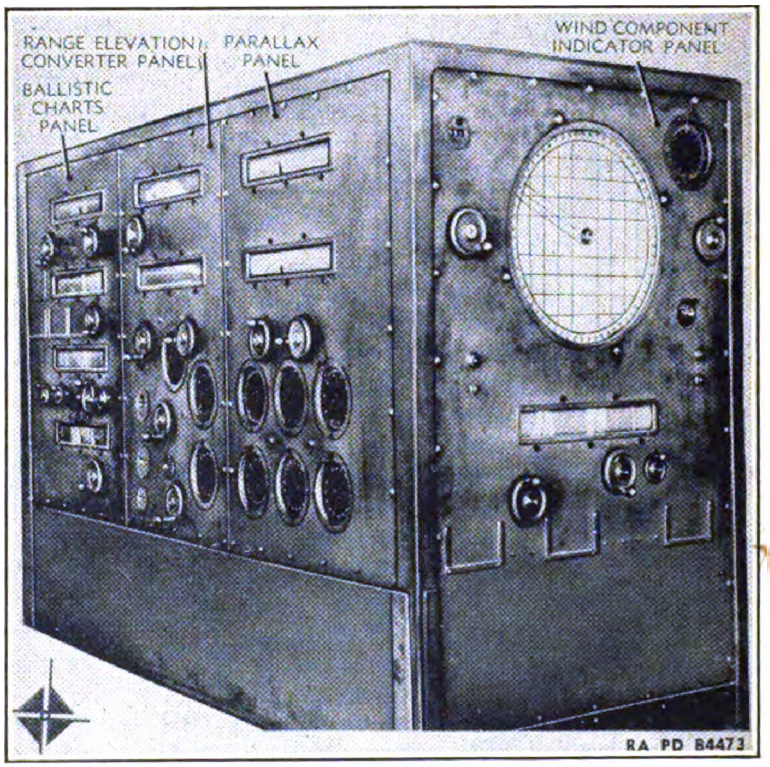

Figure 45. Gun Data Computor M1.

Director M7. The discussion of mechanical directors so far presented applies without exception to the M4. It was found, however, that this director did not meet adequately enough the requirements of an antiaircraft firing data computor. Modifications were made which among other things increase the maximum altitude and rate of change of altitude. This new director, designated the M7, also had a device for correcting transmitted fuze data for 'dead-time.' Fuze setting is transmitted to the guns and is received there by a fuze setter which in turn is used to set the proper fuze on the shell. However, some time elapses between the setting of the fuze and firing of the shell. During this time predicted fuze setting may change, and even though the shell may pass very near to the target it can not burst there as it carries an erroneous fuze setting. The M7, therefore, has a prediction mechanism in it which will multiply the speed at which fuze numbers are changing at any instant by the average time (dead-time) for the battery to cut the fuze, load and fire the shell. This product is an estimation of how much fuze setting will change during the dead-time period. The correction is applied directly to the value of fuze determined from the ballistic cam before it is used to position the fuze transmitting self-synchronous motor armature.

Director M7A1B1 and M7A1B2. Under combat conditions, it is found that the four trackers can not operate their mechanisms smoothly. For example, they

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tend to over-run the proper setting, attempt to correct this error and fall under the true setting, recorrect, and so on. Thus not only are the values being set into the director probably wrong at any instant, but the rates will also be badly in error. The future position calculated, therefore, at any instant will be in error both because of improper present values and, to a greater extent, because of improper prediction from erroneous rates. However, on the average, the rates set in over a few seconds are nearly correct.

The M7 director has therefore been modified to make it possible to use average rates for the north-south and east-west prediction multipliers instead of the instantaneous rates. There are two mechanisms available for this modification, one mechanical and one electrical. The modified directors are further designated as the M7A1B1 and the M7A1B2, according to whether the mechanical or the electrical modifying components have been used.

List of Terms and Symbols for Heavy Mechanical Directors

Symbol	*Term*	*Definition*
T_o	To	The observed position of the target.
H_o	Present Altitude	The vertical distance to a target in space from a horizontal plane through the director.
E_o	Present Elevation or Angular Height	The vertical angle between the line of sight and the horizontal plane through the director.
R_o	Present Horizontal Range	The horizontal distance from the director to a vertical line dropped from the present position of the target.
A_o	Present Azimuth	The horizontal angle measured in a clockwise direction from a north point which is zero to the present vertical plane of position of the target.
T_p	T_p	The future position of the target.
H_p	Future Altitude	The vertical distance to the future position of the target' measured from a horizontal plane through the guns.
T_p	Future Horizontal	The horizontal distance from the position of the guns to a vertical line dropped from the future position of the target.
A_p	Future Azimuth	The horizontal angle measured in a clockwise direction from the north point to the future vertical plane of position of the target.
A.T.	Angle-of-Train	The azimuth at which the gun is aimed in order to hit the target at a future position.
Q.E.	Quadrant Elevation	The vertical angle between the horizontal and the axis of the bore of the gun when the gun is fired.
F	Fuze Range	The fuze setting necessary to produce a burst at a given point along the trajectory of the shell.
S. R.	Slant Range	The distance measured along the line of position to the target.
t	Time-of-Flight	The length of time necessary for the projectile to reach the future position of the target.
t_d	Dead-Time	The time elapsing between the setting of the fuze and the firing of the shell.
$\frac{1}{M}$	Mil	That angle which subtends a chord which is 1/1000 of the range. (Actually 1/6,400 of a circle).

GUN DATA COMPUTOR M1

The firing problem which the seacoast gunner must solve is similar to that of the antiaircraft gunner. Thus, we have a moving target which is quite small compared with the range from which we must hit it. However, this waterborne target moves more slowly than an aerial target does; and, moreover, its movement is confined to a single plane, the surface of the sea. The altitude computation, therefore, which must be made is that one introduced because of the curvature

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of the earth and the effect of tides. There is also another simplifying factor. A fuze setting need not be calculated for antiship fire for all the projectiles used have an impact detonating fuze on them. However, since we shall fire to greater ranges against ships than against aircraft, the ballistic corrections needed are more extensive and must be more accurately set in.

In order to solve this gunnery problem the gun data computor M1 has been developed.

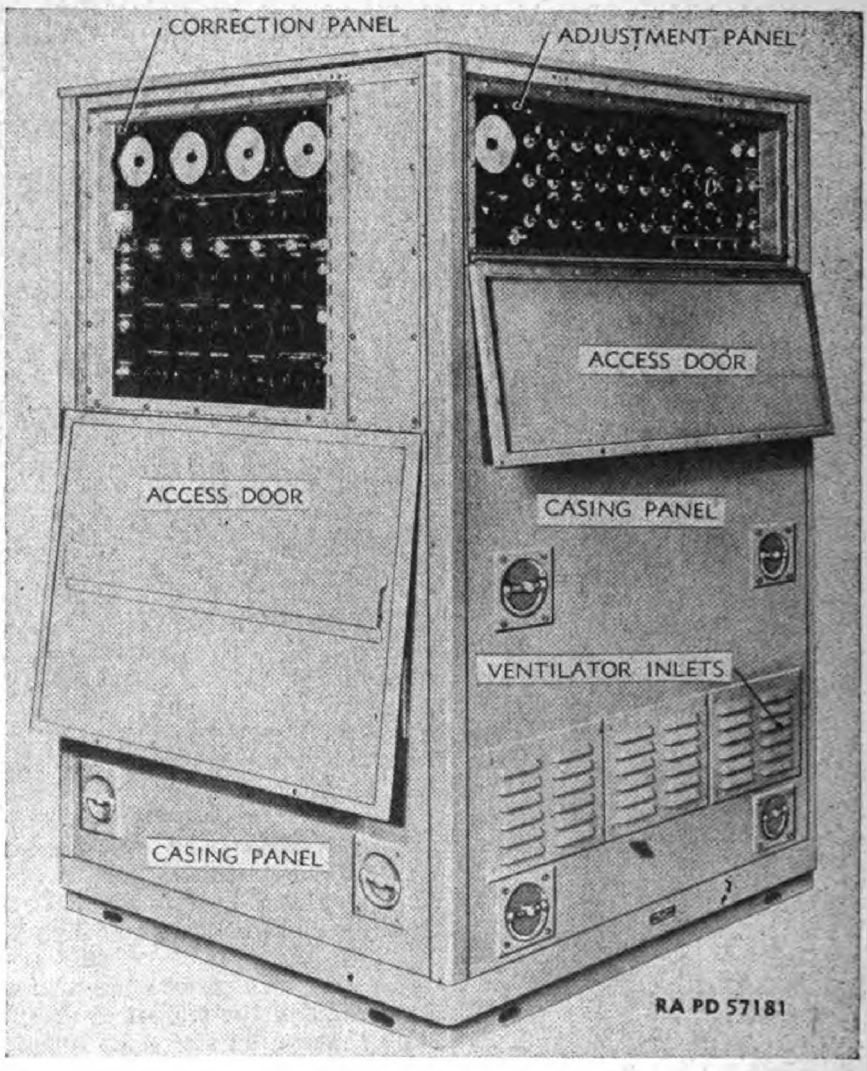

Figure 46. Computor M3, M3A1, or M4—Front and Left Side.

At this time suitable ballistic data has been made up so that 12" and 16" guns can be controlled by this computor. Ballistic information is supplied to the director on charts rolled on drums. These drums are turned in the computor. A pointer is caused to follow the curves on the drums by a handwheel. By this means time-of-flight, effect of earth rotation, wind and all the other ballistic corrections are set into the computor. These drums may be replaced without excessive difficulty in order to convert the computor to one capable of solving the gunnery problem for a gun of different caliber or for a different ammunition.

Computors are used for producing firing data for two guns simultaneously. The data is computed for one gun initially, but there is a unit incorporated in the mechanism which then modifies this data for the other gun by correcting it for the parallax between the guns.

Data suitable for finding the present position of the target is supplied by

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two external observation points at known range and azimuth from the computor. This information is used to compute the present azimuth and range of the target. By observing how fast these values change, the speed of the target may also be determined. These values are then used as a basis for prediction and hence the calculation of future position of the target. This computed data serves to determine firing data which is transmitted electrically to the guns.

ELECTRICAL DIRECTORS

The electrical AA director was designed to fulfill a need for more accurate firing data to be used by an antiaircraft gun battery employed as a defense against high altitude bombers. As the vertical range of bombers increased, the inherent errors of mechanical directors became more evident. This is apparent from the fact that the yardage error increases directly with the range.

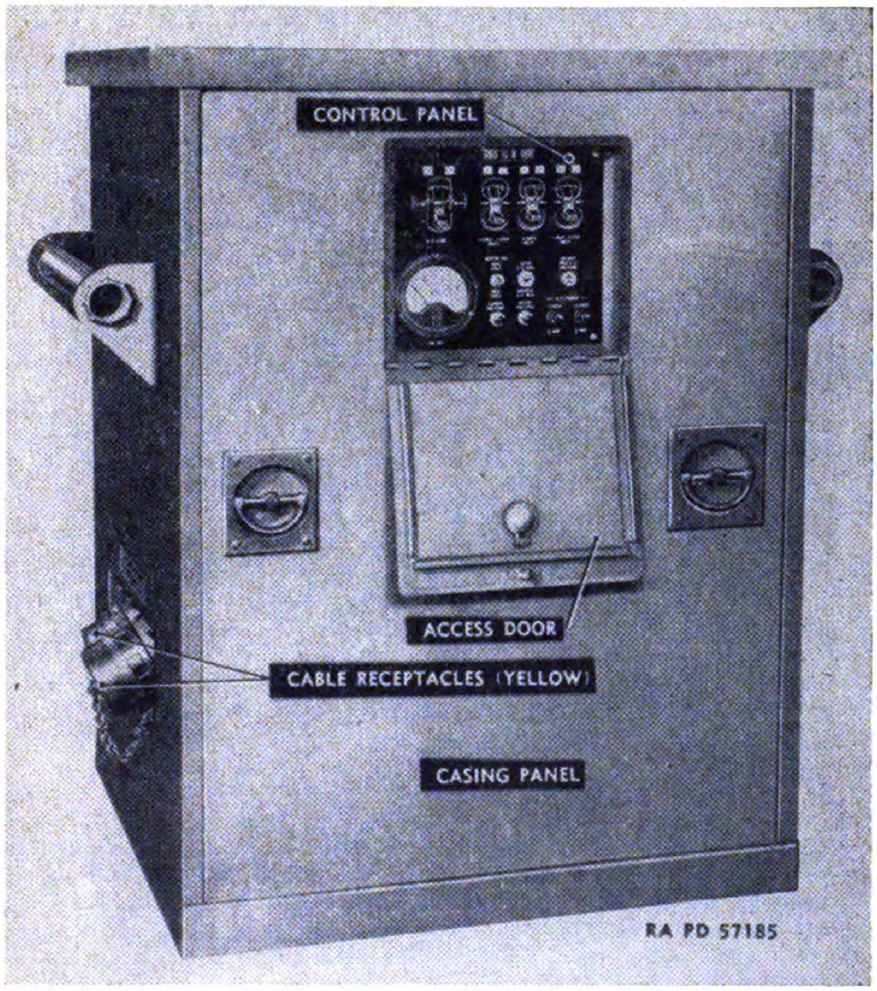

Figure 47. Power Unit M8.

The problem confronting the electrical director is the same as that solved by the mechanical director. From the present position of the target and the rate of change of that position, the director must compute the location of a future position of the target and must also compute corrected firing data so as to cause the shell to burst at the plane. To solve this problem the electrical director also employs the linear speed method for reasons previously discussed in the introduction to AA fire control. The electrical director is also classified as semiballistic but employs more built in ballistic corrections than any other AA director.

At present there are the following electrical AA directors: M9, M9A1, M9A2,

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M10, and M10A1. In all these directors, the principles of operation are identical. The M9 and its modifications are designed to be used with any of the 90mm guns, while the M10 and the M10A1 are to be used with the 120mm AA gun. The differences between the M9 and the M10 are a result of the differences in the trajectories of the 90mm shell and of the 120mm shell. Because of the fact that only the ballistic correction circuits within the directors are affected by these differences, the following discussion of electrical directors is, in general, applicable to any one of the above types. The M9 director is composed of four units and an associated cable system. These units are: Computer M3; Power Unit M8; Tracker M2 on tripod M12; Altitude Converter M2; and the Cable System M7.

The M10 director uses the same units except that the computer M4 is substituted for the computer M3.

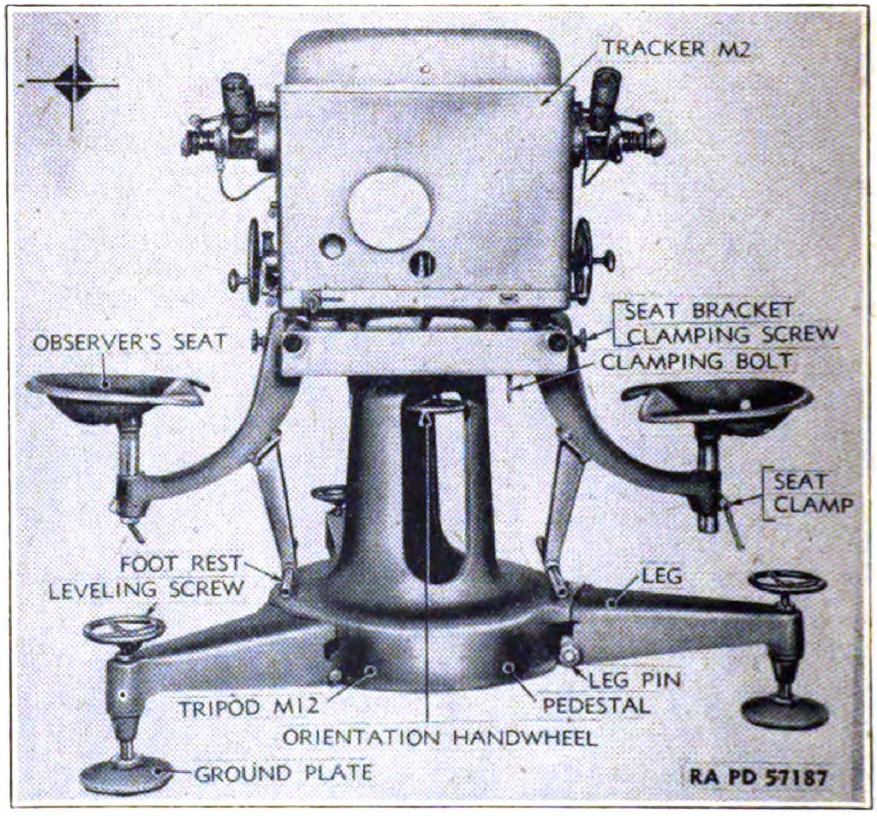

Figure 48. Tracker M2 on Tripod M12.

Power is supplied to the director through the power unit from generating Unit M7, M15, or M18, or from any source of 100-130 volts, 60-cycle, 3-phase power. The director, then, working in conjunction with height finder M1 or M2 or with any of the various AA radar units, supplies the gun battery with an angle of train (azimuth), an angle of elevation, and a value of fuze setting.

OPERATION

Before going into the principles of operation of the director, the reader must be aware of several important considerations. All distances involved in the solution of the problem are represented in the director by DC voltages, one volt representing 200 yards distance. Thus, if the slant range distance from the position of the director to the target is 10,000 yards, the DC voltage used in the director to represent this distance will be 50 volts.

Those 50 volts represent the present distance to the target; but in a short time that distance might have changed to 9,800 yards, and the voltage necessary to represent it will then be 49 volts. It therefore becomes necessary to be able to change voltage easily, quickly, and by small units. This is accomplished

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through the use of a potentiometer consisting of wire wrapped around a hard rubber card and a brush that moves along the one uninsulated edge of the card and makes contact with the wire at that point. This, then, is essentially a voltage divider, i.e., where one end of the wire is connected to ground (zero voltage) and a voltage is applied to the other end. If the applied voltage is 100 volts and if the brush is making contact at a point exactly half the length of the card from each end, the voltage at the brush is 50 volts. When the brush is moved toward ground one 1/100th of the length of the card, the voltage at the brush changes from 50 volts to 49 volts. The voltage at the brush, therefore, is directly proportional to the voltage applied to the end of the card and to the displacement of the brush along the card from the zero or ground point. The difference in voltage at the brush before and after movement of one unit along the card will always be equal, no matter at what portion of the card that unit is located, as long as the applied voltage is constant. If 100 volts is applied to a 10 inch card and if the brush is moved from ground one inch toward the other end, the change in voltage will be from 0 to 10 volts—a difference of 10 volts. If, for the same card, the brush is moved from the mid-point of the card 1 inch away from ground, the change in voltage will be from 50 volts to 60 volts—also a difference of 10 volts. This type potentiometer card is known as a linear card as it represents a linear mathematical equation.

The mathematics involved in the solution of the antiaircraft problem, however, do not consist entirely of linear equations. We are also interested in trigonometric relations and in an electrical method of working with these relations. If, rather than making the hard rubber card of equal width throughout its length, the width of the card is varied according to a mathematical function, then the voltage at the brush will vary in accordance with that mathematical function as the brush is moved along the card. This can easily be proved by a consideration of the fact that the voltage at the brush is equal to the product of the current through the wire on the card and the resistance of the wire from the brush position to ground. The current through the wire is the same in all parts of the card, and the resistance is directly proportional to the length of the wire. Since the wire is wrapped around the card, the length of wire between two points on the brush-contact edge (and, therefore, the resistance) will depend on the width of the card. Thus the voltage at the brush on any potentiometer card will be proportional: (1) to the voltage applied to the card; (2) to the displacement of the brush from the zero point; and (3) to the shape of the card on which the wire is wound.

If a current, however, is flowing out through the brush, the current is not the same in all parts of the card. The current between the brush and the point of application of voltage to the card will be equal to the current flowing through the remainder of the card plus the current flowing through the brush. This fact disrupts the voltage at the brush causing it to be less than desirable for accurate distance representation. If the current through the brush can be made to vary only with the voltage at the brush and not because of any changes in the circuits following, the shape of this card can be altered so as to compensate for the additional current through part of the card. Having shaped the card, it now becomes necessary to isolate a potentiometer from the circuits that follow. This is accomplished by using a DC amplifier. There are 29 such units in a director, all located in the computer, serving several purposes in addition to isolation of circuits. The DC amplifier has the ability to reverse the polarity of voltage without changing the magnitude. Thus, if one voltage of plus 10 volts is applied to an amplifier, the output voltage will be minus 10 volts, i.e., 10 volts below ground (zero). At the same time, the amplifier can add voltages algebraically. If three voltages of the following values are applied, —10 volts, +8 volts, and —2 volts, the output will be equal to the algebraic sum with the sign reversed,—in this case +4 volts.

With a clear knowledge of the representation of distances by voltages, of the use of potentiometers, and of the uses of a DC amplifier, the reader may now proceed to a study of the principles of operation of the director proper.

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ALTITUDE CONVERTER

Assuming that the optical height finder is being used with the director and that the height finder is obtaining values of the present slant range distance to the target, such values of slant range will be received at the altitude converter by a selsyn receiver. A dial bearing a pointer is attached to the rotor of this selsyn and the slant range can be read off a fixed scale mounted concentrically with the selsyn. But there is also a mechanical dial bearing a pointer, the movement of which is controlled by a handwheel. The zero point of this mechanical pointer is the same as that of the selsyn pointer. A brush moving along a linear potentiometer is geared to, and synchronized with, the mechanical dial. The potentiometer is fed by a voltage representing the maximum slant range distance (28,000 yards) that is to be used. Therefore, as the mechanical pointer is moved by the handwheel so as to match the selsyn pointer, the brush moves along the potentiometer and the voltage at the brush is proportional to the present slant range to the enemy bomber. Thus slant range as a selsyn movement has been received and has been converted to a DC voltage suitable for use in the computing circuits of the director.

TRACKER

Let us now leave the altitude converter for the time being and consider the operation of the tracker. Two observers on the tracker are each keeping telescopes on the target, the first observer moving the telescopes in elevation, the second in azimuth. Thus, the remaining information necessary to define completely the present position of the plane—an angle of elevation and an angle of azimuth respectively—are being obtained. It now becomes necessary to change these spherical coordinates to rectangular coordinates — three mutually perpendicular linear measurements.

Consider, for the present, a static position of the target in space. This distance from the director on the ground to that static position is the slant range, D_o. The angle which is formed by the intersection of the slant range, D_o, and the horizontal is the present angle of elevation, E_o. To complete the triangle two sides are necessary: (1) the vertical distance from the target to the horizontal plane through the battery position, this being the present altitude, H_o; and (2) the distance along the horizontal plane from the director position to a point directly below the bomber, this distance being the present horizontal range, R_o. R_o and H_o intersect at the point directly below the plane, and, since R_o is horizontal and H_o is vertical, the two are perpendicular. These various components make up a right triangle, the sides of which are slant range, horizontal range, and altitude (D_o, R_o, and H_o). The angle between D_o and R_o has already been shown to be the angle of elevation, E_o, that is, the angle in the vertical plane through which the telescopes must be turned so as to sight on the target.

A study of trigonometry proves that, as long as the angle E_o is constant, R is going to be a definite, fixed fraction of the side D_o. This is true for all values of the angle E_o; for each value of that angle, R_o bears a very definite relation to D_o. This relation is known as the cosine of the angle E_o and is defined as the ratio of R_o to D_o. Values of the cosine can be found in tables of trigonometric functions.

Likewise, H_o bears a fixed relation to D_o for any one value of E_o—this relation being known as the sine of the angle E_o whose values can also be found in tables of trigonometric functions.

The following equations have now established:

$$\text{cosine } E_o = \frac{R_o}{D_o}; \text{ and}$$

$$\text{sine } E_o = \frac{H_o}{D_o}.$$

If, in each equation, both sides are multiplied by D_o the results are:

$$D_o \text{ cosine } E_o = D_o \frac{R_o}{D_o} = R_o; \text{ and}$$

$$D_o \text{ sine } E_o = D_o \frac{H_o}{D_o} = H_o.$$

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It can now be seen that by multiplying D_o (slant range) by the cosine of E_o and by the sine of E_o, the results will be R_o (horizontal range) and H_o (altitude) respectively.

Thinking back, the reader will remember that, in the director, a voltage proportional to D_o has been obtained and that the telescopes have been moved through an angle equal to E_o. It has also been shown that, by proper shaping of a potentiometer card, the voltage taken off that card by a brush can be made to vary in accordance with a mathematical function. Therefore, by shaping a card to follow a cosine function and applying the voltage D_o to the card, the voltage at the brush will be representative of R_o, if the brush is moved in accordance with the elevation angle. Similarly, the value of H_o may be obtained as a voltage by using a sine card. Each card is a multiplier; and since they give the product of D_o (the applied voltage) and the cosine or sine functions of E_o (the functions are in the shape of the cards), the value of the angle is determined by the position of the brush.

Thus one angle has been eliminated as desired, but there yet remains the present azimuth angle, A_o. This angle is measured in the horizontal plane clockwise from north. By using the sine and cosine functions of this angle and the horizontal range, R_o, the N-S and E-W components of R_o can be determined. These components will be such that, by moving a certain distance east or west and then a certain distance north or south, the final point will be the same as if the motion has been for a distance R_o along an azimuth A_o. The equations to be solved are:

E-W component, $X_o = R_o$ sine A_o; and
N-S component, $Y_o = R_o$ cosine A_o.

The solutions are accomplished by moving brushes over sine and cosine potentiometer cards that are fed by the voltage R_o. These brushes are geared to the azimuth tracking drive.

The present position of the target has now been defined with rectangular components. But this discussion has assumed a static position of the target. However as the plane moves, these processes take place continuously and simultaneously so that X_o, Y_o, and H_o are constantly being determined in the director.

Another outstanding assumption of this discussion is that the selsyn in the altitude converter has been displaced by an amount proportional to D_o. Using that assumption, a voltage proportional to D_o was found, and from that voltage and E_o a voltage proportional to H_o was determined. If, however, the selsyn in the altitude converter is displaced an amount proportional to H_o (the usual case when the optical height finder is used), a different procedure must be followed. In this case, a second mechanical dial is moved so as to match the pointer of the selsyn. To this mechanical dial is geared a brush moving on another linear potentiometer. The voltage applied to this card is proportional to the maximum altitude to be used (10,000 yards). As the second mechanical dial is moved to match the selsyn pointer, the voltage at the brush is proportional to the measured present altitude. But D_o is necessary for use in the tracker in computing R_o. The reader should remember that $H_o = D_o$ sine E_o and that E_o has been determined. When a computed H_o can be produced so that it equals the measured H_o, the value of D_o employed in that computation must be correct. The range operator on the altitude converter turns the handwheel until the two H_o's are equal, as evidenced by a nullmeter used to compare the measured H_o with the computed H_o. At this time, the D_o voltage used for computations is correct. Therefore it is necessary to know whether the height finder is sending altitude or slant range, but either can be used as a basis of computations.

COMPUTER

Using the tracker and the altitude converter, three voltages representing the three rectangular coordinates of the present position of the plane have been obtained and are electrically transmitted to the computer. As the plane flies, these voltages will be changing in accordance with the movement of the present position of the target. To make an accurate prediction, rates at which these voltages are changing are necessary. This is accomplished by differentiating networks. These rates are then multiplied by the time-of-flight of the shell to

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obtain the prediction for each coordinate. Actually, the rates (X, Y, and H) are multiplied by the maximum time-of-flight and are applied to potentiometers. The brushes of the potentiometers are positioned so that their displacement from zero bears the same relation to the entire length of the card as the time-of-flight bears to the maximum time-of-flight. The voltage from each brush will then be equal to the prediction for one coordinate (ΔX, ΔY, or ΔH). The networks, in addition to the differentiation, also smooth the data and supply rates that are average rates for the past 10 seconds or for the past 20 seconds, at the discretion of the operating personnel. There is also an automatic operation in which the 10 second rate is used until an accurate rate can be obtained from the 20 second network, at which time the changeover is made automatically. These data smoothing networks provide extremely accurate rates and thereby increase the accuracy of the director.

Having obtained present position coordinates from the tracker and prediction values from the time-of-flight potentiometers (ΔX, ΔY, and ΔH), the two can be added to give the future position of the target on the basis of the time-of-flight used in calculating ΔX, ΔY, and ΔH. X_o and ΔX are fed into an amplifier whose output will be X_p, the E-W coordinate of the future position of the target. Likewise, Y_o and ΔY, and H_o and ΔH are added to give the future coordinates Y_p and H_p respectively. The future position of the target is now defined by the rectangular coordinates X_p, Y_p, and H_o. It now becomes necessary to determine the future azimuth angle and a future angle of elevation so that the gun can be positioned. Knowing X_p and Y_p, these two values can be used to determine the future azimuth angles A_p. This solution involves more trigonometry.

Consider the triangle in the horizontal plane whose sides are X_p, Y_p, and the future horizontal range, R_f. By making the future position fall northeast of the battery position, the picture is more easily seen, although the solution actually works in all quadrants. The azimuth angle A_p, is formed by the intersection of R_f (which is not known) and Y_p, and it is this angle whose value is desired. If a perpendicular to R_f is erected so that it passes through the intersection of X_p and Y_p, the original triangle is now cut into two smaller ones. The newly erected side, n, is common to the two small triangles and the angle formed by the intersection of X_p and the side n is equal to A_p. The equality of these two angles is proved by a theorem from plane geometry which states that angles are equal whose sides are either mutually perpendicular or parallel. In this case, X_p is perpendicular to Y_p and n is perpendicular to R_f; therefore, the two angles are equal.

The length of the side n can be expressed in two ways:

$$n = X_p \text{ cosine } A_p$$
$$n = Y_p \text{ sine } A_p$$

By using voltages representing these two expressions, the two voltages will be equal only when A_p is of the proper value. A 'negative' voltage representing X_p cosine A_p and a 'positive' voltage representing Y_p sine A_p are fed into a DC Amplifier; the output of this amplifier will be zero when A_p is of the correct value, X_p and Y_p having already been established. But, if the two voltages are not equal in magnitude and opposite in polarity, the output of the amplifier will not be zero. This output is fed into a unit known as a modulator-amplifier which controls an AC, 200-cycle, 2-phase motor known as the servo or spinner motor. As the motor turns, it moves the brushes on the sine and cosine cards (fed by $+ Y_p$ and $- X_p$) changing the values of $+ Y_p$ sine A_p and $- X_p$ cosine A_p that are fed into this amplifier. When the brushes have moved so as to make the two voltages equal in magnitude, the output of the amplifier becomes zero. At this time, the servo motor stops running since the modulator-amplifier will not pass AC voltage to the motor when there is no DC input to the modulator-amplifier. The brushes are then positioned at an angle A_p with respect to the zero position. Such a reentrant circuit is known as a servo loop. Geared to and synchronized with the brush shaft is a pair of selsyn transmitters which transmit the value of A_f to the remote control system on the gun.

Going back now to the two small triangles contained in the larger, the two remaining unknown sides (one in each small triangle) will, when added together, equal the length of R_f whose value is desired. This relation can be expressed:

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$R_f = Y_p$ cosine $A_p + X_p$ sine A_p By using two more brushes and other potentiometers, negative voltages representing $- Y_p$ cosine A_p and $- X_p$ sine A_p are obtained. These two voltages are fed into an amplifier whose output is $+ R_f$. It can be seen, however, that this value of R_f is only correct when the azimuth angle, A_p, has been solved satisfactorily.

R_f and H_p can now be used to solve for E_p in a manner similar to that just employed in determining A_p from X_p and Y_p. The voltages used are $- R_f$ cosine E_p and $+ H_p$ sine E_p. A servo loop, as employed in the case of A_p, is used for automatic operation.

The gun has now been positioned on the future position of the target, assuming a time-of-flight and disregarding corrections. It is possible by using the same method as used in the determination of R_f to find the future slant range with the use of the H_p, R_f, and E_p. But such a value is of no use. The length of the actual trajectory measured in seconds is of much greater interest. The length of this trajectory can be found by adding the following three values:

R_f cosine E_p;
H_p sine E_p; and
KR_f cosine E_p

The last term is one used to make the results fit the firing tables. All these voltages are fed into an amplifier as positive inputs. The negative inputs are controlled chiefly by time of flight (t) and are — b (t) — g (E) f(t). 'b,' 'g,' and 'f' are purely mathematical functions that fit the ballistics and are contained in the design of the circuits, principally in the shape of the potentiometer cards. When time-of-flight is correct, the output of the amplifier is zero; automatic operation is accomplished through the use of another servo loop. This time-of-flight is the one used in the determination of ΔX, ΔY, and ΔH, and elsewhere in the director.

The reader can now begin to realize how involved the director is and how interdependent the different circuits are. The original time of flight is an assumption; and, if it is wrong, prediction will be off as will be the output data. But this in turn, changes the time-of-flight and consequently prediction. The error becomes progressively less until all values are correct. Actually, the process requires very little time.

The firing data necessary for the guns still lacks a value of fuze setting. This value will depend almost wholly on the time-of-flight, t. The actual value of fuze numbers differs slightly from the time-of-flight in seconds. To allow for these discrepancies, a potentiometer card in the time-of-flight servo unit is shaped, and a brush making contact with it takes off a negative voltage which is fed into an amplifier. A linear potentiometer fed by a positive voltage is located in the fuze servo unit; a brush is moved over this potentiometer by a fourth servo motor. The voltage from this brush is also fed into the amplifier, and the output of the amplifier is used to control the movement of the fuze servo motor. This is the fourth and last servo loop, and the firing data sent to the guns is complete, excepting corrections.

Of all corrections, one or two immediately come to the attention of anyone considering gunnery. First of these is superelevation. This stems from the fact that gravity pulls the shell down as it travels through space, requiring that the gun actually be aimed at a point above the future position of the target. The angle of elevation E_p, therefore, must be increased. The magnitude of this correction is going to depend largely on the time-of-flight and slightly upon the future altitude of the target (the altitude to which the shell must travel). The correction is set into the director as a superaltitude, H_s, and is added to the future altitude of the target, H_p, to give H_f. This value, H_f, is used in the determination of the future angle of elevation, E_p. The actual correction is automatically introduced and cannot be controlled externally.

Another ballistic correction is that necessary to compensate for the drift of the shell to the right while in flight. This error, and therefore the correction, depends on time of flight and on the future horizontal range. After the first directors were designed, it was realized that drift correction must also include some dependency on altitude, H_p. Therefore, this quantity has been included in the drift correction circuit of the director M9A2. In all directors, however, the correction is introduced

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as an additional input to the A_f summing amplifier of the azimuth servo loop. This voltage causes an unbalance in the loop such that the A_f servo motor must move the brushes in a counterclockwise direction to restore the voltage balance and thus to decrease the value of the azimuth angle transmitted to the guns. The gun, therefore, is positioned a little to the left allowing for the shell drift to the right. Drift correction is not controllable externally.

All discussion thus far has assumed that the guns and the director were located at the same point, that is, the gun has been positioned in accordance with data figured from the director position. This is not true, and the separation of the two must be compensated for. The correction is easily made by first determining the removal of the guns from the director in terms of rectangular coordinates (X_G, Y_G, and H_G). These parallax distances are either subtracted from or added to X_o, Y_o, and H_o respectively. The resulting coordinates are then effectively measured from the battery directing point (center of gun area), and these coordinates are actually used in all calculations in the computor. Parallax distances as great as 500 yards in each coordinate can be set in to the director, but actually such distances can never be realized with our present cable systems. It must be remembered that, when setting in a parallax correction, the distances to be set in are the distances from the guns to the director.

Differences in location of the director and the gun have been considered, but a difference in absolute altitude of the director and of the auxiliary range-finding equipment has not. Such a difference will not matter if the director is being supplied with slant range, but it will matter if being supplied with altitude. The reader will remember that, when receiving altitude, slant range is moved so as to make the computed altitude equal to the measured altitude. Thus, by introducing another voltage either to add to or to subtract from the measured altitude, the computed altitude will be correct for the director position when the third voltage is proportional to the vertical distance between the director and the height finder. This correction is known as the altitude spot and is set in at the altitude converter for distances as great as ± 150 yards.

It can easily be seen that a wind will affect the flight of the shell. This effect can be resolved into two components, one affecting azimuth and the other affecting range. So the correction is made in two parts. The first is introduced as another input to the A_f summing amplifier; the second as another input to the R_f amplifier. The magnitudes of the corrections are determined by the velocity of the wind, the angle between the wind azimuth and A_f, the time-of-flight, and slightly upon the angle of elevation, E_p. Actually, a slight correction is also fed into the H_p amplifier since the wind effect is not entirely independent of E_p. The wind correction is set in in two places. First, the velocity of the wind is put in by turning a knob on the corrections panel; this can be as high as 60 miles an hour. Second, the azimuth from which the wind is blowing is set in by turning the knob on the azimuth servo. The difference in the azimuth of the wind and that of the shell is then automatically figured, the wind effect is resolved into components, and the corrections are added to the computations.

To provide a correction for dead-time (see mechanical directors) requires that the product of rate of change of fuze numbers and dead time be added to the t input to fuze summing amplifier. This causes the F servo motor to run to a different position that will, in effect, be the value of fuze setting necessary to hit the plane when the shell is actually fired. The rate of change is derived by a differentiating circuit. Dead-time correction is nothing but a prediction on fuze value and can be set to predict for dead-time as high as four seconds.

The next two corrections can be studied together because of their similarity. They are the correction for deviation from standard muzzle velocity of the shell and the correction for an air density other than normal. Off-standard powder temperature and shell weight have the same type effect as do muzzle velocity variations and can be included in that correction. The corrections depend on the difference between actual and standard conditions, altitude, time-of-flight, and E_p, and involve corrections to H_p and R_f with a slight correction to fuze setting. These corrections are necessary since a low muzzle velocity or a high air density will cause the shell to burst below and on the near side of the target; the fuze is corrected to allow for a decrease in the rotational velocity of the shell. Muzzle

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velocity from 2,400 ft/sec to 2,800 ft/sec can be set on the M9 and from 2,800 ft/sec to 3,200 ft/sec on the M10. Air density variations of ± 20% from standard can be compensated for in either director.

There now remains only the spot corrections that are used to correct for any errors that show up during trial fire when time is not available to repair the trouble. There are four such spots:

Range spot of ± 5%,
Azimuth spot of ± 50 mils,
Elevation spot of ± 50 mils; and
Fuze spot of ± 10%

The director has now computed firing data for the gun battery and has corrected that data for the various factors influencing the gunnery problem.

The data is more accurate than that supplied by any other AA director. Several factors increase the accuracy of this director. First, the matching of pointers in the altitude converter can be done by setting in a rate equal to the rate at which the selsyn is moving. The actual moving of the brush is then accomplished by a motor through a variable speed drive (VSD). The speed output of the VSD is controlled by the handwheel used in the manual matching operation. But the brush is moving over the card smoothly and at an even rate; the voltage, therefore, is changing at a smooth rate and erratic changes of D_o voltage have been eliminated.

The tracker contains two variable speed drives that are used to move the telescopes to keep them sighted on the plane. The azimuth and elevation brushes are also moved by these added drives, so that these, too, are moving over the cards at smooth rates.

Erratic changes in X_o, Y_o, and H_o have been minimized and the rates can be accurately determined.

The accuracy of those rates is yet further increased by two factors. One is the data smoothing network already discussed. The other is necessary to compensate for the construction of the potentiometers. These cards have wire wound around them and the brush contacts only one edge. Thus, as the brush moves from one turn to another, there is a slight jump in the voltage rather than a smooth change. This jump is slight since there are 160 turns of wire per inch of card length, but at a scale of one yard equal to 0.005 volts even that small jump is undesirable. This granularity, as it is called, is filtered out of the voltages before they reach the differentiating and data smoothing networks.

With such a combination of smoothing units, the rates are very accurate. The accuracy of other computations is also insured, first by extremely close regulation of all DC voltages and then by various wave traps and filters to insure the absence of stray AC voltages in the calculations. No other director has as many or as far reaching data smoothing features.

EMPLOYMENT WITH RADAR

If radar is used with the director instead of the optical height finder, some changes might be necessary. When radar set number SCR-268 is employed, no change need be made to the foregoing discussion since this unit supplies the director with a selsyn movement proportional to slant range. But, if SCR-547 is used, a slight change is necessary. This radar unit supplies the director with a voltage proportional to slant range; therefore, the altitude converter can be dispensed with. The altitude converter is not necessary when using either SCR-545 or SCR-584. In such a setup, the tracker need not be used, but, when the target is visible, optical tracking is usually employed; the tracker, therefore, is in most cases included in the setup for use when conditions permit.

When optical tracking is being used, should the plane disappear behind a cloud, a unit known as a cloud switch is used to change the tracking to the radar until such time as the plane again becomes visible.

It can be seen that the electrical director can use data from the optical height finder or from any of the present AA radar units.

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List of Terms and Symbols for Electrical Directors

D_o	Present slant range	Distance measured from director position to the present position of the target
E_o	Present angle of elevation	Angle measured in a vertical plane from the horizontal through which the telescopes must be turned so as to sight on the target.
A_o	Present azimuth angle	Angle measured in a horizontal plane clockwise from north through which the telescopes must be turned so as to sight on the target.
R_o	Present horizontal range	Horizontal distance from director position to point directly below the target.
H_o	Present altitude	Vertical distance measured from horizontal plane through the director position to the target.
X_o	Present E-W distance	Horizontal distance measured along an E-W line from the director position to a vertical N-S plane through the target position.
Y_o	Present N-S distance	Horizontal distance measured along a N-S line from the director position to a vertical E-W plane through the target position.
$\dot{X}$	Rate of change of X_o	Rate at which X_o is changing.
$\dot{Y}$	Rate of change of Y_o	Rate at which Y_o is changing.
$\dot{H}$	Rate of change of H_o	Rate at which H_o is changing.
t	Time-of-flight	Time required for shell to fly from gun to predicted future position of the target.
ΔX	E-W prediction	Product of $\dot{X}$ and t or amount by which X_o will change during flight of shell.
ΔY	N-S prediction	Product of $\dot{Y}$ and t or amount by which Y_o will change during flight of shell.
ΔH	Vertical prediction	Product of $\dot{H}$ and t or amount by which H_o will change during flight of shell.
X_p	Predicted E-W distance	Sum of X_o and ΔX or E-W distance to future position of target.
Y_p	Predicted N-S distance	Sum of Y_o and ΔY or N-S distance to future position of target.
H_p	Predicted altitude	Sum of H and ΔH or altitude to future position of target.
A	Future azimuth	Azimuth of future position of target.
R_f	Future horizontal range	Horizontal range to future position of target.
E	Future angle of elevation	Angle of elevation of future position of target.
H_f	Firing altitude	Sum of H_p and super elevation, or vertical distance to fictitious position of target allowing for effect of gravity on shell in flight.
X_G	X parallax	E-W displacement of director from guns.
Y_G	Y parallax	N-S displacement of director from guns.
H_G	H parallax	Vertical displacement of director from guns.

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POWER UNIT AND TRAILER

It has already been mentioned that the director operates on any source of 3-phase 60-cycle AC power whose voltage is from 100-130 volts. Such power is received at the power unit through a 3-conductor cable. The voltage is then regulated in the power unit to 115 volts ± 3 volts.

Also in the power unit are located four rectifier units. These comprise the source of all DC voltages used in the director. These voltages then go to regulator units in the computor. The regulated voltages are those used in the computing circuits of the director.

The electrical director is checked by a series of tests, each designed to test a part of the director; the entire director (all circuits) is tested by a complete series of tests. An understanding of these tests and a knowledge of proper analysis of the results provide foundation for an accurate inspection of the director. These tests are listed on a log sheet showing data to be set in on the director, data to be read on servo dials, and allowed tolerances between the observed readings and the standard readings. The log sheets come in booklet form together with instructions as to how to run each test. These booklets are furnished with each director and are kept and used by the battery. Certain of these tests, as indicated on the log sheet, should be run at least once each day when the director is set up. Thereby the battery commander will know the condition of the director.

The adjustment of the director prior to use is not complicated but must be done precisely and in proper sequence. Only trained operators should be used because the accuracy of the director depends largely on the adjustment. For instance, each of the 29 DC amplifiers must be zero set, that is, the output of the amplifier must be zero when there is no signal input. If one amplifier has an output of one volt under such input conditions, then, with signal inputs, that amplifier output will be incorrect by 200 yards. The operating personnel, therefore, must be familiar with the director. In the discussion of the operation of the director, four operators were assumed at various points: a range operator, an altitude operator at the altitude converter, an azimuth operator, and an elevation operator at the tracker. Two more operators are required: one at the tracker to slow the tracking head so as to sight the telescopes approximately at new targets, and the other at the computer to check zero set during off-periods, to set in corrections, to observe rate meters, etc.

Therefore, the director crew consists of six men, three are located at the tracker and three are located in a trailer, which houses the computer, the power unit, and the altitude converter. During travel, the tracking head is also carried in the trailer, but the tripod is carried in a truck along with the cables. The trailer will be either M13 or M14. The M13 has a canvas cover; the M14 is an all-metal trailer and includes a heater, a blower, lights, and service receptacles. In an emplacement, the trailer can be hidden or camouflaged since only the tracker need be able actually to see the target.

HEIGHT FINDER

In the computation of altitude for use with the heavy antiaircraft directors, two general systems of instrumental determination have been employed—the two station and the single station.

Regardless of the method employed, three dominant factors must be considered: (1) the finding must be accurate, since all computed firing data will be dependent upon this value; (2) the determination should be obtained in a minimum time after the assignment of a target; and (3) the successive determinations should be made as rapidly as possible.

The two-station system utilized the altimetric roof principle, which involved the measurement of two angles to the target from the ends of a very accurately surveyed base line. The angle measuring instruments, called Altimeters, contained charts and mechanical devices for the rapid and accurate solution of the triangle. During operation, constant telephonic communication had to be maintained between the two stations.

However, both the principle and the instruments themselves have been discarded in favor of the single station system. This system employes one instrument entirely self contained, which accomplishes the measurement through

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the solution of a right triangle created by the instrument, the target, and a perpendicular dropped from the target to the horizontal plane included in the instrument. In this triangle, the product of the sine of the angle of elevation and the slant range will produce the altitude. A height finder is the instrument employed here.

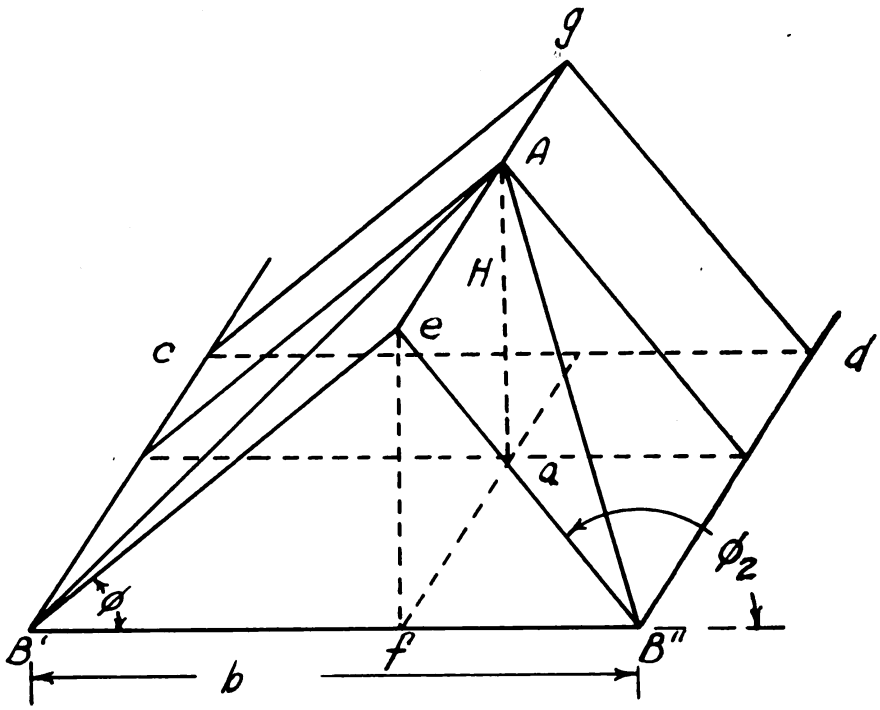

Figure 49. Altimetric Roof.

While much can be said as to the advantages and disadvantages of each system, the single station arrangement is superior with respect to installation, control, and time. Height finders are classified in relation to their manner of operation as optical or nonoptical. The *nonoptical* height finders employ the principle of

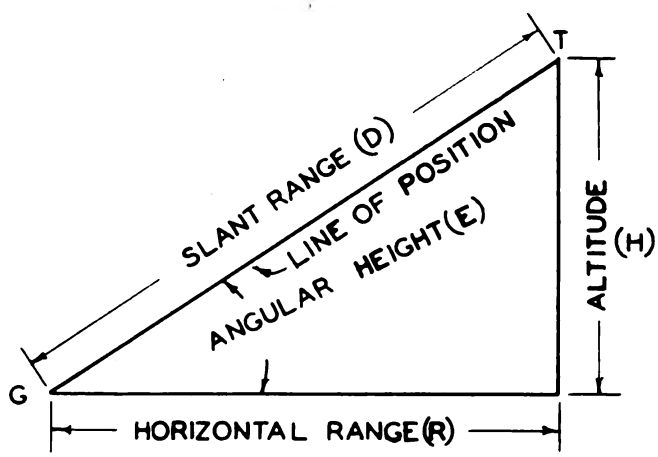

Figure 50. Right Triangle in Space.

"radar" and are Signal Corps equipment. The Ordance Department's height finder at present is of the optical type.

Two *optical* height finders are in use today. Their technical listing is found as 'Finder, Height, 13½-ft, M1A1' or 'Finder, Height, M2A1', 13½-ft is the base length of the instrument and is comparable to the surveyed distance of the two-station system. Both instruments are standard equipment, employ the same

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principles of operation, and function through the following limits: (1) Computation of either height or slant range of the target from 550 to 50,000 yards; (2) angles of elevation from 0° to 90°; (3) and angles of azimuth through a full 360°. The A1 part of the nomenclature concerns a modification which will be discussed later.

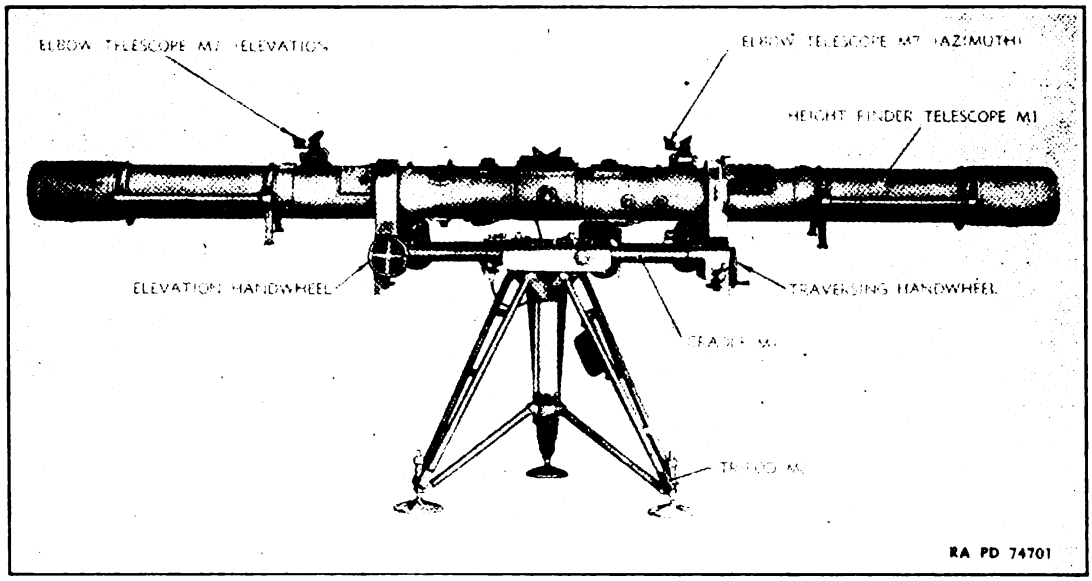

Figure 51. 13½-ft Height Finder M1, Rear View.

The slant range or height information is transmitted by a self-synchronous motor system to the antiaircraft director of the AA Battery with which the height finder is associated. The system employed limits the data which can be transmitted, however, to a maximum of 10,000 yards.

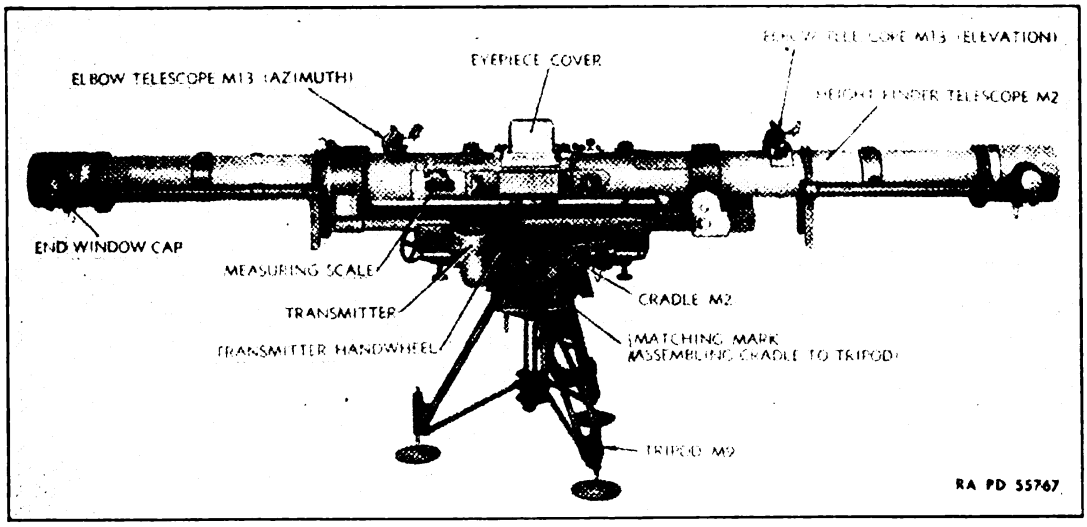

Figure 52. 13½-ft. Height Finder M2, Front View.

The instrument is kept sighted on the aircraft by two operators, or trackers, who follow the target through azimuth and elevation telescopes mounted on the height finder. Handwheels affecting direct gear trains accomplish the required movements. To assure the tracking of the same target at both the height finder and the director, the elevation and azimuth settings of the director are transmitted to the height finder and can be matched by mechanical pointers actuated by the height finder elevation and azimuth gear trains.

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The two models of height finders are similar in optical characteristics, but vary in weight (the M2 model being slightly heavier), in naming and arrangement of controls, in operations, and in adjustments. For physical comparison, see figures 51, and 52.

Both instruments are composed of three major units: the height finder telescope, the cradle, and the tripod. These units are packed separately in steel boxes for transportation; the combined weight when packed is about one ton.

The height finder is basically two military telescopes mounted longitudinally in substantial tubing. Conveniently located knobs and cranks permit the operations and adjustments of the various optical and mechanical elements. The main structural elements necessary for the support of telescopes and measuring devices consist of three tubes: a double-walled body tube formed by two tubes, an outer and an inner tube, and an optical tube, known as the optical bar, mounted within the inner tube. The purpose of having a double-walled body is to prevent changes in temperature from affecting the accuracy of the readings. The spacing between these two tubes (about ½ inch) plus a hair felt and canvas covering on the outer tube act as a heat insulator.

The outer tube hermetically seals the interior and is charged with a dry gas. Thus a possible condensation of moisture from a change in temperature inside the tube is prevented. The outer tube also serves as a cover for the instrument proper and supports the inner tube without strain. It is mounted to turn in elevation on two sets of ball bearings, one on each side of the center of the tube. A gearing arrangement on the left side accomplishes the changes in elevation.

The inner tube is encased by the outer tube and cannot be seen without breaking the hermetic seal. To the inner tube are attached those optical parts which should remain stable and in perfect alignment. Thus the main tube is supported in the outer tube so that perfect balance exists with no sagging in either the center or the ends. Furthermore, the inner tube is free to expand and contract, is incapable of any longitudinal shifting, and can be rotated slightly (1° total) on its bearings by a control knob. This rotation makes it possible for an observer to raise or lower the target image with respect to the reticle markings so as to facilitate the altitude or range measurement.

The optical bar carries the most sensitive parts of the height finder and therefore is made with the greatest exactitude. Not only must this tube be made of special steel (low coefficient of expansion), but it must also be free from stress and strain. This tube also is mounted to permit freedom of expansion and contraction, but, since it is secured to the inner tube, the optical bar also rotates 1°.

The cradle contains the necessary mechanisms for driving the height finder in azimuth and elevation, along with the electrical elements for data transmission and lighting. The mechanisms for elevation and traversing are encased in the left and right cradle housings respectively. The driving handwheels, with change-of-speed knobs, are conveniently located for the trackers. While this is entirely true for the M1 or M1A1 height finder, the elevation mechanism for the M2 or M2A1 is found on the telescope itself.

The two target designating receivers are equipped with 'follow-the-pointer' dials. One pointer (the electrical pointer) is fastened to the rotor of each receiver. The mechanical pointer at the elevation indicator is geared directly to the elevation mechanism; however, the mechanical pointer at the azimuth indicator is so constructed that traversing the instrument either by driving it with the azimuth hand wheel or by slewing (through a friction mechanism) will drive this pointer with respect to the azimuth scale. A knob and suitable gearing are provided so that the mechanical pointer at the azimuth indicator may be oriented to agree with the actual direction in which the instrument is pointing.

Orientation in elevation is no problem on the M2 height finder, since the gear train is never broken. However, on the M1 finder part of the elevation mechanism is on the telescope tube and part in the cradle. Indexes are provided on the outer tube support and the tube itself, which, when aligned, indicate 0 mils elevation. With these two marks aligned and with the elevation mechanical pointer of the elevation indicator set to 0 mils, a continuance of the gear train accomplishes orientation.

The range or height transmitter has a graduated scale attached to its rotor, so

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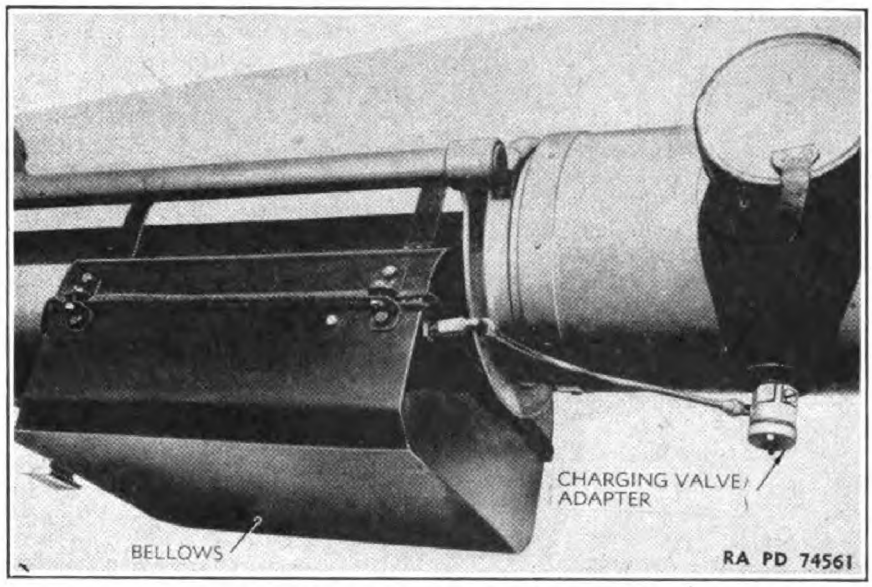
that the dial and the rotor can be driven by a handwheel. Vertical parallax (vertical difference in altitude between the director and height finder) from 0 to plus or minus 500 yards can be set into the transmitter.

The tripod is constructed to support the cradle and height finder telescope in



13½-ft Height Finder M1A1, Helium Retention Apparatus on Left End.

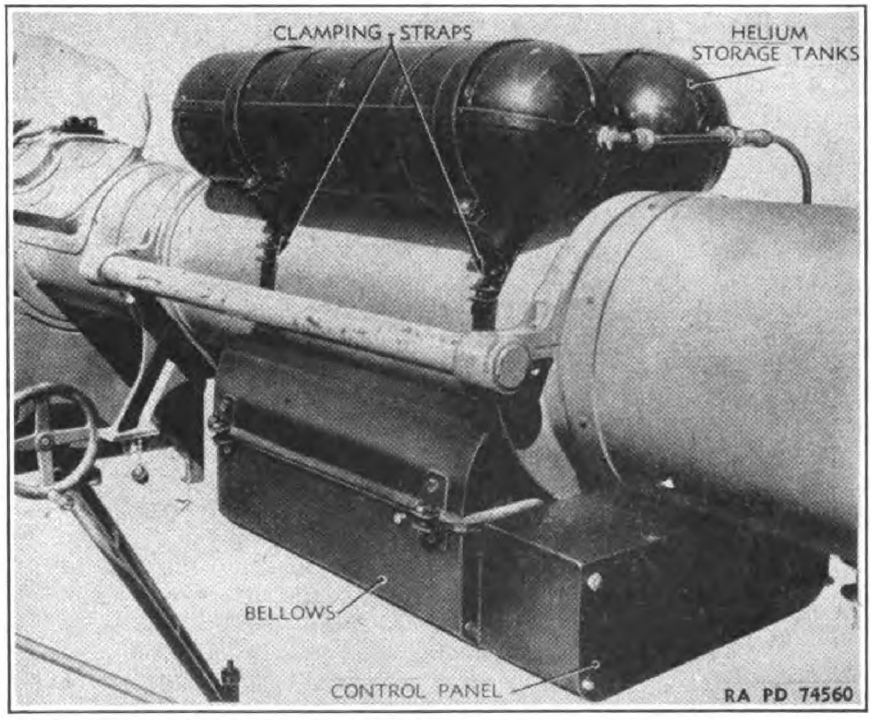


Figure 53. 13½-ft Height Finder M1A1, Helium Retention Apparatus on Right End.

a firm, rigid manner. The tripod for the M1 height finder contains the friction device that allows the instrument to be driven either mechanically or by slewing. This mechanism for the M2 is located in the cradle. The tripod also is provided with an adjustment at the foot of each of the three legs which makes it possible to level the instrument.

All height finders are charged with helium. Due to its physical properties,

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namely, high thermal conductivity character, and low affinity for moisture, this gas is the ideal substance with which to charge the tubes. If a height finder were subjected to a variation in temperature, a stratification of the air would result and would produce erroneous range or height values. Special apparatus for keeping a constant pressure and a constant percent by volume of helium in the telescope has now been standardized and accounts for the AI designation. (See figure 53).

The same problem of stratification in extremely cold climates resulted in the design and standardization of additional special equipment, viz., an electrically heated cover. This blanket commences operation through thermostatic control at about 40° F. In addition to its prime purpose, the heater also facilitates mechanical functioning.

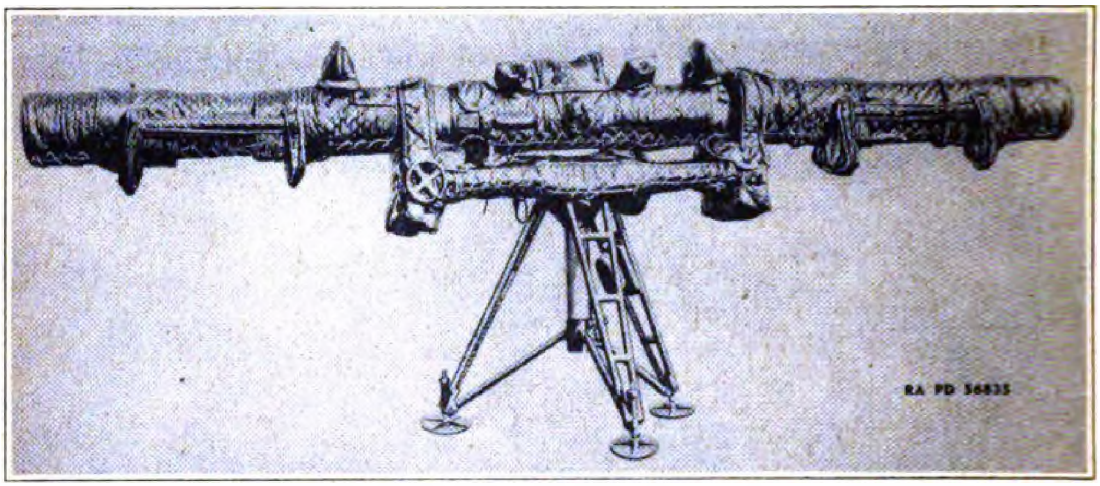

Figure 54. Height Finder Cover M404.

Stereoscopic Vision and Unit of Error. Unlike most range finders, the principle of operation of the height finder employs the observer's stereoscopic vision (binocular depth perception). Here we are not concerned with lining up two images of an outside target to match corresponding points, or superimposing the two images so that no duplicate margins of the image appear on either side of the field of view, or even sliding a middle portion of the image so that a complete picture is present. But we *are* concerned with producing a condition where the target appears to be the same distance away as some fixed reference mark. In creating the above condition we accomplish the linear measurement involving the target.

Such a means of measurement has several advantages: (1) a clear sharply defined target is not necessary. In cases where the airplane is partly obscured by clouds or hazy atmospheric conditions prevail, an accurate mensuration can be performed as long as the target is visible. (2) Fast moving targets can be tracked and measured with nearly the ease of a fixed ground target. There will be no oscillations of the image as would be found in a coincidence range finder. (3) Greater accuracy is attainable. The latter two advantages will be more fully understood as further consideration is given to the subject.

To elaborate somewhat on stereoscopic vision will present a better concept of operation. The perception of depth or three dimensions is the ability to recognize the existence of a difference in linear distance to two or more objects by visual means. This ability may be either monocular or binocular and is a learning process. A person with just one eye can tell whether one object is nearer than another through learning. Here such factors as the partial concealment of one object by another, the apparent sizes of two objects differing from that known to be the true sizes, perspective, relative movement of the objects by a movement of the head, and some other devices make this possible While these same various means of detection may also be available to a person with two eyes, that faculty of receiving and perceiving a different view of the objects in each eye (stereoscopic vision) has thus far proven to be the only method adaptable to qualitative

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range measurements. A different view of the two objects is obtained normally due to the separation of the two eyes. This is the same effect as is produced from two aerial photographs taken of the same location with a slight time interval between photographs. When these two photographs are held before the eyes, the features of the locality assume an appearance of three dimensions due to their slight dissimilarity.

A consideration of these two photographs will show that the dissimilarity is actually a lateral difference in distance between the corresponding points of any 2 objects on the two photographs.

It will also be noted that equal distances between corresponding points of any two objects would result in the sensation of both objects being the same distance away in space. If the distance between corresponding points for one object were greater than that for another, the object with the greater lateral distance would be perceived as being farther away. The converse is also true.

In the height finder, two reference marks (reticles) are held at a fixed distance apart, and one of the two images from the outside target is moved laterally with respect to the reference marks before the observer's eyes. A measurement of range is obtained when the reference mark and the target appear the same distance away in depth.

To facilitate reading stereoscopically, a row of nine marks, each spaced 2.5 mils apart (true field of view) is used. All these lie in the same depth plane. While the center mark is the one usually used for comparison, it is possible to use any one of the marks, since the target may be off to one side of the field or the other because of poor tracking in azimuth. Fore and aft marks located in front and behind this central row further assist in determining whether the

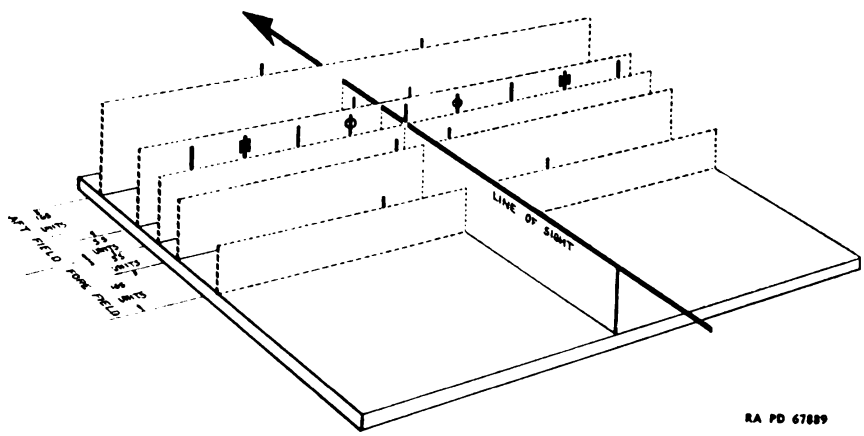

Figure 55. Sterescopic Impression of Reticle Markings.

target is in front or behind or at the correct point. Due to the accurate positioning of these marks, the instrument could also be used for spotting.

The degree of stereoscopic vision greatly influences the accuracy of readings with the height finder. Everyone has appreciated, at one time or another, the loss of three dimensional vision at great distances. This loss is due to the fact that dissimilarity in the two objects was not great enough for detection.

If two objects were considered and one were moved toward or away from the observer with respect to the other until the difference in depth could just be appreciated, a means would exist for finding stereoscopic acuity. In figure 56, T_1 and T_2 are the two objects so placed, AB is the interpupillary distance, and α and β are the two angles formed at the targets. The difference of the angles α and β expresses the acuteness of stereoscopic vision and is known as the discernible angular difference. If the difference were decreased, no appreciable change in depth would result. The distance T_1-T_2 would then contain an error which could not be detected.

For the greatest number of people this angular differnce is 30 seconds. Although it can be reduced by training, it nevertheless will reach a limit. The Coast

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Artillery observers using the instrument must have an appreciation of not more than 18 seconds. Some observers can perceive an angular difference of 6 seconds.

Since the error in T_1-T_2 is influenced inversely by the distance between the two eyes (the angular difference being a constant for the observer), an increase in the interpupillary distance would reduce this error. Optically, the eyes are

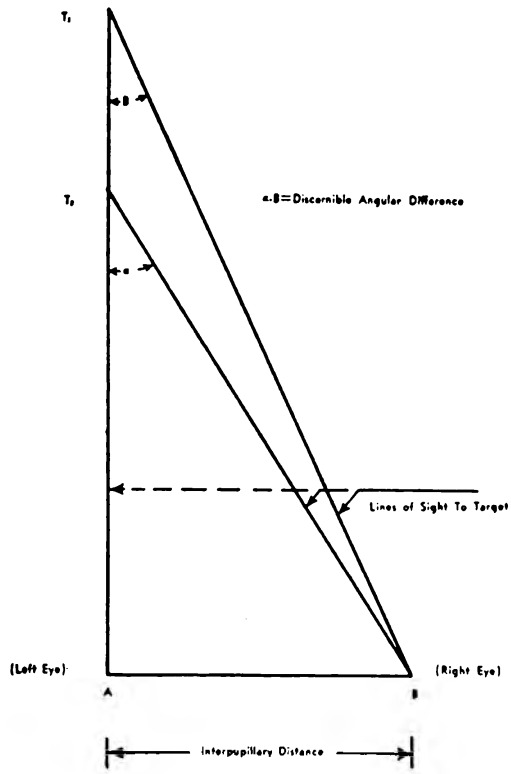

Figure 56. Stereoscopic Acuity.

separated a distance of 13½ feet by the height finder. The error then is reduced to approximately 1/60 of the original error. The size of the height finder not only gives a desirable decrease in error, but yet is not too large to prohibit transportation.

To further decrease this error, magnification is employed. The actual error in T_1-T_2 would be reduced to an amount equal to 1/magnification times the original error, since the actual range distance is apparently reduced and the angular difference remains constant. The height finder is designed with a choice of magnification of 12x or 24x. Atmospheric conditions, heat waves, fog, etc., will determine the selection as these disturbances are exaggerated directly as the magnification.

The application of stereoscopic vision of an individual to the accuracy of range or height determinations is found in an arbitrary unit of measurement. This unit, the unit of error, expresses a linear error in the true range to the target resulting from an arbitrary angle of discernible difference of 12 seconds As has been mentioned, the Coast Artillery observers must possess a stereoscopic acuity of not more than 18 seconds. Obviously, then, any range readings would be accurate only to 18/12 or 1.5 units of errors. For rapid checkings in determining whether the computed range to a given target is of the prescribed accuracy, a mathematical expression is employed:

$$\text{Tolerance of Range in yards} = .81\left(\frac{\text{True Range}}{1000}\right)^2.$$

From this equation, we compute the permissible error for any range. Applying the expression to the upper and lower limits of data transmission, a tolerance of ± 81 yards at 10,000 yards and of ± 10 inches at 550 yards will be evident.

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For the determination of height tolerance, the angle of elevation will have to be considered. The height tolerances will be the same as range tolerance at an elevation of 90°, but for angles of elevation below 90° innate errors are introduced which make the permissible error a bit greater than would be expected. Graphs, however, are provided which furnish the accepted tolerances.

Besides the two military telescopes mentioned previously, certain optical devices for bending the light in convenient directions and a measuring unit for determining the range or altitude of the target must be employed.

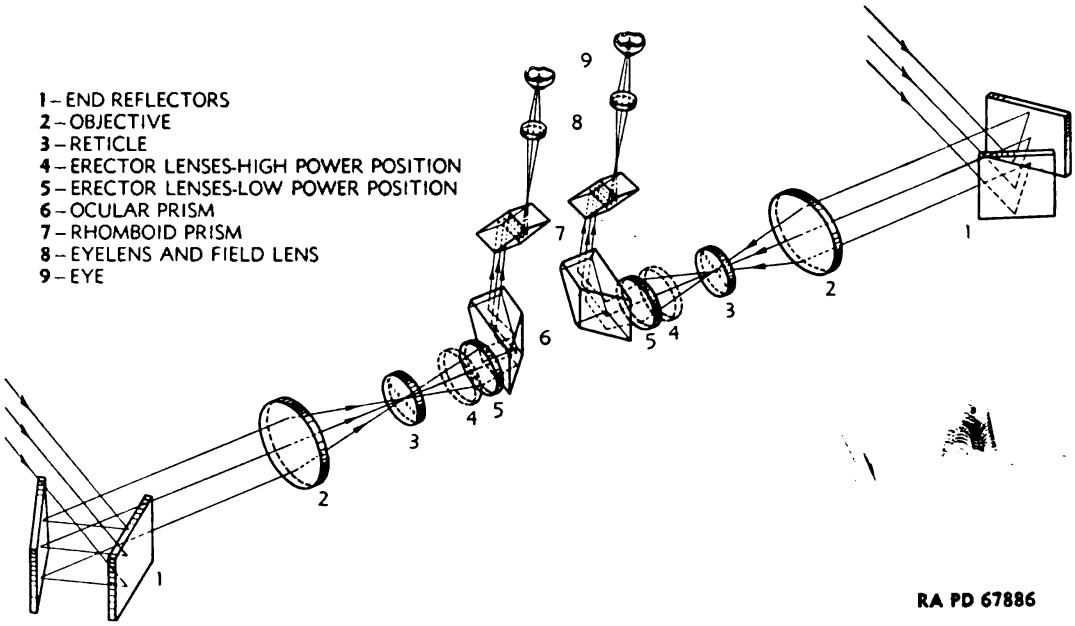

Figure 57. Perspective of Simplified Image—Forming Elements of Height Finder M1.

Figure 57 shows a perspective of the optical elements making up the military telescopes and light bending devices. The function of each is as follows: (1) End Reflectors—bend the light through a constant angle of 90°; (2) Objectives—gather the light from the outside target and form an image on the reticles; (3) Reticles—constitute reference marks for comparison with the image; (4 and 5) Erectors—erect the image and permit a change in magnification by their lateral shifting within the optical bar; (6) Ocular Prisms—bend the light to a convenient position for observation; (7) Rhomboid Prisms—permit a change for various interpupillary distances for different observers; (8) Eyepieces—magnify the images for the observer's eyes. Also, located between the left objective and left reticle is a plano parallel piece of glass, the height of image plate, which raises or lowers the left image to the same vertical position as the right.

Principles of Operations. From the above it will be possible to follow schematically the principles of operation and a derivation of the complete measuring unit.

Figure 58 presents schematically the central rays of light from a star object as they pass through the height finder. The light is bent 90° by the end reflectors and is imaged on the reticles. (Note: only those parts necessary for this discussion have been shown). To an observer looking through each eyepiece (monocularly), the field of view would be that of a clear reticle and a clear image. The circles in the diagram represent the fields of view as seen through each eyepiece. Observing binocularly, the fused picture would show the star and the reticle mark the same distance away in depth since the lateral distances between the two corresponding objects would be equal. This condition, where the target and the reticle are the same distance away in depth, is referred to as 'stereo-contact'.

If the lines of sight originated from some object at a finite distance, they would no longer be parallel. Then the distance between the reticle marks ano

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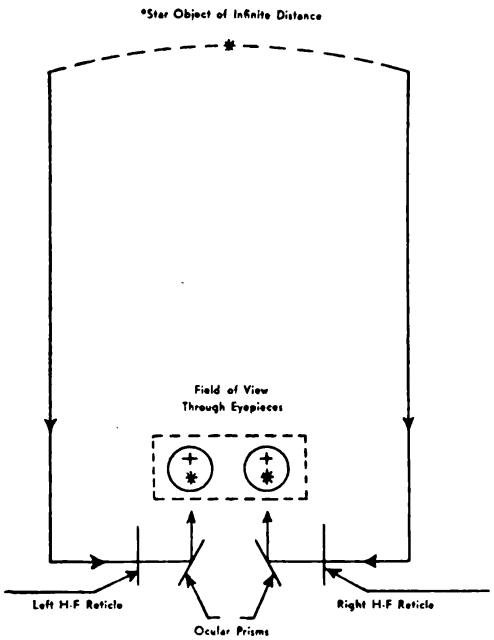

Figure 58. Rays of Light Passing Through a Height Finder.

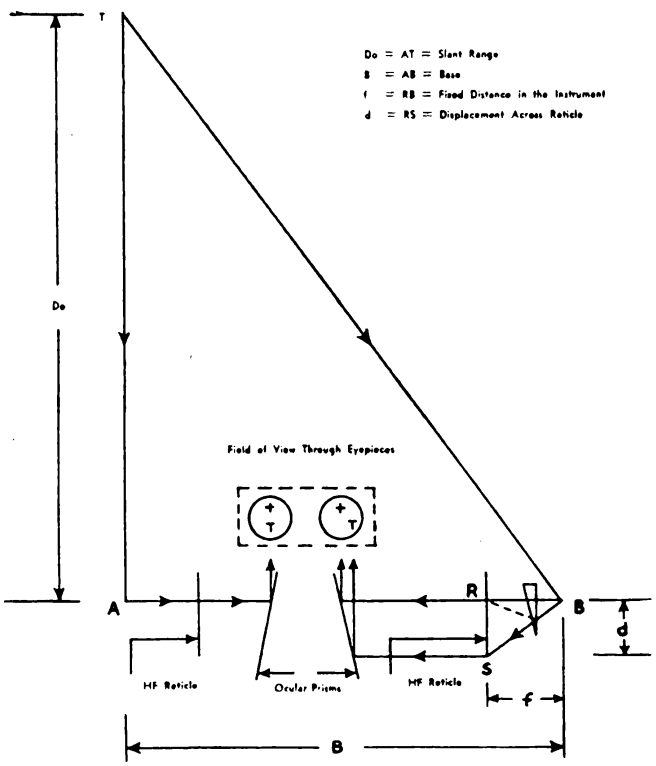

Figure 59. Operating Principles of a Height Finder.

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the image would no longer be equal and thus would not appear in the same depth plane. An analysis of this situation is shown in figure 59. Triangles TAB and BRS are obviously similar and $\frac{B}{D_o} = \frac{d}{f}$ or $D_o = \frac{Bf}{d}$.

Since the base of the instrument (B) and 'f' are constants, Figure 59, a measurement of 'd' would determine the slant range. Since 'd' is variable as the slant range, a variable means of measurement is needed. Also the measurement will accurately have been made when stereo-contact is re-established. What is needed then, is a means to bend the light so that the image on the right side is placed the same as that of the left. Despite the fact that the target was considered as lying along the left line of sight, it matters little where it is placed due to the great distance to the target compared with the base of the instrument.

A ground and polished wedge of glass, often called a refracting prism, could be manufactured to produce the desired deviation. The thick portion of the wedge, the base, would have to be pointed toward the target, and, of course, would only be correct for the given range. Obviously, then, an infinite number of wedges would be needed to include all possible ranges. In lieu of this impossibility, a special assembly, known as the compensator, or diasporameter, is employed.

A ray of light passing through a single wedge is deflected through some angle depending on the angle of the two refracting surfaces and the characteristics of

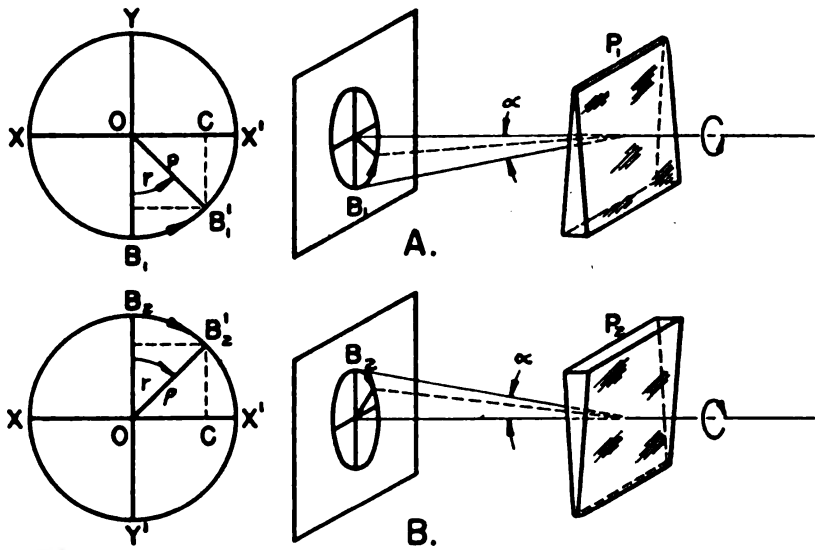

Figure 60. Optical Measuring Wedge.

the glass. If the wedge is rotated through 360°, it will describe on a screen a circle of radius $p = OB_1 = OB_2$ as shown in Figure 60. Wedge P_1 is positioned base down, and the ray is deflected to B_1. Wedge P_2 is positioned base up, and the ray is deflected to B_2. If the two wedges are placed together in this position, the deflecting angles will cancel and the direction of the incident rays will be unchanged.

Considering the wedges singly again, rotate each wedge through an angle 'r' in opposite directions. The point B_1 in Figure 58 will move to B^1, the point B_2 in Figure 60 to B^1_2. The lateral deviations of B_1, *i.e.*, in the direction parallel to the x is $OC = OB^1 \sin r$. The vertical deflection of B, *i.e.*, in the direction parallel to the y axis is $B'C = OB' \cos r$. These relations will hold for all angles of rotation.

Assume the two wedges mounted to rotate about the same axis as in Figure 61, and then rotated in opposite directions through any angles 'r'. The deflection of the pair will be the sum of the deflections of the single wedges, see Figure 62. The deflections along the y axis cancel since they are equal and opposite. The deflections along the x axis are equal to $OB' \sin r$ and since they are in the same direction, they join together to produce a deflection of $2\ OB' \sin r$. Such a com-

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bination of wedges through gears then gives a deflection which is constantly in one plane and which may be caused to vary from zero to a maximum value. The maximum deflection occurs when each wedge has been rotated through 90° or the bases are turned in the same direction and are coinciding. The compensator is composed of two such pairs of wedges with the deviation then expressed as 4P sin r, where P is the deflection or deviation of each wedge and r is the amount of rotation of the wedges.

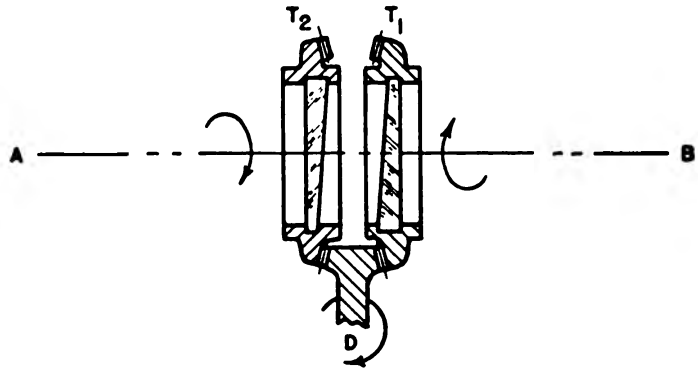

Figure 61. Optical Wedge Assembly.

Substituting the wedge unit 'd' (the deviation to produce stereo-contact), we have:

$$D_o = \frac{Bf}{4P \sin r}$$

B, f, and P are constants and can be resolved to K.

$$\text{Thus } D_o = \frac{K}{\sin r}$$

$$\text{Then } D_o \sim \frac{1}{\sin r}$$

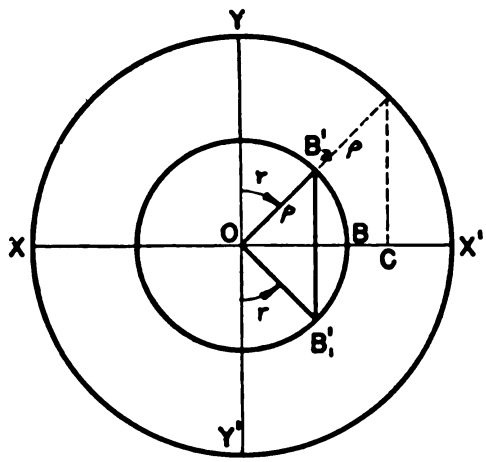

Figure 62. Combined Wedge Deviations.

Having determined the above, it is apparent that a range dial or some scale could be attached to a drive shaft, and this would indicate the proper range against a fixed index for the various amounts of rotation of the shaft and hence of the wedges. The scale will be spread out at lower ranges and jam up at longer ranges since it is engraved proportional to 1/sin r or cosecant r. A control knob, the compensator, and an engraved drum compose the measuring unit. The wedges are located between the right objective and the end reflector.

If this instrument were to be just a range finder, only one pair of wedges properly designed would be needed. This is obvious from the above.

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If we consider a view of the wedge unit from the right side of the instrument and with arrow heads indicating the bases of the wedges, Figure 63a presents the arrangement of the wedges for slant range. It should be noted that the wedges are numbered outward from the center of the instrument. Figure 63b shows that the angle of elevation has no action on the rotation of the wedges, but is simply a tipping of the entire unit, and Figure 63c also shows the rotation of the wedges through some angle 'r' necessary to produce stereo-contact for some target at a given slant range.

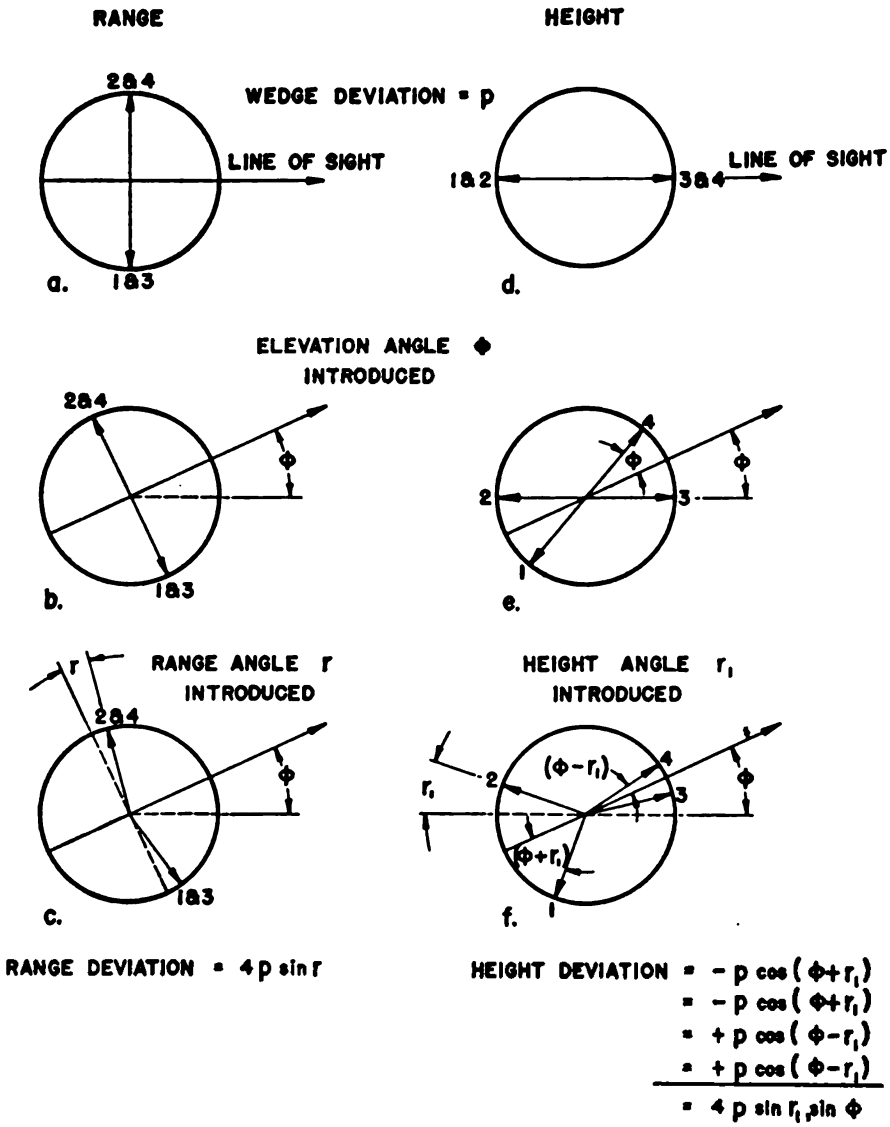

Figure 63. Wedge Motions and Deviations.

We do have four wedges though, since the same instrument, the same wedge unit, and the same scaled drum are to be used to measure altitude. In reality, the altitude of this target is not measured directly, but instead the deviation resulting from this target being at a definite slant range is measured proportionally to the angle of elevation. Thus this compensator unit instead of employing a straight gear train must include a differential arrangement to permit the introduction of the angle of elevation as well as the angle of rotation needed to produce stereo-contact.

The gear train for introducing the angle of elevation is called the 'height conversion mechanism'. To understand height measurement, one should consider

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the position of the wedges when the angle of elevation is 0° and the angle of rotation of the wedges for stereo-contact is also zero. Figure 63d shows the arrangement of the bases for this initial consideration. The wedges have been repositioned manually from their position shown in Figure 63a through a rack gear accessible from the outer tube and controlled by a lever known as the range-height lever. If the height finder is now elevated through some angle, ϕ, the motion which is introduced through the conversion mechanism is such that the wedges pair together, namely 1 and 4, and 2 and 3. Wedges 2 and 3 are stationary relative to the true horizontal, and 1 and 4 rotate twice the angle of elevation (Figure 63e). The deviation is still zero as in Figure 63d.

To create stereo-contact, the wedges are rotated from this position through an angle r_1 (r_1 to differentiate from r when measuring slant range), such that once again wedges 2 and 4 rotate clockwise and 1 and 3 rotate counterclockwise (see Figure 63f). The deviation from the wedges can now be derived. Along the line of sight, wedges 1 and 2 produce deviation equal to $2P \cos(\phi + r_1)$ and wedges 3 and 4, $2P \cos(\phi - r_1)$. These deviations however, are in opposite directions and must therefore be considered vectorially. The algebraic addition then equals:

From Wedges (1 and 2)

$$-2P \cos(\phi + r_1) = -2P(\cos\phi \cos r_1 - \sin\phi \sin r_1);$$

From Wedges (3 and 4)

$$+2P \cos(\phi - r_1) = +2P(\cos\phi \cos r_1 + \sin\phi \sin r_1)$$

or, the deviation for measuring height $= 4P \sin\phi \sin r_1$.

In this form, the displacement across the reticle resulting from the target being at a finite slant range is measured, hence the need of four wedges.

$d = 4P \sin r$	$= 4P \sin\phi \sin r_1$
Determines drum setting as a range finder.	Determines drum setting as a height finder.

Altitude or height is usually measured not only because the height of the target is fairly constant or because its rate of change is fairly constant, but also because, from inspection it will be seen that with the change in slant range the deviation across the reticle is increasing, assuming that the target is flying at a constant altitude and toward the instrument. The angle of elevation, however, is increasing at the same time, and therefore its sine is increasing. The necessary change in deviation to be supplied by the measuring wedge unit to overcome that deviation resulting from a change in the slant range is thus produced through the change in the angle of elevation, permitting the angle 'r_1' to remain constant. Thus stereoscopic contact is maintained. The angle of elevation is introduced by the position of the height finder itself and is maintained at its proper value by the actions of the elevation tracker. The angle of rotation of the wedges to accomplish stereo-contact is introduced manually by the stereoscopic observer, who turns a knob controlling the wedges and the scale drum.

INTERNAL ADJUSTMENT SYSTEM

As with all range finders so also with the height finder, a means of zeroing the instrument in order to obtain correct range or height readings must be provided. Measuring laths were tried with a few early height finders, but they quickly proved unsatisfactory, because they were too long and too heavy and because a slight change in the distance between the two marks introduced errors beyond tolerance. With the condemnation of measuring laths, there remained the possibility of using targets at known ranges either celestial or terrestial. Disadvantages inherent in this method are the uncertainty of atmospheric conditions and the lack of time to compute check ranges for a particular locality.

To provide a more satisfactory means of zeroing, adjusting devices were built in the height finder itself so that the instrument was completely self-contained. It had its own internal adjusting system, an artificial infinity target. In order for this internal target to be effective, complete assurance is required that it will not be subject to the same errors in optical alignment that occur in the main system of the height finder. This condition is satisfied by a double-ended collimating system which gives out parallel rays and, because of its design, is not sensitive to slight errors in mechanical mounting or alignment.

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The principle of the double objective, self-collimating system is shown in Figure 64. Each objective has a line, which is the infinity target for the other objective, etched on its plane face, axial with and close to its optical center. The objectives are mounted so that each face is at the principle focus of the other objective. Thus each objective produces a virtual image at infinity of the mark on the other objective, and these two images are located at opposite ends of that line which passes through the optical centers of the two target objectives. In use, each target line is illuminated by the diffused light reflected from its adjacent lamp, so that the image of the line stands out in black against a milky-white background. These reflectors are of polished optical glass, therefore each can also transmit the major portion of the light coming from the opposite reflector and objective. The images of the target are reflected by the small pentaprisms into the end reflectors of the main height finder system. Thus the infinity line of the left internal target objective is seen by the right eye, and that of the right objective, by the left eye of the observer.

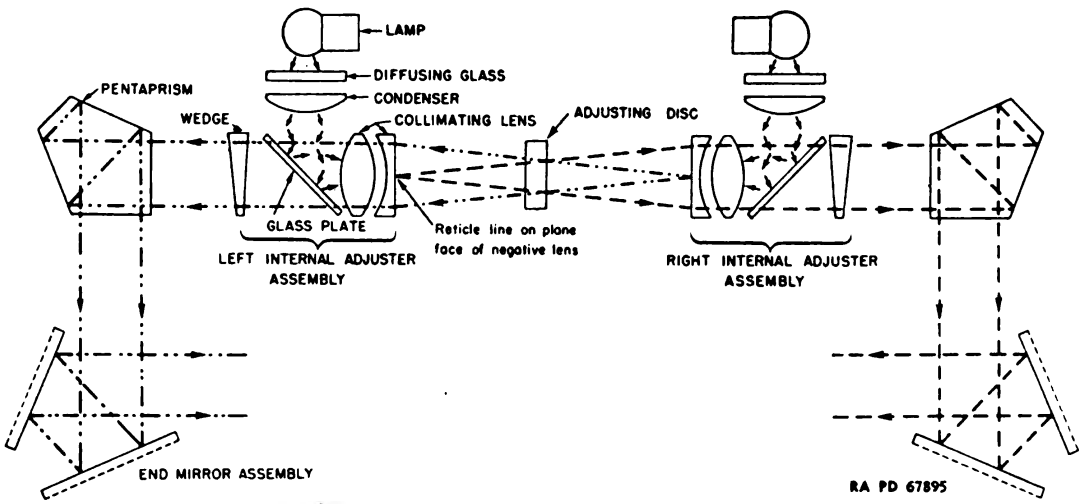

Figure 64. Diagram of Self-Collimating Internal Target System.

The rays emerging from both ends of the internal target system maintain their direction relative to each other regardless of any likely distortion of the height finder. If variations occur in the optical alignment of the height finder, the target lines will not appear at the same depth relation in space as do the main reticle marks when the compensator wedges are set at the infinity range setting. This is readily corrected by rotating a correction wedge which is mounted base down in the path of the left main telescopic system and is rotated until stereo-contact between the internal target and reticle marks is restored. The movement of this wedge is accomplished by a knob on the outside of the instrument and the amount of movement itself can be noted on a convenient scale.

In addition to its essential optical units, the internal target system contains elements to permit adjustments to the system itself. The centering disk (adjusting disk), Figure 64, is located approximately midway between the objectives, and it allows the internal target lines to be displaced laterally an equal amount to a convenient position for reading. The centering disk is composed of a plano parallel glass plate and therefore will not affect the eventual parallelism of the rays going to the pentaprisms or of stereo-contact.

Since the pentaprisms and other parts of the internal system may not be optically perfect, collimating wedges are mounted next to the objectives to allow the internal target lines to be brought into stereo-contact and yet permit a full scale movement of the correction wedges.

Although the height finder was designed primarily for use with a heavy anti-aircraft battery, it is also employed with seacoast artillery to measure the ranges to water-borne targets.

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REMOTE CONTROL SYSTEMS

Unless the gun is positioned accurately, rapidly, and continuously in accordance with the data calculated by the director, errors will be introduced in the gun positioning. Also, since most directors are at a considerable distance from their guns, the calculated firing data must be transmitted between the equipment by suitable means.

Because of the speed with which firing data changes, an operator could not read the future values at the director, call them over to the gun, and then expect a gun tracker to keep the gun at the proper azimuth or elevation. It becomes, therefore, essential for the firing data to be automatically transmitted.

A suitable electric signal system can be developed which will meet the requirements of a firing data transmitter. This mechanism involves two self-synchronous motors (commonly referred to as a selsyns), one a transmitter and the other a receiver, and a cable system between director and guns.

The transmitter consists of a two-pole rotor housed in a three-field stator.

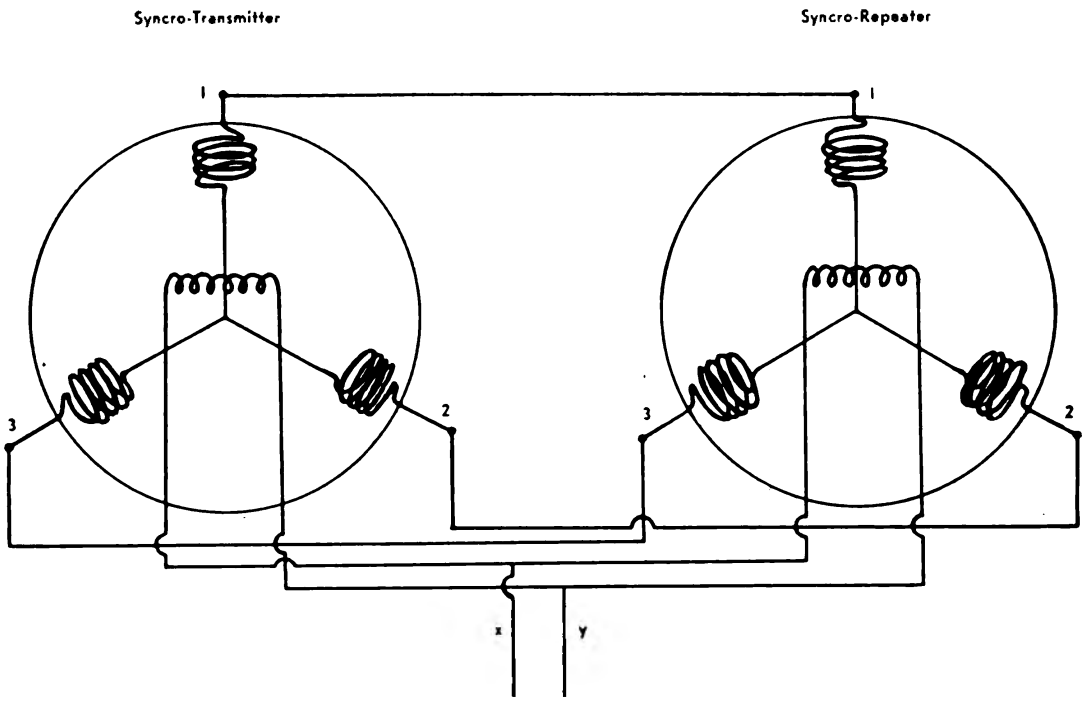

Figure 65. Schematic Wiring Diagram of Transmitter and Repeater.

The rotor is energized by standard 110-volt, 60-cycle, alternating current. As a result of the continuous variations in the flux produced by the alternating current in the rotor, voltages are induced in each of the three stator windings. The magnitude of these induced voltages will depend upon the position of the rotor with respect to each of the stator coils. Thus the three voltages produced at the output terminals of the three stator coils will present a different set of values for every stator setting. Relative to transmission of data by selsyn in director operation, the value produced in the director positions the transmitter rotor which motion causes the value to be transmitted to the stator coil of the receiver selsyn on the gun.

The receivers are similar in construction to the transmitters. Furthermore, if both the receiver and transmitter are energized by the same source, and if the rotors in both selsyns are in the same position relative to their corresponding stators, then the voltages at the output terminal of each of the transmitter stator coils will be the same as that of the corresponding output terminals on the receiver. If, this is the case and the terminals of corresponding stator coils in the receiver and the transmitter are wired together, no current will flow in these wires as the voltages at each end will be the same. If, however, the trans-

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mitter rotor were to be displaced a little, the voltages at each of the stator coils in the transmitter would differ from those at the corresponding receiver coils. Currents would therefore flow between the transmitter and receiver. If the transmitter rotor motor is held fixed, then these currents in the stator of the receiver would set up a magnetic field, which, upon interaction with that of the rotor, would cause the receiver to function like an electric motor. The receiver motor will continue to turn until there is no more current flowing in the stator windings. This will be the case when the receiver rotor is again set in the same position relative to its stator as is the rotor of the transmitter to its stator. It should be noted, however, that the amount of turning taking place within these transmitters and receivers is relatively slight and that, in fact, the elements never spin (under normal operation) as do ordinary electric motors. Thus, as the transmitter rotor is turned according to some future value of firing data, the receiver stator will follow it. By this means, all the director output data can be transmitted to the gun. Furthermore, by suitable design of the transmitter it can be used to position more than one receiver. If very accurate data transmission is called for, it will be necessary to have one transmitter send 'coarse' data to the guns by having its rotor, for example, turn through one revolution for 6,400 mils azimuth change, and to have also a fine transmitter whose rotor will turn for example, once every 400 mils. By this means, received data can be read to about half a mil at dials controlled by a corresponding pair of receivers.

In former times, an azimuth and an elevation tracker on the guns manually set the required azimuth and elevation on the gun in accordance with values indicated on dials attached to selsyn receivers. This was accomplished by matching to the selsyn dial a concentric ring which indicated the actual position of the gun in azimuth or in elevation. It was found however, that this matching of gun settings to director signals was not accurate enough for good antiaircraft fire. For this reason, automatic control mechanisms have been developed to position the guns in accordance with firing data received from the director. These mechanisms, usually called 'remote control systems', will now be described.

Remote Control Systems for Light AA Weapons

In the remote control systems M1, M3, and M5, which serve the 37mm gun and the British and American 40mm guns respectively, the data transmission system already described is used for only the azimuth indicator, or coarse data system, in which one rotation of the rotor equals one complete rotation of the gun in azimuth. Data based upon the fact that information is also being provided by a selsyn, whose rotor makes 1 revolution per 20°, is used by a system made up of two synchro-transmitters and a synchro-differential. This system is referred to as the fine data system.

A transmitter, called the director transmitter, is located in the director. Its rotor is positioned to indicate the desired gun position. Another transmitter known as the gun transmitter, is located at the gun, and, through appropriate gearing, indicates the actual gun position. For fine differences in position and consequently more accurate positioning, these rotors are geared so that only twenty degrees rotation of the gun is indicated by one complete rotation of the rotor. The stator fields of these two transmitters are wired directly to the third element of the system, the synchro-differential.

The synchro-differential, made up of a three-phase rotor and a three-phase stator, uses the difference between the desired and actual positions of the gun to cause a rotation of the rotor by a definite amount and in a definite direction. This motion is utilized to control a unit, known as an oil gear, which drives the gun, and simultaneously, the gun transmitter, to the desired position.

In the remote control systems M1, M3 and M5 there were two fine and one coarse data systems, *i.e.*, elevation fine, azimuth fine, and azimuth coarse. The elevation fine data system controls the motion of the gun in elevation through its control of the output of the elevation oil gear. The azimuth fine data system controls the motion of the gun in azimuth through its control of the output of the azimuth oil gear. The azimuth coarse data system only acts as an azimuth indicator by means of matched dials.

In all the remote control systems for light antiaircraft weapons it is necessary

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to transmit this firing data through wires between the director and gun as well as to transmit power from a source, Generator M5, to both the gun and director. In the American systems all units use 115-volt, 60-cycle power, either single or three-phase. Three-phase power is brought from the generator M5 to a gun junction box via a 225 foot, 3 conductor cable. At the gun junction box one set of leads is tapped off to operate the on-carriage components of the remote control. At the same point another set of leads is tapped off into a 15-conductor cable 60 feet long for the power requirements of the director. Other leads in this same cable carry the firing data from the director to the gun junction box and thence to the synchro-differential. This two-cable system is known as the Cable System M8.

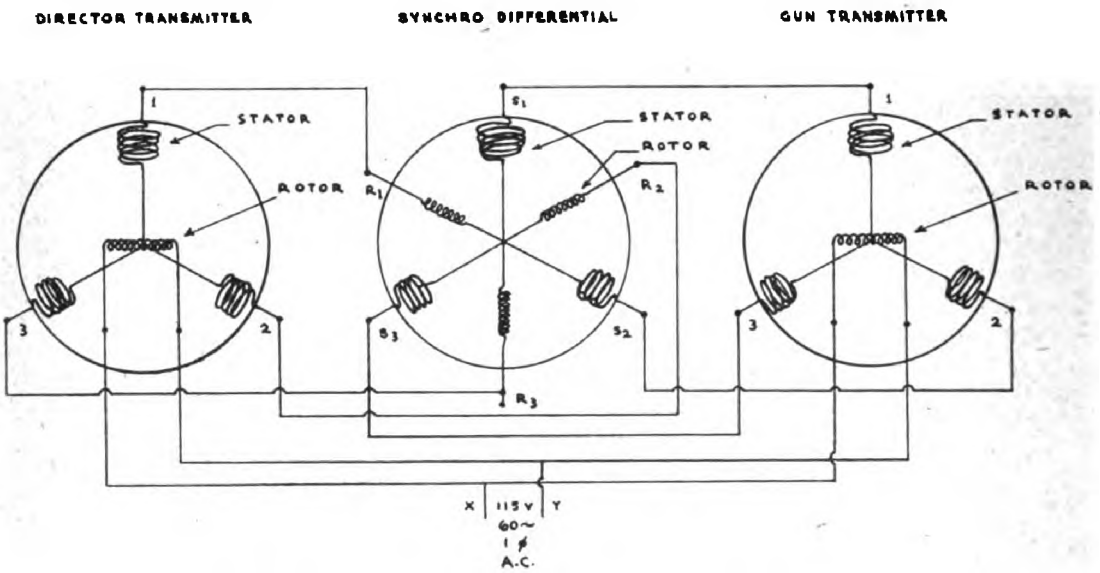

Figure 66. Schematic Wiring Diagram of Fine Data System.

In British type units the director uses 50-volt, 50-cycle power and the oil gears use 130-volt, 50-cycle power making the problem of power transmission a little more complex. 130-volt, 50-cycle, 3-phase power is transmitted from the generator M5 to a main junction box off-carriage through a 225 foot, 3-conductor cable. In the main junction box is a transformer to step down the voltage from 130 volts to 50 volts for use in the director and transmitters. From the main junction box two 30 foot, 15-conductor cables radiate. One serves to carry 50-volt, 50-cycle power to the director and also to take the firing data from the director to the main junction box; the other carries both 50 and 130-volt, 50-cycle power to the gun and also carries the firing data transmitted from the director to the main junction box and on to the gun. This cable system of three cables and a main junction box is known as the Cable System M9.

Oil Gear Operation. The on-carriage components of the remote control systems are two oil gears, one for azimuth and one for elevation operation, and the necessary wiring set to power and control these two oil gears. A contact ring at the center of the carriage allows unlimited traverse of the gun in azimuth. This contact ring is in effect, a multiple slip ring allowing electrical connection to be made between the pedestal and the top carriage.

With remote control systems M1 and M5, the oil gear M1 is used. With remote control system M3, the oil gear M2 is used. These oil gears are alike functionally except for the electrical components, and, therefore, to explain briefly the operation of one is to explain both. Basically, oil gears in antiaircraft fire control consist of a variable displacement pump and a constant displacement hydraulic motor with the necessary elements for control of the speed and direction of rotation of the motor.

The pump of the oil gear M1 consists of a cylindrical rotor with seven axial cylinders 17 millimeters in diameter, machined through its length. In each of

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these cylinders are two balls separated by a compression spring. At the center of each cylinder is a port opening to the outside surface of the rotor. This port serves as both intake and exhaust for the cylinder when the volume between the balls is increased or decreased. To obtain this increase or decrease of volume a two-lobe cam in cylindrical form is mounted at each end of the rotor. Since the balls are forced against the cams by the action of the compression spring, any rotation of the rotor will impart to the balls a reciprocating motion.

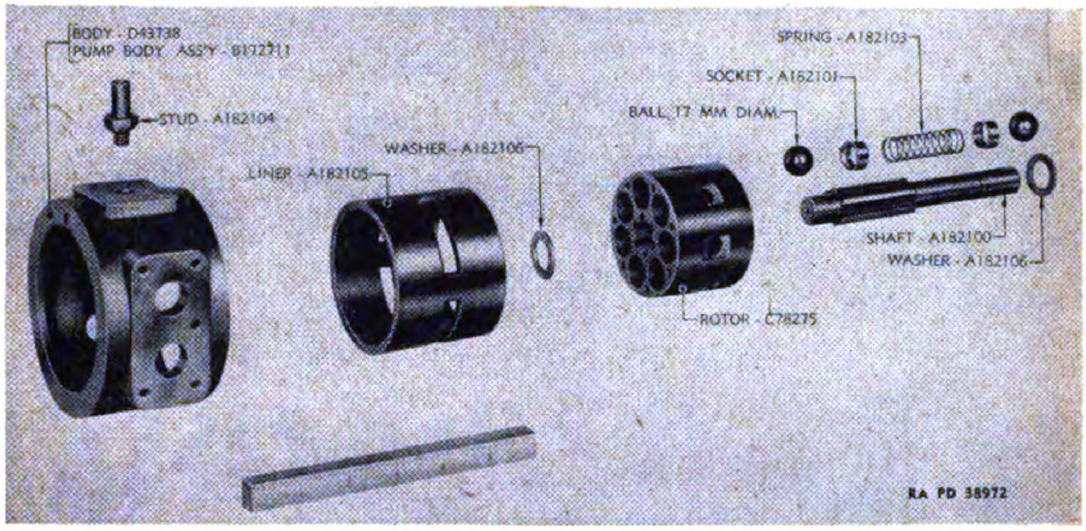

Figure 67. Pump Components.

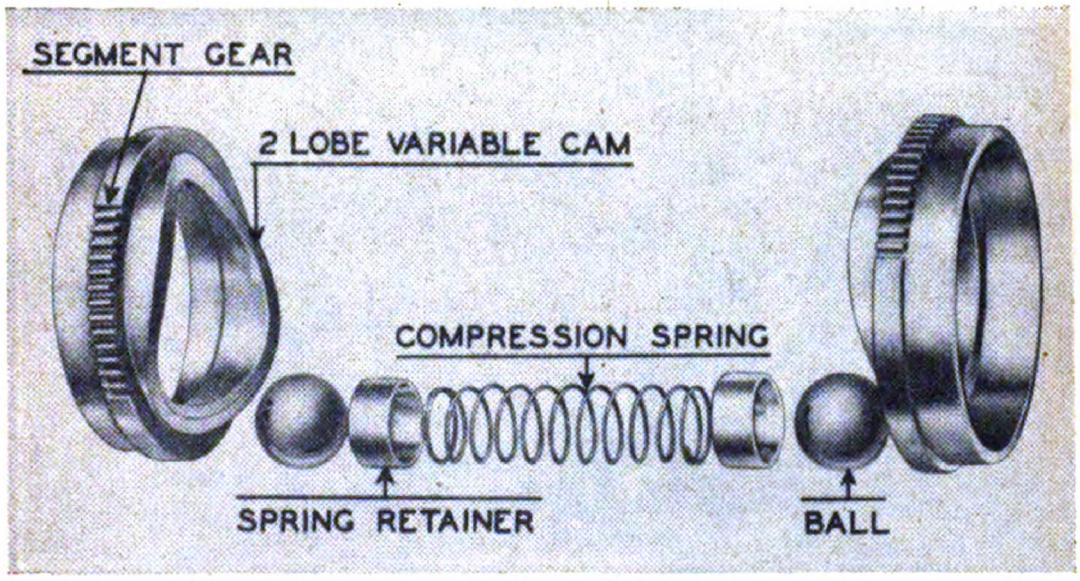

Figure 68. Oil Pump Ball and Cam Arrangement.

If the balls are both moving in the same direction and at the same speed there will be no change in volume between them and consequently no pumping. If however, they are moving in opposite directions there will be a maximum change in volume and consequently a maximum pumping action. Therefore by controlling the relative positions of the cams the output of the pump can be controlled.

In order to insure that the output of the pump will not be fed back into the

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reservoir, the rotor is mounted in a body and liner to control the porting of the oil pumped. Mounted on the body is a crown gear which controls the relative position of the cams and the output of the pump which is from 0 to 7½ gallons per minute. A pressure controller governs the position of the crown gear and thus limits the pressure at a maximum of 110 pounds per square inch. At the same time oil at 50 pounds per square inch is used to operate the control elements of the unit. The oil pump is rotated at 700 revolutions per minute continuously by an induction motor mounted on top of the unit. The induction motor rotation is transmitted to the pump by means of a roller chain and the necessary sprockets.

The oil motor is of construction similar to that of the pump. The main difference is that the cams are fixed at the position to give maximum displacement to the balls. The speed of the motor is dependent upon the volume of oil passing through it, and the direction of rotation of the motor is dependent upon the direction of flow of that oil. The volume and direction of flow in the motor are controlled by a dumbell type valve, the main valve, whose two circular lands cover two ports to the motor. Oil from the pump enters the center section of the valve and, if the valve is displaced from center, is allowed to pass into the motor through the port so opened, and is subsequently exhausted into the reservoir through the other port. The size of the port opening controls the volume of oil flowing and thereby the speed of the motor. The direction of rotation is controlled by the port that is opened to the oil supply.

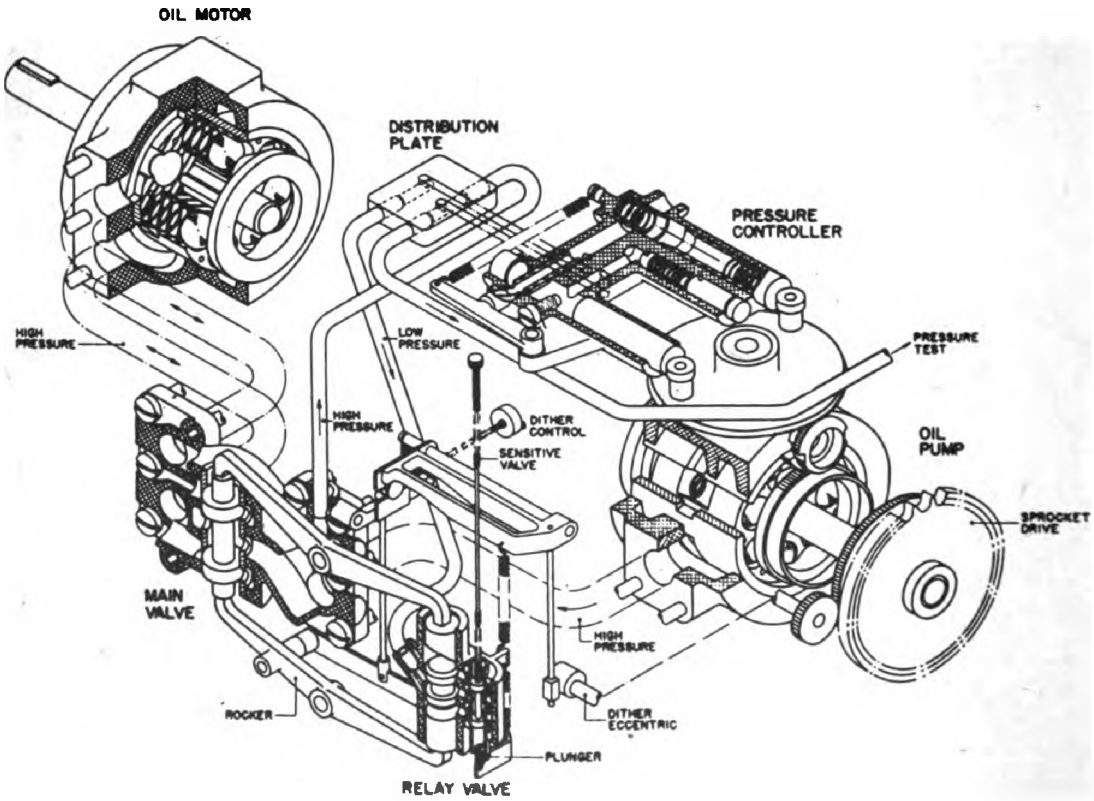

Figure 69. Schematic Drawing of Oil Gear M1.

Positioning of the main valve cannot be controlled directly by the synchro-differential, because the movement of the rotor in the synchro-differential is not strong enough to move this main valve. A relay valve assembly actually operates this main valve. A light weight pilot valve, operated directly by the synchro-differential, ports oil in the same manner as the main valve into either of two chambers behind relay valve plungers. This low pressure oil, 50 pounds per square inch, serves to amplify the torque of the synchro-differential, so that, through a two-lever system, the main valve can be moved.

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To make up for leakage in the system and to increase sensitivity a dither mechanism is employed. A sleeve with three rows of holes to coincide with the ports of the relay valve assembly, is alternately raised and lowered between the pilot valve and its ports. This motion alternately opens the ports to the low pressure oil of the pilot valve, thus causing the main valve to move up and down slightly by virtue of the changing position of the relay valve plungers. The frequency of the dither oscillation is fixed at 2,100 per minute, but the amplitude may be increased or decreased by means of the dither control button.

Using the oil gear M1 or M2, maximum rates of gun movement of 20 degrees per second in azimuth and 16 degrees per second in elevation can be attained in either direction. These rates are not great enough to operate the gun as fast as the data from the director may be changing and, consequently, the gun transmitter may lag more than one-half a revolution of the rotor, 10 degrees of gun movement behind that of the director, causing a condition known as 'jumping phase'. Actually the signal differences between the two transmitters are such as to change suddenly the direction of displacement of the pilot valve and thus the direction of movement of the gun. The signals again will reach the correct relationship although the gun will be 20° removed from its correct position.

As has been pointed out before, the synchro-differential only operates on difference of position of the rotors of the two transmitters, or lag. Greater rates require greater lags to attain the necessary displacement of the pilot valve; thus, as the rate increases, so increases the error in position.

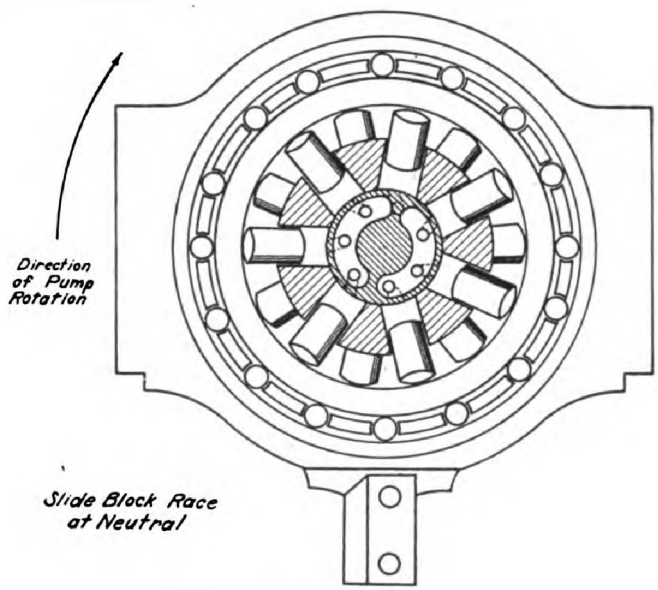

Figure 70. Slide Block Race at Neutral.

To overcome these weaknesses the oil gear M3 has been developed. It is a self-synchronous unit of high speed and high torque output with a lag correction device. In addition, a hydraulic limit stop protects the mechanical stops of the elevating arc of the gun.

The variable displacement pump consists of a cylinder with 14 radial piston bores in which are lap-fitted pistons. Outside this is a moveable slide block race, or stroking ring, against which the pistons are forced by centrifugal force as the cylinder is rotated at 2,000 revolutions per minute. As the slide block race is moved from its mean position, concentric with the axis of rotation of the cylinder, the pistons will take up a reciprocating action. Adjacent pairs of piston bores are tapped into one of seven axial holes in the pump shaft. At the end of the shaft is a flat valve with two moon-shaped grooves leading to an oil channel. As the pistons reciprocate the intake of oil is through one of these channels and the exhaust through the other.

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Whenever the slide block race is displaced from center, there will be pumping. Displacement in one direction however, will cause oil flow in one direction through the flat valve, and displacement in the other direction will reverse the direction of flow.

At 2,000 revolutions per minute with maximum displacement of the slide block race ⅛-inch in either direction, the pump can deliver about 30 gallons per minute. This maximum delivery will operate the hydraulic motor at approximately 1,800 revolutions per minute.

The hydraulic motor is of the same type construction as the pump except that the stroking ring is fixed at ⅛-inch displacement. Therefore the motor can be controlled in direction and speed from 0 to 1,800 revolutions per minute in either direction. It will deliver a maximum of 300 inch-pounds of torque at the output coupling and serve to drive the gun at maximum rates of 30 degrees per second in azimuth, and 23° per second in elevation. These greater rates make it possible for the gun to stay in synchronism with the director even when very great changes in rates are involved.

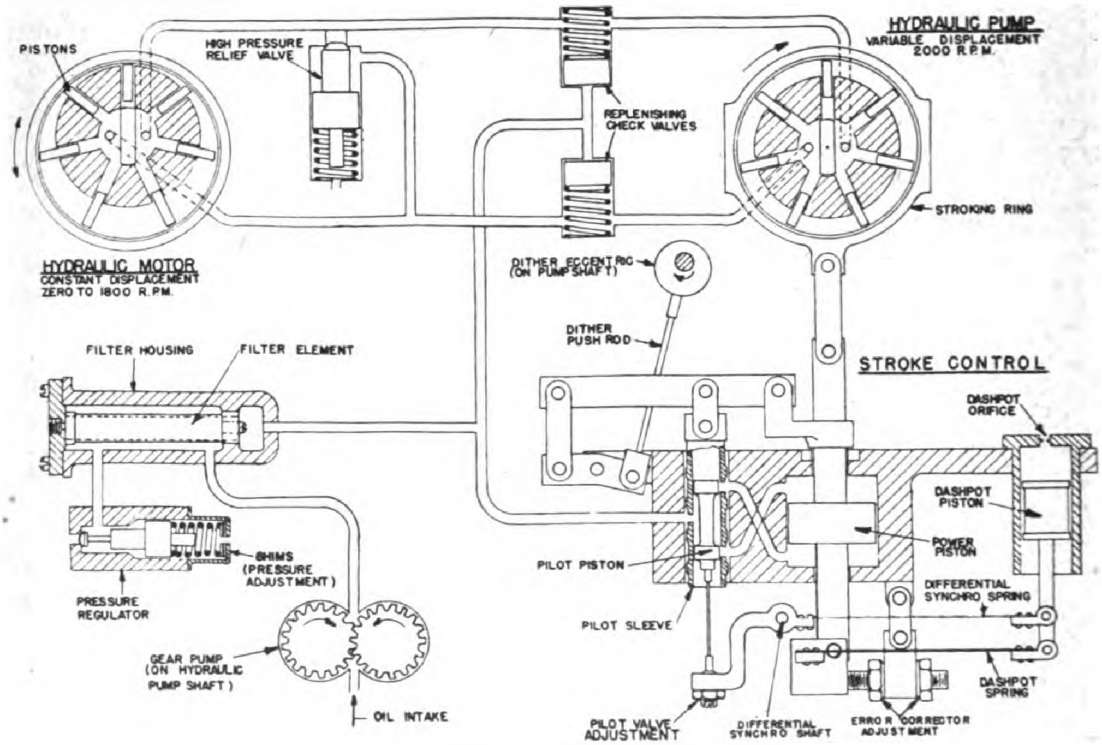

Figure 71. Hydraulic Schematic—Oil Gear M3.

The pump and motor are in a closed hydraulic system in which pressures will vary from 150 to 1,600 pounds per square inch. When the pressure reaches 1,600 pounds per square inch, a high pressure relief valve will by-pass the oil around the motor into the pump intake channel. If the pressure of the intake drops below 150 pounds per square inch, oil is forced into the system through one of the two replenishing check valves.

This oil to the replenishing check valves is furnished by a replenishing gear pump, a gear type pump operated by the pump shaft at 2,000 revolutions per minute. A pressure regulator regulates the pressure at 150 pounds per square inch by acting as a blowoff valve above 150 pounds per square inch. The reservoir for the gear pump is the housing of the whole hydraulic unit, and all the oil from the pump is run through a metal mesh filter before being allowed to enter the hydraulic transmission through the replenishing check valves. At the same time this low pressure oil is used in the stroke control unit to control the displacement of the slide block race.

The same fine data system is used with the oil gear M3 as with the oil gear

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M1, and movement of the rotor of the synchro-differential operates a pilot piston. This pilot piston, however, ports low pressure oil to either side of a spring-centered power piston. Thus, the power piston is displaced either up or down; and the slide block race, being attached to the piston rod, is likewise moved.

Sensitivity is attained again by the application of dither, the amplitude of which is fixed at plus or minus .011 inch motion of the sleeve. The frequency is fixed at 2,000 oscillations per minute by being operated by an eccentric section of the pump shaft. This small motion of the dither sleeve alternately lets low pressure oil in to one side or the other of the power piston, thus moving the slide block race up or down. Consequently, the oil motor and gun are constantly oscillating slightly.

To reduce the error in position due to the lag between transmitters necessary to operate the synchro-differential a lag corrector has been added. The lag corrector serves to hold mechanically the displacement of the pilot piston once a rate has been set in the unit and thus allows the two transmitters to synchronize. To return the pilot piston to neutral a reverse signal must be sent to the synchro-differential. The lag corrector and the fact that the unit operates at much higher rotational speeds make this unit much more accurate.

Under normal operation the control is through the same type fine data system as the M1 in which one rotation of the rotor of the transmitter indicates 20 degrees of gun travel. In addition, however, a coarse data system is employed with the oil gear M3, the same type system as the azimuth indicator, coarse transmitter and repeater. This coarse data system, through the necessary contacts and wiring, serves to pick out the correct synchronous spot for the fine data system to operate the gun. When the gun and director are more than 7 degrees out of synchronism, the coarse data system, by breaking signals to the synchro-differential and at the same time impressing single phase current across selected windings, serves to displace the pilot piston a maximum in the direction necessary to bring the gun to orientation by the shortest route. Because of this system the gun can be slewed by slewing the director.

When a remote control system M5 is altered to use the Oil Gear M3, it is given the nomenclature RCS M15. When, however, the system is built at the manufacturer to accommodate the Oil Gear M3, its nomenclature is RCS M10. The primary difference between these two remote control systems is that one has the azimuth indicator still mounted on the carriage but inoperative and the RCS M10 has no azimuth indicator.

Control Systems for Heavy AA Weapons

Data Transmission System. After World War I, when the great possibilities of bombers could be foreseen, the United States began planning and building an antiaircraft gun that would neutralize the efficiency of enemy bombers. At the outset of World War II, the army's three-inch antiaircraft gun was our answer to the problem.

This weapon was positioned manually by operators and the correct gun position was maintained by keeping dials, geared to the elevating and traversing mechanisms of the gun, positioned in agreement with dials carrying the firing data provided by the director. The task of keeping the dials matched at all times under conditions of constantly changing data, especially during battle, was most exacting. In fact, it was found to be humanly impossible to keep the gun exactly positioned in accordance with the director data. To improve this situation, remote control systems were developed to cause the gun to be positioned automatically and in agreement with the firing data as determined by the director.

Cable Systems. Either of these systems, the manual or the automatic, acts as part of the link between a mechanical or an electrical director and the gun. The director, acting as a computer-transmitter, must compute the correct azimuth, elevation, and fuze values which will allow effective firing. After firing data has been computed, it must be transmitted to the gun instantaneously and accurately. Cable systems serve this purpose for a battery of antiaircraft guns. They include sections of multiconductor cable to transmit data and power, from one unit to another. Also included is a main junction box which distributes power and data to each of the four guns. The cable used is flexible and very heavily insulated

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so as to withstand sustained exposure to weather and even to burial. Junctions between a section of cable and units such as the gun, the director, the height finder, or another section of cable are made by using special water tight connectors.

Self-synchronous motor transmitters and repeaters, commonly referred to as selsyns, are employed in the transmission of data between units. In the case of sending information from director to gun, two sets (each comprising one transmitter and one receiver) are used to convey azimuth information, two more sets are used for elevation data, and still another set is used in the transmission of fuze data. In the instances of azimuth or elevation, one transmitter and receiver indicates a coarse reading by virtue of having one complete revolution of the rotors equal to 6400 mils. The other transmitter and receiver pair carries, in a sense, vernier readings in that these rotors turn 16 times for each rotation of the coarse pair. It follows, then, that each rotation of these fine selsyns equals 400 mils. The only connections between the two elements of each pair are three wires to carry electrical impulses. Since a total of five pairs of selsyns are used, to convey all the information, however, the cables necessarily are made up of many conductors.

Indicator M4. The Data Transmission System M4 was one of the early efforts to keep a battery of antiaircraft guns controlled properly so that they might be used effectively against constantly moving enemy bombers. It was designed for use with the 3-inch antiaircraft gun. In this system, the azimuth and elevation gun data are received by the azimuth and elevation Indicators M4 respectively The azimuth indicator is mounted over and geared to the traversing mechanism on the left side of the gun carriage. The elevation indicator is mounted on the right side and geared to the elevating mechanism. In these positions, the indicator dials can be read easily by the operators of the elevating and traversing handwheels.

Each indicator houses two selsyn receivers, one for positioning the fine dial attached to the fine receiver rotor and the other for positioning the coarse dial attached to the coarse receiver rotor. The coarse and fine selsyn dials are unmarked except for a selsyn pointer. Placed concentrically around the selsyn dials are index pointers, which are also unmarked except for a pointer. The index pointers are geared mechanically through a differential assembly to the elevating or traversing mechanism of the gun. Around the index pointers are fixed circular scales, one for fine data and one for coarse. These circular scales are graduated in angular increments, 0-6400 mils on the coarse scale and 0-400 mils on the fine scale.

With this arrangement the traversing or elevating operator can match the gun position with the computed position by matching or bringing the mechanical pointers into alignment with the selsyn pointers. As long as both operators are "matching pointers," the gun will be positioned correctly in accordance with the director. The differential assemblies are provided to allow gun-director orientation to be accomplished.

Remote Control Systems. To decrease the errors in positioning the gun, existing because of the inability of gun operators to keep the pointers always matched, automatic features were developed for use with the more recent guns. The Remote Control System M2 is used in conjunction with the 90mm Gun on the M1A1 mount, the RCS M12 with the 90mm Gun M2, and the RCS M6 with the 120mm Gun M1. These systems allow the guns to be positioned in azimuth and elevation automatically. They are identical in basic principles of operation, differing primarily only in size of their components. Some few differences do exist and will be taken up later in the discussion. It is interesting to note also, that in case of a malfunction of the automatic features, dials are available so that the gun operators may position the gun manually by matching pointers as in the Data Transmission System M4.

Indicator Regulator M1. In the remote control systems, the selsyn signals from the director are brought to Indicator Regulators M1, there being one for azimuth and one for elevation. These mechanisms are located in the same relative positions and are geared in the same manner as are the indicators used in the Data Transmission System M4.

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In the indicator regulators the director signals are changed to directional electrical impulses which will be used to govern the gun movement in azimuth and elevation.

Each indicator regulator contains the two selsyns and dials for manual operation as did the Indicator M4. In addition, each contains a synchronous transformer, a synchronizer, and a lag meter which are necessary for automatic operation.

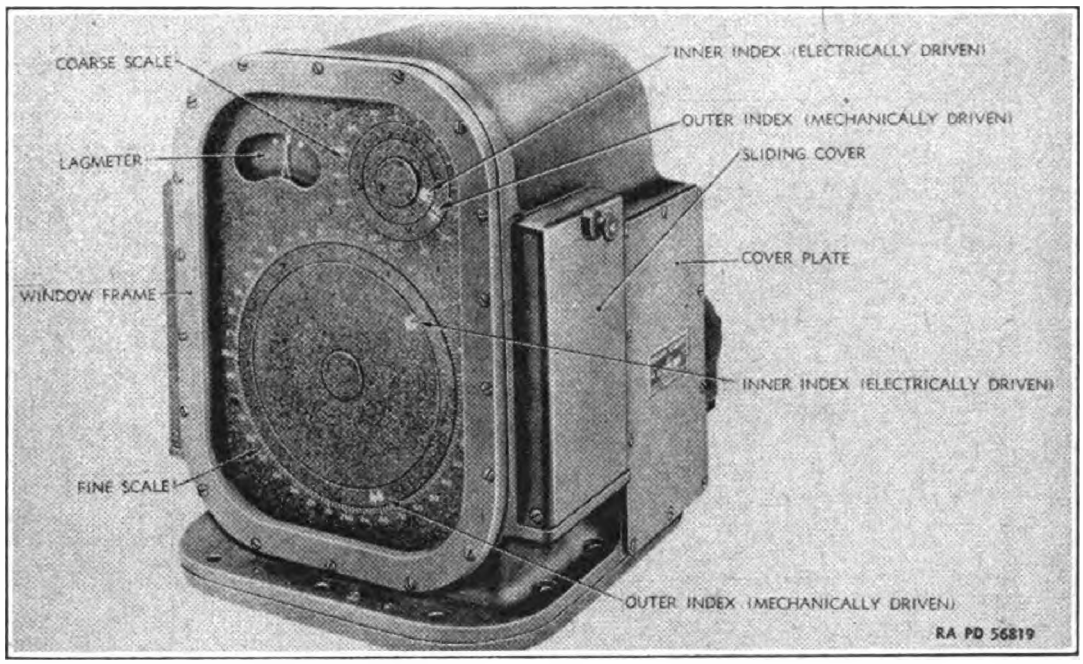

Figure 72. Indicator-Regulator M1.

Synchronous Transformer. The synchronous transformer is a variable transformer so constructed as to be very similar to a selsyn. Just as does the selsyn, it has three field coils and one rotor coil. The stationary field coils are energized by the field coils of the director transmitter which are wired in parallel with those of the gun receiver. The rotor is geared to the elevating or traversing mechanism so that it will make one complete revolution for every 400 mils of gun movement. Unlike the selsyn, however, the rotor is not energized by direct connection but has an alternating current induced in it, due to its position within the field of the three coils. Further, the rotor of the synchronous transformer is geared to the gun in such a way that when the gun is pointed in agreement with the director (or in synchronism) there will be no induced voltage. If the gun is not in synchronism, however, there will be an induced voltage of a phase dependent upon which side of the synchronous position the gun is located.

There are two relative positions of the rotor and the field where the induced voltage is zero. One of these positions is reached when the gun is in synchronism or at any multiple of 400 mils from synchronism, and the other is when the gun is 200 mils from synchronism or at any multiple of 400 mils from that position. This means that as the gun elevates, or depresses, or traverses, the signal output of the synchronous transformer will change phase every 200 mils.

Synchronizer. The synchronizer is, in effect, a switch consisting of two units, the silver slip ring assembly and the silver roller contactor assembly. The slip ring assembly, geared to and positioned by the gun, includes a bakelite ring in which are imbedded continuous silver contact rings and a segmented silver ring. The segmented ring itself is actually three separate segments, two of which are connected to the continuous rings, which are energized. The third segment is dead in that it has no connection.

The second main unit of the synchronizer is the silver roller contactor, and it is mounted to and positioned by the coarse selsyn rotor. As the rotor and dial rotate in accordance with the gun data, the roller contactor makes point

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contact with the segmented ring. As it contacts one energized segment, the circuit is such as to select an alternating current phase signal; the other live segment will select the opposite alternating current phase signal. We will see later that the phase selected will determine the direction of gun movement. When the silver roller contactor is on the dead segment, which extends for about 300 mils, the circuit is broken and no phase current is selected. The center of the dead segment when contacted by the silver roller represents synchronism of gun and director.

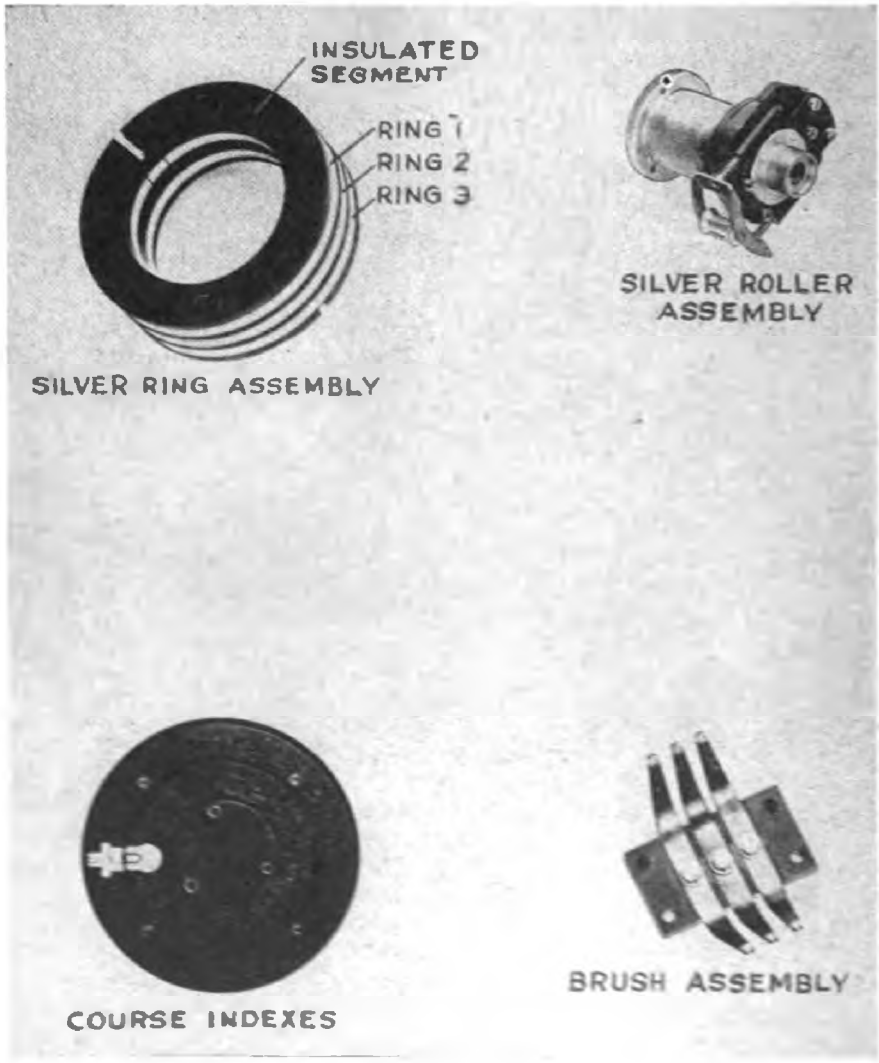

Figure 73. Synchronizer Components.

The synchronous transformer and the synchronizer are in parallel. Each has an output signal voltage, the synchronous transformer for 6400 mils gun movement and the synchronizer for all but 300 mils, i.e., 150 mils on each side of the synchronous point. While the roller contractor is contacting a live segment, the effective voltage of the synchronous transformer is minimized to a fraction of that selected by the synchronizer. When the contactor is on a dead segment, the synchronous transformer voltage becomes the control voltage.

When the gun is more than 150 mils from synchronism, the synchronizer phase output is a signal which ultimately will cause the gun to move toward synchronism until the contactor is on the dead segment. When this is reached the synchronous transformer, whose signal is of the same phase as that produced by

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the synchronizer at this point, enables the gun to continue to move into synchronism.

The lagmeter is a milliameter which is located in the Indicator Regulator M1. It is connected to the synchronizer and to the synchronous transformer output, and will indicate any current flow. If current is flowing, it shows that the gun is not in synchronism. Conversely, if there is no output from the synchronizer or synchronous transformer, the gun is in synchronism. The gun operators can use this meter for a visual indication of the proper operation of the remote control system.

Up to this point we have available for use a selected phase of electrical signal from the synchronizer and the synchronous transformer. We will now see how this signal will be used to control the positioning of the gun.

The Stroke Motor. The combined alternating current signal voltage output from the synchronizer and synchronous transformer is fed into a resistor circuit where the alternating current voltage is added to a direct current voltage, the source and purpose of which we will discuss later. The output from this resistor circuit is fed into a three-stage amplifier where the voltage and amperage are increased without affecting the phase characteristics. The variable output from the amplifier is used to energize one field of a small two-phase motor. The other field is energized by a fixed phase from the three-phase power generator. This motor, referred to as the stroke motor, will rotate in one of two directions depending upon the phase output from the amplifier relative to the fixed phase from the power generator. The stroke motor has a fractional horsepower rating and is not capable of positioning the gun. The direction of rotation, of the stroke motor, however, is indicative of the desired gun movement.

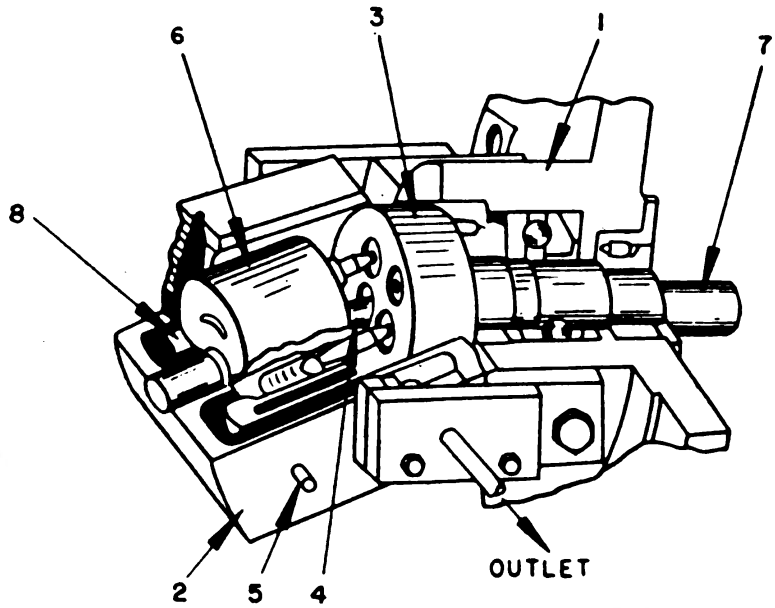

Figure 74. Schematic Diagram Showing Operation of A-End (Oil Pump).

Hydraulic Systems. The actual gun movement is caused by a hydraulic motor, to which a flow of oil is sent by a hydraulic pump, driven, in turn, by an electric power motor. A very small oscillation or vibration is purposely placed in the action of the pump so that the gun will always be oscillating imperceptibly. This small oscillation or dither causes the gun to be more sensitive to small signals from the synchronous transformer without impairing the gun's accuracy.

The pumps (one for azimuth and one for elevation) are of the rotary, variable delivery piston type. Essentially the pump consists of a flange and shaft driven at a constant speed and in a constant direction of rotation by the power motor, a cylinder block connected to the flange by a universal link so that it rotates with the flange, and seven pistons fitted into the cylinder block and connected

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to the flange by connecting rods. An inlet and outlet oil port allows oil flow to and from the cylinders.

The flange rotates in a fixed housing, but the cylinder block rotates in a housing or yoke which may be moved to vary the angle between the axis of rotation of the flange and that of the cylinder block. When this angle is zero, the cylinder block is parallel to the flange, and the seven pistons will not change their relative position within the revolving cylinder block. Thus the oil volume between the pistons and the base of the cylinder block remains unchanged, and no oil is pumped.

Now, let us displace the cylinder block housing so that it is no longer parallel to the flange. As the flange and pistons rotate, the pistons will move relative to the cylinder block. The oil volume within each cylinder is changing. During one half revolution of the cylinder block, some of the oil below any one piston will be exhausted into the outlet port, and during the next half revolution, oil will be drawn in through the inlet port. If we should cause the cylinder block housing to be displaced in the opposite direction from that position just discussed, we would find the pumping action to be reversed. That port which was the inlet now becomes the outlet and vice versa. The quantity of oil pumped is dependent upon the magnitude of the angular displacement of the cylinder block. If the cylinder block is displaced to the left of the center position, the oil flows in one direction. Similarly, the oil will reverse its direction of flow when the cylinder block is displaced to the right of center. The center position, of course, is that position of the yoke where no pumping takes place.

We can now visualize the action of the stroke motor in conjunction with the hydraulic pump. Since the movement of the stroke motor is geared through a hydraulic force amplifier to the hydraulic pump, we find that with a counterclockwise rotation of the stroke motor the cylinder block is displaced to one side of the center position; with a clockwise rotation the cylinder block will be displaced to the other. Thus, the selected phase output from the amplifier will control the direction of oil flow from the pump.

Through hydraulic lines, the oil is led to a hydraulic motor of the same principle as the pump, with the exception that there is a fixed angle of displacement between the flange and the cylinder block. Dependent upon which direction the oil is flowing, the flange will rotate in a given direction. A driving gear is turned by a shaft connected to the flange and this gear, meshed with either the elevation rack or the azimuth ring gear causes the gun to be positioned automatically from the humble beginning of a small impulse sent from the director to the gun.

In visualizing the action of the hydraulic pump it can be seen that the cylinder block will continue to be displaced by the stroke motor as long as there is an alternating current signal emanating from the synchronizer and synchronous transformer. When this signal voltage becomes zero upon reaching the synchronous point, the cylinder block will have been displaced to a maximum and the gun will be moving at a maximum speed across the synchronous point. Upon crossing the desired position of synchronism a new signal voltage of an opposite phase is induced in the synchronous transformer which reverses the rotation of the stroke motor and the displacement of the pump cylinder block. This, of course, will reverse the direction of movement of the gun. By the time we again reach synchronism, the cylinder block is again displaced to a maximum but in the opposite direction. This cycle would continue indefinitely and the gun would oscillate back and forth across the synchronous point, were some corrective device not employed.

To remove this oscillation of the gun about the synchronous point, an additional electrical circuit is used. The stroke motor, while positioning the cylinder block of the pump, is also geared to a small direct current generator. When the stroke motor runs, because of the alternating current signal from the synchronizer and synchronous transformer, the generator produces a direct current voltage of an amplitude proportional to the speed of rotation of the stroke motor. The direct current is stored in a large condenser where it is held until the alternating current signal diminishes in strength due to the gun's approach to the synchronous point. As the alternating current signal voltage decreases, the stroke motor's speed of

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rotation slackens, and this necessarily slows down the direct current generator action. The direct current voltage in the condenser discharges through the resistor circuit to the input of the amplifier. The generated direct current voltage is, of such a magnitude and polarity as to overcome the alternating current signal and to reverse the phase output from the amplifier. Since the output from the amplifier has been reversed, the stroke motor will have a reversed rotation and the cylinder block will be returned toward the center position. This reversal takes place before the gun reaches the synchronous point. The gun will come to rest on the synchronous point after approximately five oscillations. Thus, our problem of oscillation is removed by employing the direct current generator circuit.

The gun has now been positioned in azimuth and elevation using the original starting signal as a control in determining the direction in which the gun will move.

In the RCS M2 on the 90mm AA Gun M1 on Mount M1A1, a special elevation limit stop valve is placed in the elevation hydraulic lines between the pump and the hydraulic motor. At 0° (when gun tube is horizontal) or at 80° elevation, this valve by-passes the oil around the hydraulic motor to prevent the gun from crashing into and damaging the mechanical elevation limits. A valve is not necessary in azimuth as continuous traversing in azimuth is possible.

Instead of using a valve on the 90mm AA Gun M2, the RCS M12 has a small cam inclosed under the Indicator Regulator M1 which is geared to the elevation rack. The cam follower is linked to the hydraulic pump. The rise and fall on the cam causes the hydraulic pump to be removed to the neutral position upon the gun's movement to either —10° or + 80° elevation.

On the 120mm AA Gun M1, a large curved cam is mounted beside the elevation rack. This cam acts similarly to the cam on the 90mm Gun M2 in that gun movement is halted at —5° and + 80° elevation by action of the cam follower linked to the hydraulic pump.

On the M2 90mm Gun and the M1 120mm Gun, an additional stop on the cam surfaces may be selected. This additional stop will cause the gun to cease moving at 22½° thus protecting guns and operations in front from being fired upon when the enemy target is flying at low altitudes.

FUZE SETTING AND RAMMING EQUIPMENT

Most fuze setting equipment is considered fire control equipment, but ramming equipment is not. Ramming devices are artillery items and are in about the same category as recoil mechanisms. On the latest antiaircraft guns, however, the devices for setting the fuze and ramming the round are so interconnected that it is difficult to discuss one without involving the other. Therefore, this section, although nominally covering only fire control equipment, will deal with both. The equipment considered will be that used as standard equipment on 3-inch antiaircraft guns, the 90mm gun on mount M1A1, the 90mm gun on mount M2, and the 120mm gun.

The fuze setter on the 3-inch gun is a relatively simple mechanism, and the rammer is nothing more than a strong arm for the gunner. On the 120mm gun, however, the automatic fuze setting and ramming equipment is a large and complicated mechanism. The reasons for using a complicated mechanism all add up to the fundamental purpose of enabling the weapon to deliver more effective fire; but let us consider some of the individual problems in more detail before moving on to discussion of actual fuze setting and ramming equipment.

The setting of time fuzes in antiaircraft fire must be accurate. If a shell is traveling at a speed of 2,000 feet per second at the time of burst, an error of .5 seconds in the fuze setting would cause the burst to occur at a point 1,000 feet from the target. This is obviously too great an error to tolerate. Fuze setters are constructed to set fuzes within a time limit tolerance at .05 seconds. This requires rather precise mechanisms. The fuze setting operation must also be accomplished rapidly enough so that the rate of fire of the weapon is not retarded.

Rapidity of fire is also a primary consideration in the ramming operation. Antiaircraft weapons can be loaded by hand, but machinery can do it faster, particularly at high elevations during sustained fire when men get tired but machines do not.

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The effect of dead-time is another factor influenced by fuze setting and ramming equipment. Dead-time is defined as the time that elapses between the setting of the fuze and the firing of the round. It tends to cause inaccuracy of fire because fuze data changes during this period. In other words, the fuze setting may be correct at the instant of setting, but will no longer be correct by the time the round is fired. As is mentioned under the section on directors, approximate compensation for dead-time is made in the director; but this compensation will be more nearly accurate when the dead-time is short and uniform. With manual fuze setting and ramming, dead-time will be a matter of seconds. Also it will vary from round to round for any one gun, and the different gun crews of a battery will cause different average dead-times. Automatic fuze setting and ramming equipment, however, can reduce this dead-time to a fraction of a second and make it practically uniform for all rounds fired.

For convenience of discussion, fuze setting and ramming equipment may be divided into three main groups: manually operated fuze setters; spring rammers; automatic fuze setting and ramming equipment. Manually operated fuze setters are used either as primary or auxiliary equipment with each of the weapons being considered. A spring rammer is used with the 90mm M1A1 gun. Automatic fuze setting and ramming equipment is used on the 90mm M2 and the 120mm weapons.

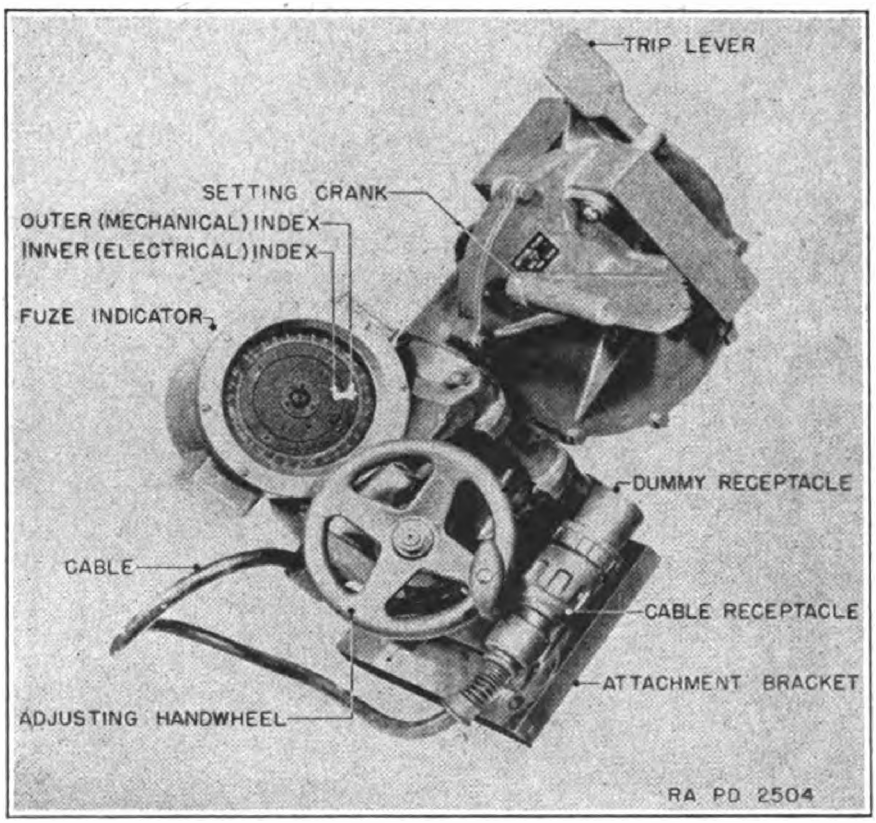

Figure 75. Fuze Setter M13—Closed.

Manually Operated Fuze Setters. Fuze setters M8, M13, and M18 are all of this type. The M8 is the only fuze setting equipment provided for the 3 inch gun. The M13 is the only fuze setting equipment used with the 90mm M1A1 gun. It is also provided with the 90mm M2 gun for use when the automatic equipment on the gun is not used. The M18 is auxiliary equipment on the 120mm gun for use when the automatic fuze setter is not used.

All of these fuze setters operate on the same principles and are very similar in construction. The chief difference among them is that they are built to accommodate projectiles of different diameters. They are precise mechanisms capable of setting fuzes very accurately. Their operation, however, does involve a pointer

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matching procedure which introduces a possible source of error. Figures 75 and 76 are illustrations of the fuze setter M13. The other two fuze setters are very similar in appearance, and each consists of three principal mechanisms: an indicating mechanism, an adjusting mechanism, and a setting mechanism.

The heart of the indicating mechanism is a selsyn repeater which is connected electrically to the fuze transmitter at the director. This repeater has a dial mounted on its shaft which indicates accurately the fuze data being transmitted from the director. Also included as part of the indicating mechanism is an outer index which is geared to the adjusting mechanism and which indicates the fuze range at which the setting mechanism is positioned.

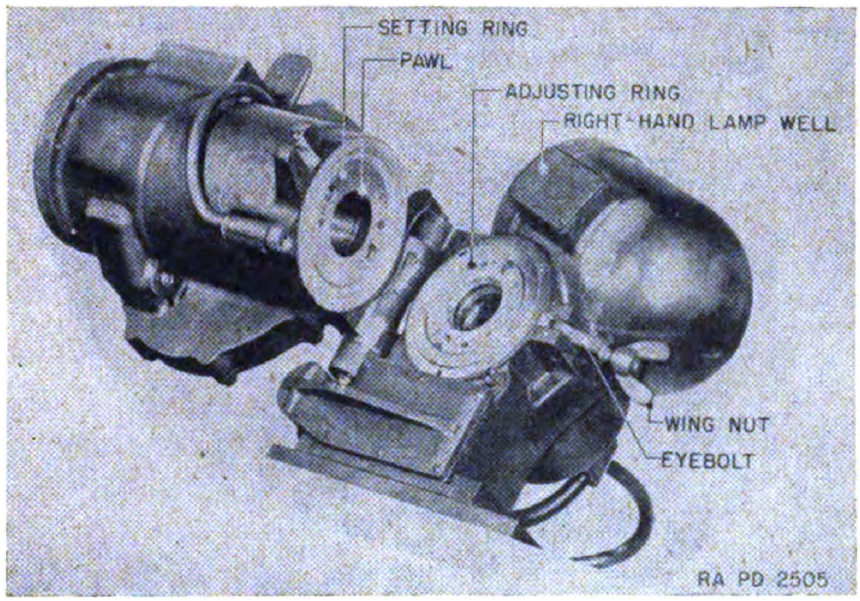

Figure 76. Fuze Setter M13—Open.

The adjusting mechanism is the part of the fuze setter that determines the fuze range to which a fuze will be set. It consists essentially of an adjusting ring, a handwheel, and gearing between these two elements whereby the adjusting ring is rotated when the handwheel is turned. The adjusting ring contains a pawl which engages the slot in the movable or forward portion of the fuze. It is the position of this pawl that determines the fuze range to which the fuze will be cut.

The setting mechanism consists primarily of a chamber to receive the projectile, a setting ring, and mechanism for rotating this chamber and ring two revolutions when the setting crank is turned one revolution. The setting ring carries a pawl that engages the slot in the fixed or rear part of the fuze. This pawl always starts and ends its motion at one particular position.

Over-all operation is as follows: The inner index continually shows the desired fuze setting. An operator turns the handwheel to keep the outer index lined up with the inner index and in so doing keeps the adjusting ring in the proper position to produce the desired setting. In setting the fuze on a round, the projectile is inserted into the projectile chamber in any angular position; the trip lever is pushed; and the setting crank is turned one revolution. Motion of the crank is limited to one revolution by a ratchet mechanism operated by the trip lever. At some point during the first revolution of the setting ring, its pawl will engage the slot in the fixed portion of the fuze and cause the entire round to rotate. As the round turns, the pawl of the adjusting ring will engage the slot in the movable portion of the fuze when the two devices are aligned. From then on the movable part of the fuze is held stationary while the projectile and fixed part of the fuze rotate. When the setting ring completes its second revolution, the movable portion of the fuze will have been rotated with respect to the fixed part of the fuze through an angle equal to that between the setting and adjusting pawls. Since

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the handwheel operator, by matching pointers on the dials of the indicating mechanism, keeps this angle at the proper value to produce the fuze setting shown by the inner dial, the fuze is set to agree with the fuze data being transmitted by the director.

When a gun is in firing position, these fuze setters are mounted in a position convenient for passing ammunition to the fuze setter and from the fuze setter to the breech of the gun. When the gun is in traveling position, the fuze setters are secured elsewhere on the mount.

Spring Rammers. This type of rammer is used on the 90mm M1A1 gun. The M8A1 model is at present standard equipment. A rammer of this type is shown in Figure 77.

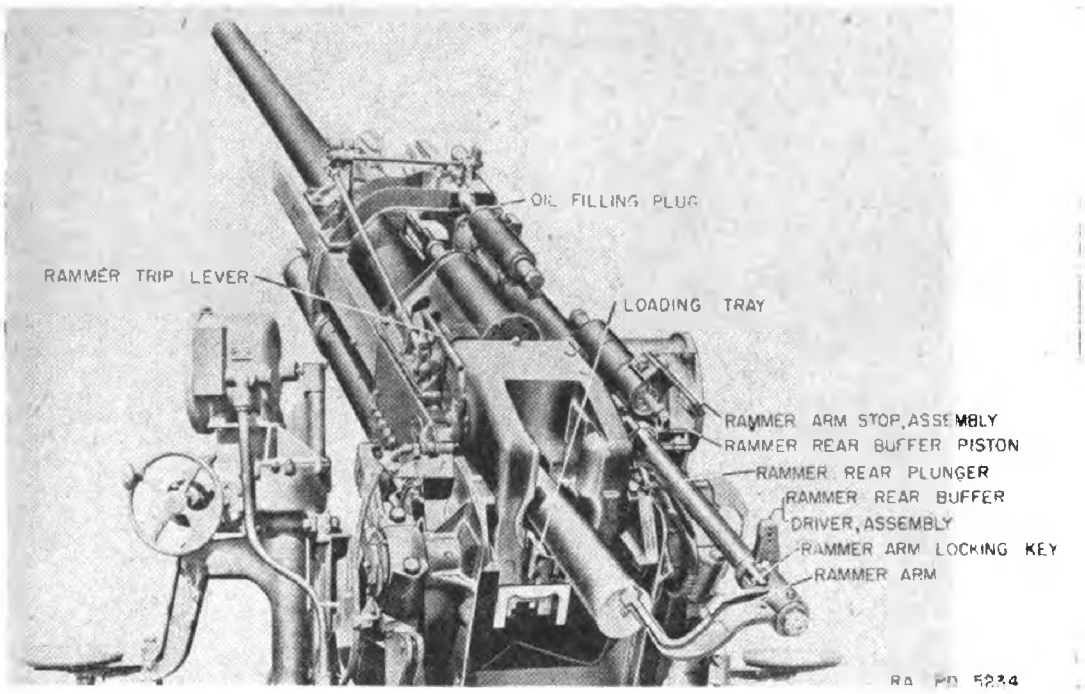

Figure 77. Rammer—Ready to be Tripped.

Fundamentally, this rammer is a mechanism for forcing the round into the chamber by the action of a strong spring. During recoil this spring is compressed and the mechanism positioned for ramming the next round.

The spring is contained in a cylinder mounted on the top of the right side of the cradle. Projecting from the rear of this cylinder is the rear plunger. This plunger carries the rammer arm which can be rotated on the plunger. When the spring is compressed, the plunger and rammer arm are moved sufficiently to the rear for the rammer arm to be rotated down behind a round of ammunition, placed as shown in Figure 77. Upon release of the spring, the plunger and arm are carried forward, forcing the round into the chamber. As the breech block moves up behind the round, it strikes the rammer arm and starts to move the arm upward. This upward motion is continued by spring action until the arm is in a position to be clear of the gun during recoil. An interlock mechanism is included to prevent the gun being fired unless the arm is clear.

The spring is compressed during recoil by a hook on the tube support engaging a rack on the forward end of a plunger which projects from the front of the spring housing. When the spring has been compressed, the hook is disengaged and the gun continues to recoil. The rammer is held in the cocked position with the spring compressed by means of a latching mechanism. Rearward motion of the rammer is brought to a smooth stop by action of the front buffer, which is engaged just after the hook is released.

The ramming operation is started by pulling the trip lever which releases the

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latch and allows the spring to expand and to move the plungers and attached parts forward. Forward motion is stopped with a cushioned effect by action of the rear buffer.

Since this rammer is cocked by recoil, it is necessary to ram the first round of ammunition by hand. Thereafter the loading operation consists of placing the projectile in the loading tray, rotating the rammer arm down until it is locked in position behind the base of the cartridge case, and then pulling the trip lever.

Fuze Setter-Rammer for 90-mm Gun M2. The automatic fuze setting and ramming equipment on this gun is composed of three major items: the amplifier M1A1, the motor drive M2E1, and the combination fuze setter-rammer M20. The first two of these units are primarily electrical. They function to transform the fuze data, which is received in electrical form from the director into mechanical form so that it can be used by the fuze setter-rammer. The combination fuze setter-rammer M20 is a mechanical device that rams the round, and while doing doing so, sets the fuze according to the data delivered by the amplifier and motor drive. This automatic equipment greatly improves the characteristics of this weapon as compared to the M1A1 gun. The fuze setting is entirely automatic, thus removing the chance for errors in pointer matching. Power ramming speeds up the rate of fire to twenty-five rounds per minute. Dead-time is reduced to about .4 seconds and is practically constant for all rounds fired

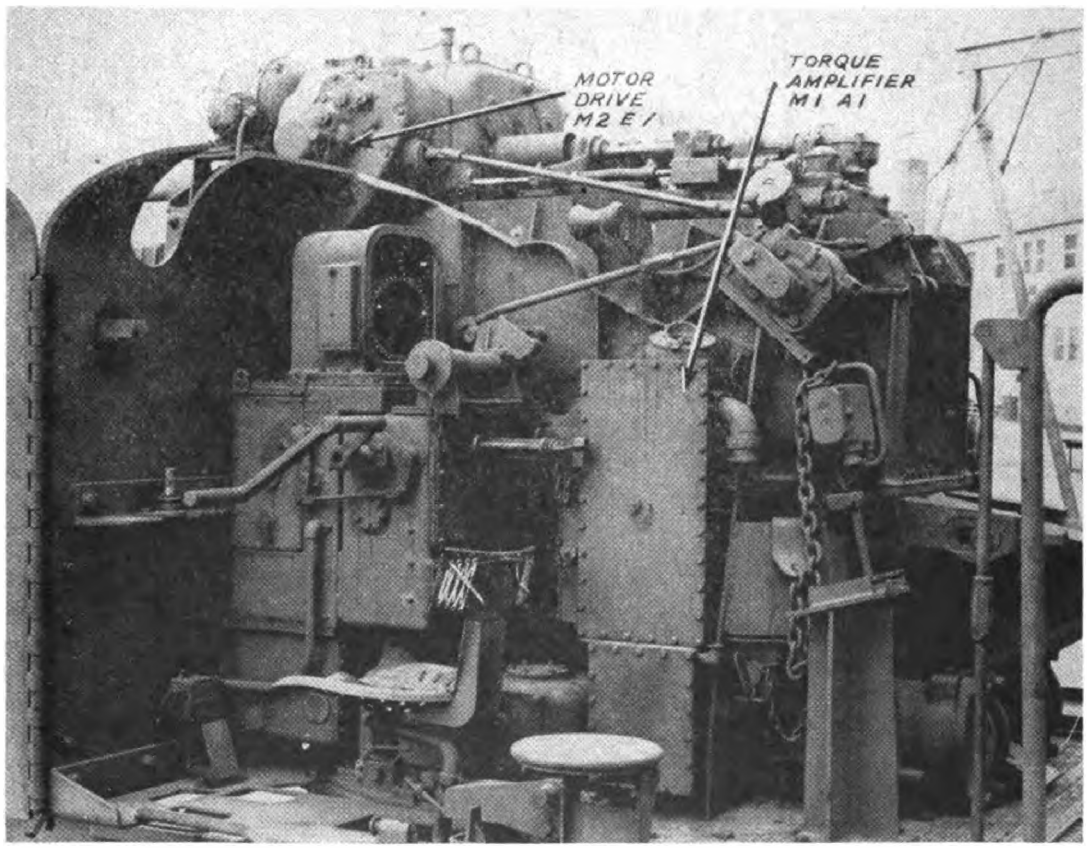

Figure 78. Amplifier M1A1 and Motor Drive M2E1 Mounted on Gun.

Amplifier M1A1 and Motor Drive M2E1. These two units are shown in Figure 78. The motor drive is mounted on the side of the transmission of the fuze setter-rammer; the amplifier is mounted on the left side of the gun mount just above the platform. Although they are separate units, their operation is very much interconnected. They are often referred to collectively as the torque amplifier or fuze setter servo-mechanism.

As an input this torque amplifier receives fuze data from the director electrically. As an output it delivers fuze data to the fuze setter-rammer in the form

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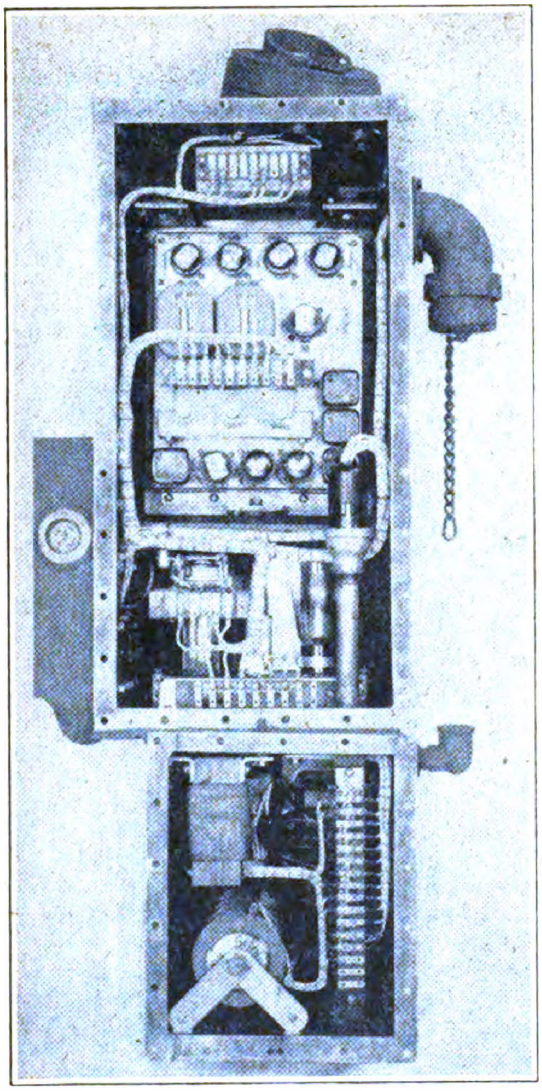

Figure 79. Amplifier M1A1 with Covers Removed.

of the position of an output gear in the motor drive. This gear meshes with a gear of the fuze setter-rammer.

Within the motor drive is a unit known as a synchro-transformer. In construction it is very similar to a selsyn repeater. It is this unit which receives fuze data from the director through electrical connection to the director fuze transmitter. Its rotor is positioned by the output gear of the motor drive and thus the synchro-transformer receives the fuze data being fed to the fuze setter-rammer. Figuratively speaking, the synchro-transformer compares the two sets of data and renders a decision as to whether or not they agree. If they do not agree, it produces an alternating current output signal. If they agree, it produces no signal.

The output signal from the synchro-transformer is fed to the amplifier M1A1. This unit is essentially an electronic amplifier and rectifier. Within the amplifier the signal is changed to direct current; its power is amplified; and it is otherwise altered so that it is able to operate properly a direct current motor capable of producing up to ¼ horsepower. This motor is mounted in the motor drive and is geared to the output gear.

Whenever the output gear is positioned so that the fuze data going into the fuze setter-rammer does not agree with the director data, the signal from the synchro-transformer, after passing through the amplifier, causes the motor to run and turn the output gear until its position does agree with the director data. With the output gear in this position, the synchro-transformer ceases to produce an output, and the motor stops turning the output gear. Any slight difference between input and output data causes this corrective action to take place. If the fuze data is constantly changing, as is usually the case, the motor is kept turning just fast enough to keep the output gear properly positioned.

In case of malfunction in automatic operation, provision is made for manually introducing fuze data into the fuze setter-rammer. By operating a knob on the motor drive the motor may be disconnected from the output gear and a handwheel connected instead. In operating this handwheel, the operator is guided by observing an electric meter called a lagmeter. When the needle of this meter is in the center position it indicates that the output gear is positioned to agree with director fuze data. The handwheel operator turns his handwheel to keep the lagmeter needle centered.

Combination Fuze Setter-Rammer M20. As its name implies, this equipment sets fuze first and rams the shell into the chamber. Ramming is accomplished by a pair of rubber rolls shaped like hour glasses and mounted in a housing behind the breech ring of the gun. These rolls are power driven and once the projectile is entered between them, it is drawn in and projected into the gun chamber.

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Their action might be compared to that which would result from feeding a pencil between the rollers of a laundry wringer. In addition to being rotated, these rolls are so mounted that they can be separated far enough that the cartridge case can pass between them during ejection.

Setting of the fuze is accomplished by three jaws mounted in the same housing as the rolls and projecting down into the passageway to the breech just ahead of the rolls. Each of these jaws carries a small knife which bites into the moveable part of the fuze when the round is forced against the jaws by the ramming rolls. In setting the fuze the jaws rotate; and, since they engage the moveable portion of the fuze, this is turned also. After the fuze is set, the jaws are opened out to allow the round to proceed into the chamber. They remain in the open position during recoil to allow ejection of the cartridge case.

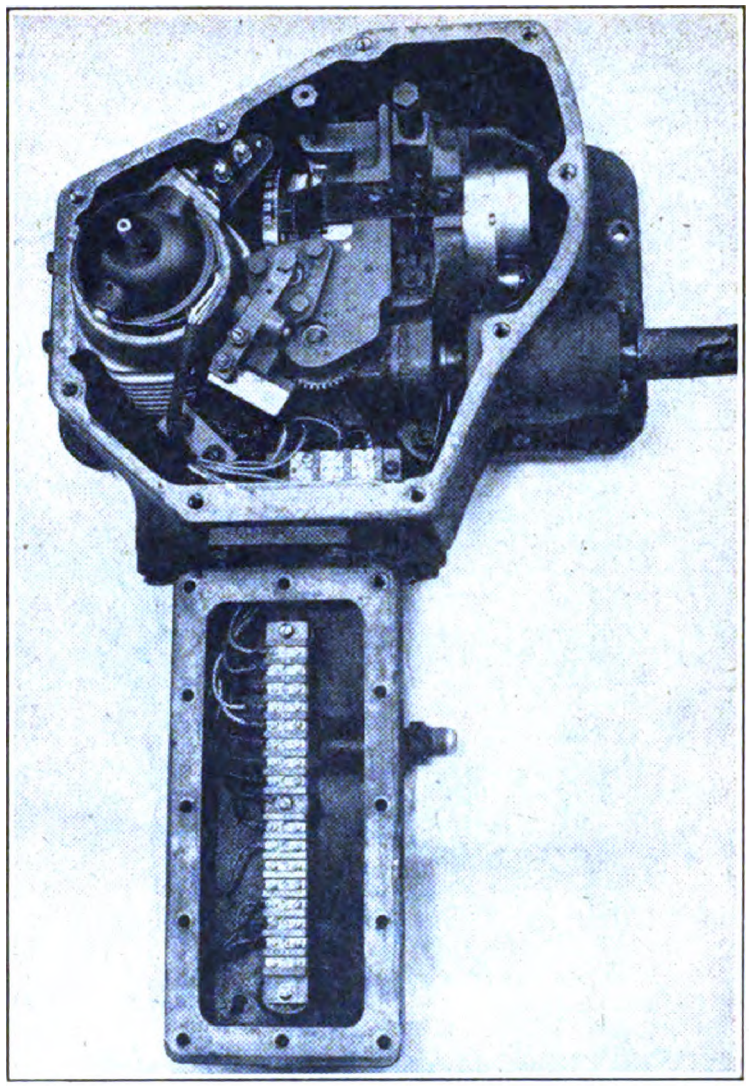

Figure 80. Motor Drive M2E1 with Covers Removed.

Motion for operating the ramming rolls and fuze jaws is transmitted to them through four shafts which are mounted above and parallel to the gun tube. These shafts show clearly in figure 81. One shaft rotates the ramming rolls; a second opens and closes the ramming rolls; a third rotates the fuze jaws; and the fourth opens and closes the fuze jaws. These shafts, together with the ramming rolls and fuze jaws, recoil with the gun.

The shafts mentioned in the foregoing paragraph are operated by the transmission. It is mounted on the cradle and does not recoil. Connections between the transmission and the shafts which rotate the rolls and fuze jaws are couplings which separate during recoil. The shafts that open and close the rolls and fuze jaws are operated by contacting parts of the transmission, since the motion of these shafts is longitudinal rather than rotary. The transmission itself contains a rather intricate mechanism that actuates the external shafts in the proper sequence, at the proper time, and in the proper amount during the ramming and fuze setting cycle. Power for the transmission is obtained from an electric motor mounted just in front of the transmission.

The sequence of operations during a cycle is as follows. At the beginning of the cycle the ramming rolls are positioned close to each other and are rotating at a low rate; the fuze jaws are projecting down into the shell passage; and

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the mechanism within the transmission that determines the fuze setting is being continuously positioned by the torque amplifier. A round is entered between the ramming rolls. The fuze on this round must be set at 'safe', for, unlike the manual fuze setters, this device will not set a fuze correctly from any initial

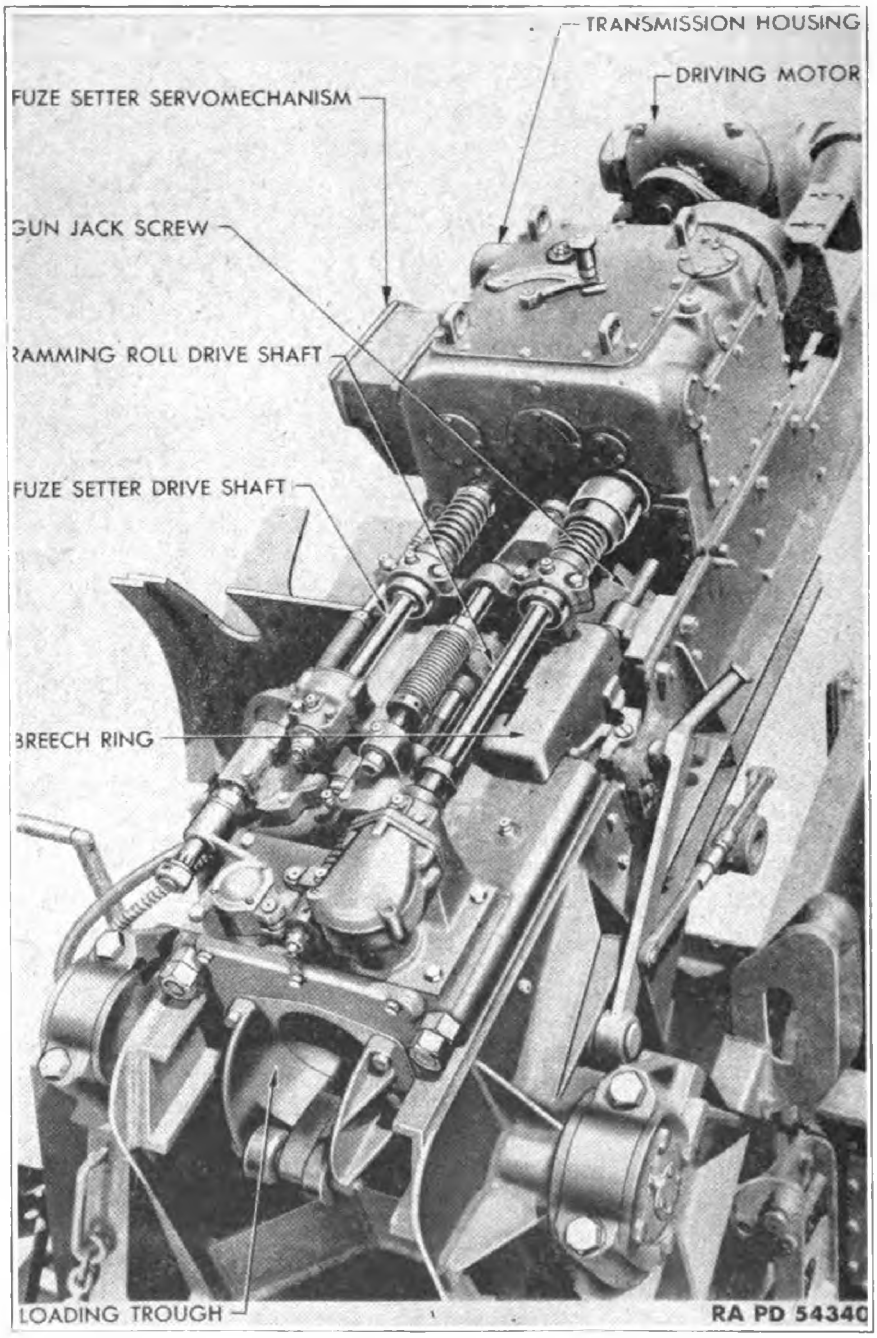

Figure 81. Combination Fuze Setter-Rammer M20—Right Side.

setting other than 'safe'. The rolls draw the round in until the fuze strikes the fuze jaws. This stops forward motion of the round and causes the ramming rolls to stall. Stalling of the rolls actuates a mechanism within the transmission that causes the fuze jaws to rotate just the right amount to set the fuze according to the data being fed into the transmission by the torque amplifier. Once the fuze is set, the fuze jaws open out; the ramming rolls start rotating at

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a high rate; and the round is projected into the chamber. At the same time the fuze jaws, while still open, rotate to their starting position. After firing the gun recoils with the ramming rolls and the fuze jaws open, so that the cartridge case can be ejected. During recoil the action of the counterrecoil buffer causes the transmission to recycle back to starting conditions. When the gun returns to battery and the external shafts contact the transmission, the rolls and fuze jaws are closed and the rolls are driven at low speed. The fuze setter-rammer is ready to receive another round.

For use with ammunition not having a time fuze, the operation is somewhat different. By shifting a lever on top of the transmission the fuze jaws are held continuously in the open position and the rolls are driven continuously at high speed. This operation allows the round to be rammed at a high rate of speed directly into the chamber without pausing on the way for the fuze setting operation.

Fuze Setter and Rammer for 120mm Gun M1. The fuze setting and ramming equipment for the 120mm AA gun is composed of two major items, the automatic fuze setter M19 and the power rammer M9. The former is a mechanical and electrical device which automatically sets the fuze according to the fuze range data transmitted to the fuze setter from the director. The latter unit is a power driven, arm-type rammer which rams the round after the fuze has been set. The power rammer also includes a mechanism for moving the automatic fuze setter into position, setting the fuze, and for withdrawing the fuze setter to its idle position after the fuze has been set. These items are provided for the same reasons as is the automatic fuze setting and ramming equipment on the 90mm AA gun mount M2. They make for accurate fuze setting, short and constant dead-time and rapid rate of fire.

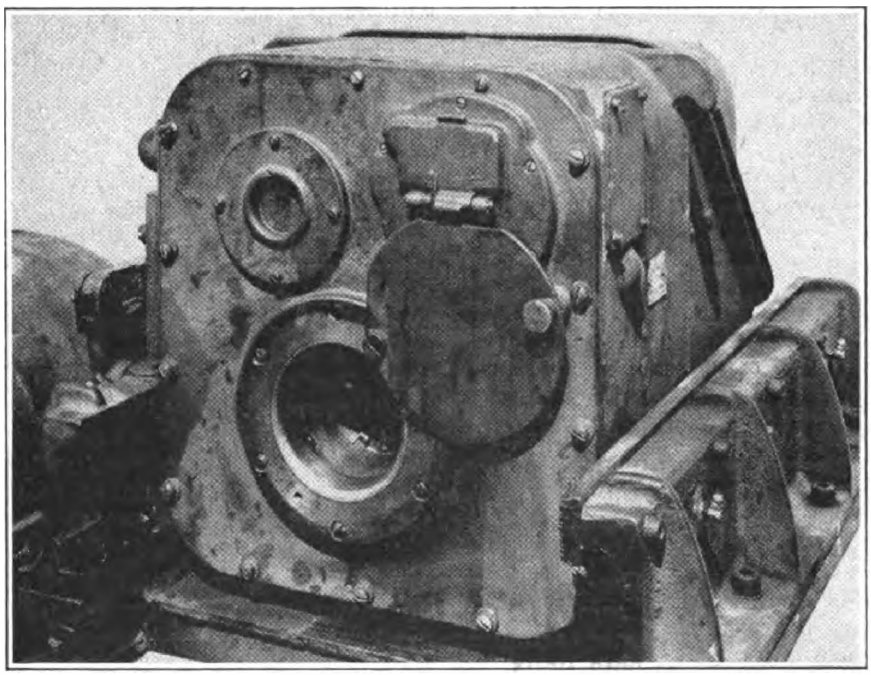

Figure 82. Fuze Setter M19.

Automatic Fuze Setter M19. Figure 82 shows the fuze setter off the gun. To the eye it is a metal box having an opening to receive the fuze. It is mounted on rails so that it can be moved back and forth parallel to the gun tube by part of the rammer mechanism. When idle, it is in its forward position. When setting a fuze, it is moved to the rear so that the fuze of a projectile placed in the rammer tray projects into the opening in the front of the fuze setter.

Let us now consider what happens within the fuze setter when it is in the rearward position setting a fuze. In some respects the operation of the auto-

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matic fuze setter M19 is similar to that of the manual fuze setters already discussed. Thus we find it has rings carrying pawls which engage the slots on the fuze to be set. A synchronous repeater is used for receiving data from the director. Furthermore, the fuze setter will set the fuze properly regardless of the initial setting on the fuze. Rotation of the pawls, however, is accomplished by an electric motor; and control of the fuze setting is exercised by electrical devices rather than by a pointer matching procedure.

When the fuze setter moves rearward and the fuze enters the fuze cavity of the fuze setter, the fuze is placed so that it projects through a holding ring and a setting ring. The holding ring carries a pawl which will be forced by spring action into the slot in the rear or fixed portion of the fuze when the ring is rotated to a position where pawl and slot are aligned. Similarly, the setting ring carries a pawl which engages the slot in the forward or moveable portion of the fuze.

These rings are rotated by an electric motor through a planetary gear and brake arrangement. This mechanism causes the holding ring to be driven counterclockwise if it is free to rotate; or it causes the setting ring to be driven clockwise if the holding ring is held stationary. The electric motor mentioned before is started running by the fuze striking and closing a switch when the fuze enters the fuze cavity of the fuze setter. The holding ring then rotates until its pawl engages the slot in the fixed portion of the fuze. The holding ring is then held stationary, causing the setting ring to rotate. As the setting ring rotates, its pawl engages the slot in the front part of the fuze, then continues to rotate turning the forward part of the fuze along with it, and so changes the fuze setting. This rotation continues until the setting on the fuze agrees exactly with the fuze data being received from the director by the selsyn repeater. At this instant a switch in an electric control circuit operates and causes three things to happen. First, a spring-operated mechanism, known as the knockout sleeve, is released and instantaneously disengages the setting pawl from the slot in the forward part of the fuze. This leaves the fuze set at exactly the proper value. Second, the electric motor is turned off. Third, the rammer is set in motion to withdraw the fuze setter from the fuze.

Let us now see how the switch in the electric control circuit is closed at exactly the right time. The sun gears of a spur gear differential are driven by the setting and holding rings, causing the differential case to be positioned according to the angle between the setting and holding pawls. At any given instant this angle corresponds to the actual setting of the fuze at that instant. The case of the differential is geared to one contact of a rotary switch, keeping this contact also continuously positioned according to the actual setting on the fuze. The other contact of the switch is mounted on the rotor of the selsyn repeater, so that this contact is continuously kept positioned according to fuze data from the director. When the two contacts touch, the actual setting on the fuze agrees with the director fuze data. This rotary switch is in the electric control circuit; and when it is closed by the contacts touching, the events described in the latter part of the preceding paragraph take place, leaving the fuze set at exactly the right value.

Power Rammer M9. The power rammer M9 is a mechanical, cam driven, arm-type rammer and is composed of two major parts, a fuze setter actuating mechanism, and the rammer actuating mechanism. A five-horsepower electric motor supplies power to both units.

The function of the fuze setter actuating mechanism is to move the fuze setter M19 back to the fuze setting position, allow it to dwell while the fuze is being set, then return it to its initial position. This motion is imparted to the fuze setter by a cam whose follower is linked to the fuze setter. One half a revolution of this cam moves the fuze setter from the idle to setting position, and completion of the revolution returns the fuze setter to its idle position. The cam is driven by the electric motor through a power train consisting of a speed reducer and a jaw clutch with a throwout mechanism. Once the clutch is engaged, this throwout mechanism will disengage the clutch after the cam has rotated 180°. Engagement of the clutch can be brought about in two ways. It may be engaged by pulling the clutch control lever, used in the starting operation

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of the rammer, or it may be engaged by a solenoid operated by the electric control circuit of the fuze setter M19. To insure that the cam stops as soon as the clutch is disengaged a brake is included in the mechanism. This brake is automatically set just as the clutch disengages. It is automatically released just after the clutch is engaged.

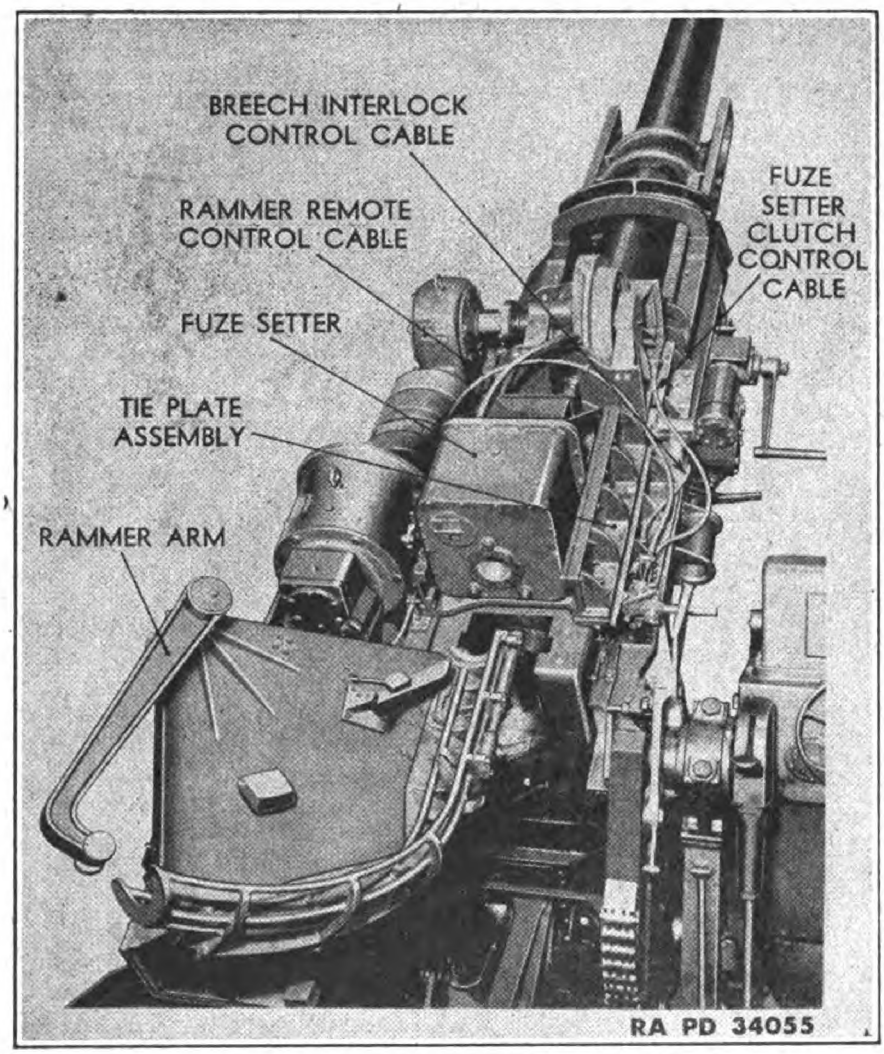

Figure 83. Power Rammer M9—Covers Removed.

The sequence of events taking place in the fuze setter actuating mechanism during a fuze setting cycle is as follows. The cycle is started by pulling the clutch control lever which engages the jaw clutch. Engagement of the clutch causes the electric motor to rotate the cam, which releases the brake and moves the fuze setter toward the setting position. After the cam has rotated 180° bringing the fuze setter to the setting position, the clutch throwout mechanism disengages the clutch, and the brake is set to hold the cam and fuze setter. After the fuze has been set, the electric control circuit of the fuze setter energizes the solenoid which causes the clutch to re-engage, thereby causing the cam to rotate. As before, the clutch throwout mechanism disengages the clutch after 180° rotation of the cam has brought the fuze setter back to its idle position. The brake is then set and the cycle complete.

The function of the rammer actuating mechanism is to ram the round into the chamber. Figure 84 shows the equipment mounted on the gun. The projectile and cartridge case of the separated ammunition are placed into the tray when the tray is in the upper position as shown in the figure. In this position, the

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fuze of the projectile is in line with the cavity of the fuze setter. After the fuze setter has been moved to the rear, the fuze set and returned to the idle position, the tray is dropped to the line of bore position as shown in Figure 84, and stays there momentarily while the rammer arm forces the round into the chamber of the gun. The tray and arm are then returned to their original position.

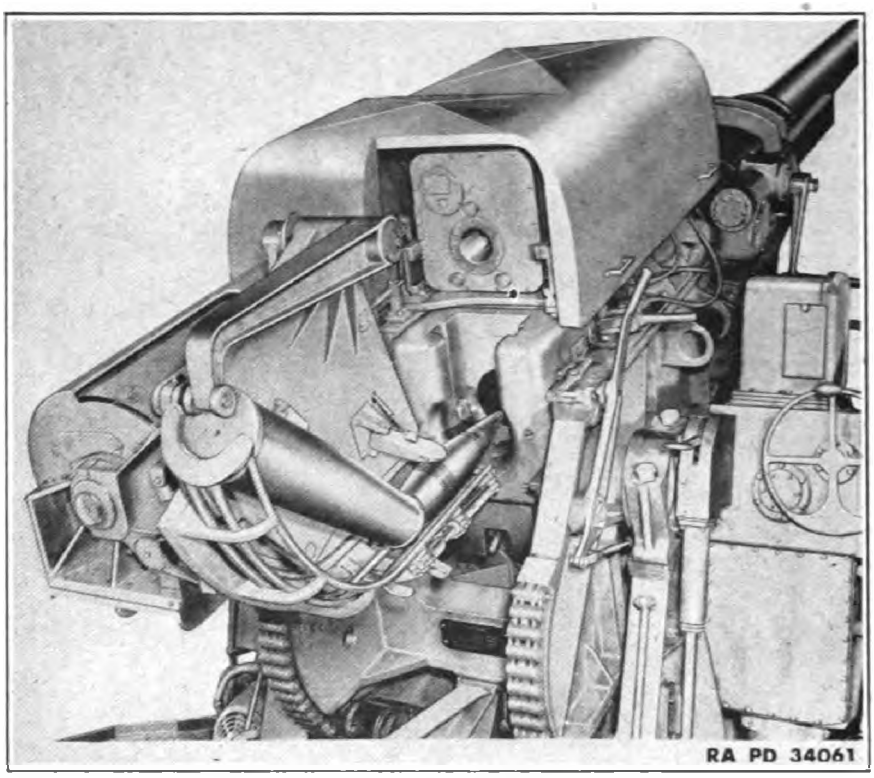

Figure 84. Power Rammer M9—Covered.

This motion of tray and rammer arm is obtained by a cam assembly composed of two cams mounted on the same shaft below the tray. The follower of one cam drives the tray and the follower of the other cam drives the rammer arm. One revolution of the cam assembly causes the tray and rammer arm to complete the cycle of motion described in the preceding paragraph.

The cam assembly is driven by the five-horsepower motor through a power train composed of a speed reducer and jaw clutch. Like the jaw clutch of the fuze setter actuating mechanism, this clutch also has a throwout mechanism. This throwout mechanism, however, acts to disengage the clutch after the cam assembly has made one complete revolution. When both the fuze setter M19 and the power rammer M9 are being used, the clutch is engaged by a control mechanism as the fuze setter returns to the idle position. If it is desired to ram without fuze setting by the fuze setter M19, a selector lever (located on the clutch control lever discussed in connection with the fuze setter actuating mechanism) may be positioned so that pulling the clutch control lever engages the clutch of the rammer mechanism rather than the clutch of the fuze setter actuating mechanism. As with the fuze setter actuating mechanism a brake is included to stop motion of the cam assembly immediately upon disengagement of the clutch,

The following sequence of events occurs in the rammer actuating mechanism during the ramming cycle. The clutch is engaged by the return of the fuze setter to its idle position in the case of a complete fuze setting and ramming cycle, or by pulling the clutch control lever in case of a ramming cycle only. Engagement of the clutch causes the cam assembly to start rotating and releases the brake. The cam assembly makes one revolution, driving the tray and the

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rammer arm through their cycles of operation. At completion of this revolution, the cam assembly stops through disengagement of the clutch and action of the brake.

To prevent injury to personnel or damage to equipment in case of malfunction or improper operation, safety devices are built into the power rammer M9. One safety interlock prevents pulling the clutch control lever if the breech block is closed. This makes it impossible to ram a projectile into a closed breechblock. Another interlock prevents the gun from striking the tray during recoil by making it impossible to fire the gun while the tray is down in the line of recoil.

GENERATING UNITS

Under field conditions, commercial power facilities are generally remote or nonexistent. Therefore, an antiaircraft installation must of necessity be self-sufficient in regard to power for operating the various components that control the movements of the guns. Power plants for field usage must be self-contained, mobile in nature, and compact and rugged in construction. Varying power problems have necessitated the development of a series of generating units.

Basic Operating Principles. In general, the power unit consists of a generator driven by a gasoline internal-combustion engine. A standard type of automotive engine is employed, varying in size and capacity with the power unit. The ignition, cooling, lubrication, electrical, and fuel systems necessary for proper functioning of the engine are similar to those generally identified in standard commercial engines.

The generators, or alternators, are of the stationary armature, revolving field type, in which field excitation is obtained from a small, direct current generator built integrally with the unit. With few exceptions, the direct current generator armature and the rotating field, or rotor, of the alternator are mounted on a common shaft which is directly connected by means of a flexible coupling to the flywheel of a gasoline engine. Controls and meters for the various components are mounted on a centrally located instrument and control panel.

The rotor of the alternator and the armature of the direct current exciter are turned at a governed speed by the gasoline engine. The direct current generator, composed of a rotating armature and a stationary field, is shunt wound, and initial field excitation is provided by permanent magnets in the pole pieces. The stationary field of the direct current generator and the rotating field of the alternator are wired in parallel with the direct current generator armature. Control of the direct current excitor output is afforded by the introduction of a variable resistance rheostat which is placed in series with the exciter field, thereby regulating the current flow through the rotating field.

Slip ring connections are used to transfer the excitation voltage from the exciter armature to the rotating field of the alternator. Impression of a direct current across the rotating field results in a uni-directional magnetic field which may be varied in intensity by controlling the output voltage of the direct current exciter. This magnetic field is rotated within a three-phase, Y-wound, stationary armature. As the field rotates, there will be induced upon each armature winding, a voltage proportional to the speed and the strength of the magnetic field. The generated voltage is transmitted to the generator power receptacle after passing through the fuses, the main power switch, and the various meters which determine the electrical characteristics of the output. By means of a cable system, the output of the generating unit is conducted to the various components of the antiaircraft installation.

Types and Their Basic Functioning

Generating Unit M5. The Generating Unit M5 furnishes 125-volt, 60-cycle, 3-phase power for the various remote control systems and the directors employed with the 37mm and 40mm guns. Provisions are made for supplying 130-volt, 50 cycle, 3-phase power by changing the links on the generator subpanel and reducing the engine speed. The rated generator output is three KVA and the unit can stand a 25% overload for a period of two hours. The normal current load is 13.3 amperes for 50 cycles operation and 13.9 amperes for 60 cycle operation.

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The engine is a Hercules, Model ZXB, 4-cylinder, 4-stroke cycle, L-head, 11-horsepower (SAE rating), water-cooled, gasoline engine. The generator and engine are coupled together and mounted on skids for ease of movement. The weight of the entire assembly is approximately 805 pounds and the unit can be carried by six to eight men using porter bars inserted into the brackets provided.

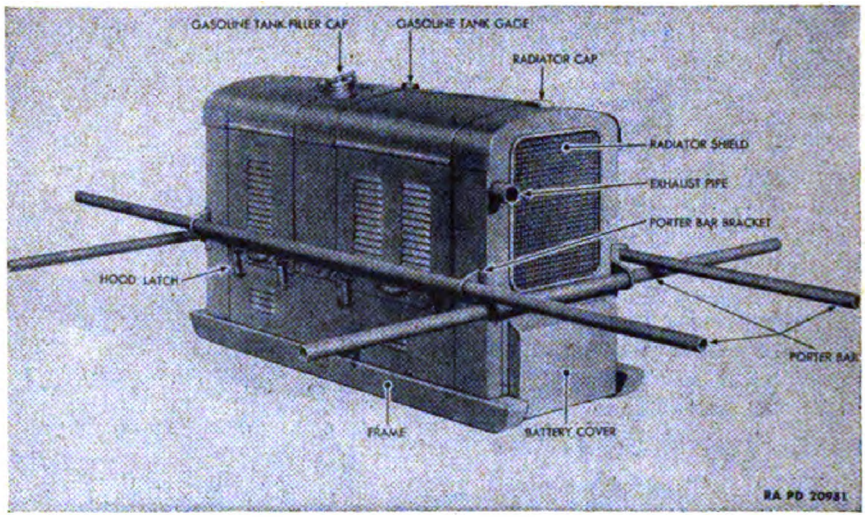

Figure 85. Generating Unit M5.

Generating Unit M6. The generating unit M6 is similar in construction and appearance to the generating unit M5. It is so wired, however, that it can develop either single or three-phase power at 125 volts and 60 cycles. Single phase power is used when the generating unit is employed with the directors M4 and M7, with data transmission systems M4, M4A1, and M6. When used for three-phase operation, it may be employed in place of generating unit M5 for 60-cycle, 125-volt power. The rated generator output is 2.5 KVA when set for single phase operation.

Generating Unit M17. The generating unit M17 is identical in construction to the generating unit M5 with but few exceptions. The unit differs in that it is sealed so as to be completely dust proof and in that it is provided with complete radio suppression. Rated generator output values are the same as those stated for the generating unit M5.

Generating Unit M7 and M7A1. Power for installations employing either 90mm AA guns on the M1A1 or M2 carriages, or the 120mm guns, is supplied by the generating unit M7 or M7A1. The output of the unit is 125-volt, 60-cycle, 3-phase power and the generator is rated at 35KVA at an 80% power factor. The full load current drawn is 162 amperes. The engine is a Hercules Model, WXLC-3, 6-cylinder, 4-stroke cycle, L-Head, water-cooled, 43.3 horsepower (SAE rating), gasoline engine.

Depending upon the unit manufacturer, the direct current exciter may be internally or externally built. The complete assembly may be mounted on either the generator skids M1, or the generator trailers M7 or M18. The trailers are especially constructed, 4-wheel type which are capable of high speed travel over suitable terrain. The combination of generating unit M7 and the generator trailer weighs approximately 7,750 pounds.

The generating unit M7A1 is equipped with an automatic voltage regulator which maintains the voltage output to within plus or minus 2% of the rated voltage from full load to no load operation.

Generating Unit M15 and M15A1. The generating unit M15 is utilized to furnish power for the same type of installation as the generating unit M7. The output of the unit may be either 125 volt or 250 volt, 60-cycle, 3-phase power. The rated generator capacity is 35 KVA at an 80% power factor. At full load,

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the normal amperage drawn is 162 amperes when operating at 125 volts, and 81 amperes when operating at 250 volts. An output of 250 volts is not normally used in an antiaircraft installation.

The engine used is basically the same as the one employed on the generating unit M7. The engine accessories, however, have been modified to provide more adequate protection from dust and water. The ignition system has been changed from the standard 6-volt to a 12-volt system. Dual starting motors are employed to facilitate cold weather starting. The complete assembly may be mounted on either skids or the generator trailer M7 or M18.

The generating unit M15A1 is equipped with an automatic voltage regulator.

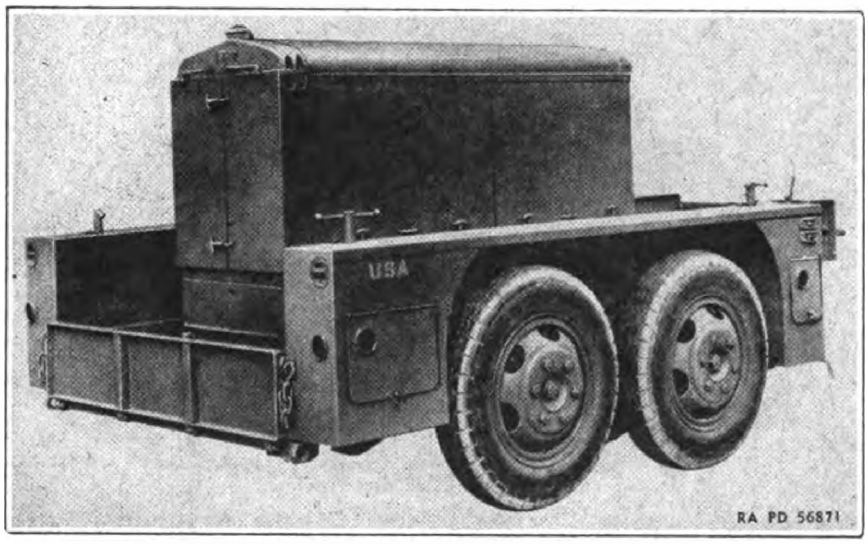

Figure 86. Generating Unit M7 and Trailer M7.

Generating Unit M18. The generating unit M18 may be used to replace the generators M7, M7A1, or M15 in an antiaircraft installation. The rated generator outputs are identical to those of the generating unit M15. With minor exceptions and modifications, the engines of the two units are the same. The generating unit M18, however, is sealed so as to be completely dust proof and is provided with complete radio suppression. The automatic voltage regulator is an integral component of the unit. The complete assembly may be mounted either on skids or on the generator trailers M7 or M18.

General Operating Precautions. Prior to starting a power generating unit, a pre-starting check of the components should be accomplished to assure proper operation of the engine and the accessories. During the starting operation, the rheostat controlling the direct current exciter output should be rotated to its minimum position. After the engine has warmed up, rotate the rheostat knob slowly toward its maximum voltage position until the desired generator output is established.

The main power switch at the generator should be placed in the 'off' position while connecting or disconnecting cables throughout the system. Failure to do so may cause arcing, resulting in burned-out fuses and electrical equipment. During operation a constant check should be maintained by the operator to detect abnormal functioning as indicated either by the sound of the engine, by the smell of overheated and burning units, or by the meters on the instrument panel.

In shutting down the unit after operation, the DC exciter field rheostat should once more be placed into the minimum position. Before turning off the ignition switch, allow the engine to idle at least a minute in order to prevent backfiring and possible muffler damage.

The engines of the generator unit should be given frequent periodic inspections, adjustment, and repair to overcome operational mechanical failures.

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REFERENCES

GENERAL INSTRUMENTS

TM 6—220 .....Field Artillery Fire Control Instruments
TM 9—1100 .....Inspection of Ordnance Materiel

ORDNANCE MAINTENANCE TECHNICAL MANUALS

TM 9—1525 .....Angle of site instrument M1917
TM 9—1527 .....Gunner's Quadrant, M1 and M1918
TM 9—1530 .....Aiming circles M1, M1918 (French), M1916, and M1916M1
TM 9—1535 .....Sights M4, M3 (for 60mm and 81mm mortar material), sights M2A3, M2A1, M2 (for 81mm mortar material)
TM 9—1539 .....Telescope mount M35 and Tel. M31
TM 9—1545 .....Telescope mount M25 (for 4.5 inch gun carriage M1 and 155mm howitzer carriage M1)
TM 9—1547 .....Mount, telescope M16; Quadrant, range M3; Telescope, elbow M5
TM 9—1548 .....Panoramic telescope and Telescope mount M3
TM 9—1549 .....Mount, telescope M15A1; Quadrant, range M1
TM 9—1550 .....Sight M1901 (French)
TM 9—1551 .....Telescope mounts M21 and M23; panoramic telescope M5A3 and M12A2; range quadrant M4; elbow telescope M16 and instrument light M5
TM 9—1552 .....Mount, telescope M22; quadrant, range M5, telescope, panoramic M5A4; telescope, panoramic M12A1; telescope elbow M14; mount, telescope M23 (for 75mm gun carriage M2A3)
TM 9—1553 .....Mount, telescope M18A1; mount, quadrant M1; telescope, panoramic M5A5
TM 9—1554 .....Telescope mount M6A1
TM 9—1555 .....Quadrant sights M1917, M1917A1, M1918, and M1918A1
TM 9—1557 .....Elevation quadrant M1
TM 9—1569 .....Plotting boards for field artillery
TM 9—1570 .....Plotting boards for seacoast artillery
TM 9—1578 .....Telescope M6 and telescope M19
TM 9—1580 .....Battery Commander's telescope M1915A1
TM 9—1581 .....Telescope sights M1 and T3
TM 9—1582 .....Panoramic telescope M8
TM 9—1583 .....Telescope, panoramic M1917M1, M2A1, M3A1, M4, M5A2, M5A3, M5A4, M5A6, M6
TM 9—1584 .....Telescope, panoramic M12, M12A1, M12A2, and M12A3
TM 9—1585 .....Range Finders, 1-meter base and 80cm base, all types
TM 9—1595 .....Prismatic compass M1918
TM 9—1596 .....Compass M2 (Keuffel and Esser, and Sperry)
TM 9—1600 .....Direct fire telescopes for 3-inch and 90mm antiaircraft
TM 9—1606 .....Sighting System M2 with telescope M7 for 37mm antiaircraft gun
TM 9—1607 .....Sighting Systems M5 and M6
TM 9—1608 .....Periscopes, telescopes for periscopes, and direct sighting telescopes for use in tanks
TM 9—1610 .....Instrument, flank spotting M1; rule, flank spotting M1
TM 9—1611 .....Field Glasses, type EE
TM 9—1665 .....Antiaircraft battery commander's observation instrument M1
TM 9—1674 .....Telescope mount M20
TM 9—1675 .....Azimuth instruments M1910 and M1910A1 (degrees)
TM 9—1680 .....Azimuth instruments M1918
TM 9—1685 .....Depression position finder M1907
TM 9—1695 .....Depression position finder M1
TM 9—575 .....Auxiliary fire control instruments (field glasses, eyeglasses, telescopes, and watches)
TM 9—2300 .....Standard Artillery and Fire Control Materiel
TM 9—2571 .....Instructon Guide: Plotting board M1918A1

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TM 9—2579 .....Telescope, T15
TM 9—2601 .....Elementary Optics
TM 9—2602 .....Instruction Guide: The instrument repairman
TM 9—2674 .....Instruction Guide: Telescope mount M20, panoramic telescope M8 and elevation quadrant M1
TM 9—2681 .....Instruction Guide: Plotting boards M3 and M4
TM 9—2682 .....Instruction Guide: Plotting board M3
TM 9—2683 .....Instruction Guide: Plotting board M5
TM 9—2684 .....Instruction Guide: Sound ranging plotting board M1

DIRECTORS MS, M5A1 AND M5A2

OS 9—58 .....Directors M5 and M6 (disassembly, assembly and adjustment)
FM 4—110 .....Coast Artillery Field Manual: Gunnery, Fire Control and Position Finding, Antiaircraft Guns
FM 4—112 .....Coast Artillery Field Manual; Gunnery, Fire Control and Position Finding, Antiaircraft Automatic Weapons
FM 4—113 .....Coast Artillery Field Manual: Gunnery, Fire Control and Service of the Piece, Antiaircraft Automatic Weapons (Case III Firing)
FM 4—151 .....Coast Artillery Field Manual: Fire Control, Automatic Weapons
TM 9—235 .....37mm AA Gun Materiel
TM 9—252 .....40mm Automatic Gun M1 and 40mm Antiaircraft Gun Carriage M2
TM 9—659 .....Director M5, M5A1, M5A2, and M6 (To be published)
TM 9—1659 .....Ordnance Maintenance, Directors M5 and M6

COMPUTING SIGHT M7

FM 4—151 .....Coast Artillery Field Manual: Fire Control, Automatic Weapons

DIRECTORS M4 AND M7 AND GUN COMPUTOR M1

FM 4—10 .....Gunnery
FM 4—110 .....Coast Artillery Field Manual: Antiaircraft Artillery, Gunnery, Fire Control and Position Finding, Antiaircraft, Guns
TM 9—658 .....Directors M7, M7A1B1 and M7A1B2
TM 9—1646 .....Ordnance Maintenance, Gun Data Computor M1
TM 9—1655 .....Ordnance Maintenance, Director M4.
TM 9—1658 .....Ordnance Maintenance, Director M7.
TM 9—2646 .....Instruction Guide, Gun Data Computor M1
TM 9—2655 .....Instruction Guide, Director M4
TM 9—2658 .....Instruction Guide, Director M7
Sperry Publication #14-8080, Prediction Mechanism for Directors M7A1B1 M7 Director, Bulletin #14, Jan. 20, 1944, Sperry Gyroscope Co., Inc., Brooklyn, N. Y.

ELECTRICAL DIRECTORS

TM 9—671 .....Directors M9 and M10
TM 9—1671A .....Directors M9 and M10, General Maintenance; and Computers M3 and M4
TM 9—1671B .....Directors M9 and M10, Power Unit M8, Tracker M2, and Altitude Converter M2
TM 9—1671C .....Directors M9 and M10, Wiring Diagrams
TM 9—1671D .....Director M9A2, Wiring Diagrams

OPTICAL HEIGHT FINDERS

TM 4—250 .....Stereoscopic Range and Height Finding
TM 9—623 .....Height Finders, 13½ ft., M1 and M1A1
TM 9—624 .....Height Finders, 13½ ft., M2 and M2A1
TM 9—1623 .....Height Finders, 13½ ft., M1 and M1A1
TM 9—2601 .....Elementary Optics
TM 9—2623 .....Height Finder M1
FM 4—110 .....Antiaircraft Artillery—Gunnery, Fire Control and Position Finding, Antiaircraft Guns

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REMOTE CONTROL SYSTEMS

TM 9—2300 .....Standard Artillery and Fire Control Materiel
FM 4—113 .....Antiaircraft Artillery
SNL F—208 .....System, Remote Control M1 and M5
TM 9—252 .....Gun, 40mm, M1 AA
TM 9—1643 .....Remote Control Systems M1 and M5
OS 9—42 .....Remote Control Systems M1 and M3
N/M .....Remote Control System M1
N/M .....Oil Gear M3
TB 1649—1 .....Cable System M1 and M2
TM 9—1642 .....Ordnance Maint.—Remote Control System M2
TM 9—2642 .....Instruction Guide—Remote Control System M2
OS 9—51 .....Remote Control System M2
Base Shop Data— ...Remote Control System M2
TM 9—1649 .....Ordnance Maint.—Cable System M1
SNL F—207 .....Remote Control System M2, M6, M7, M12, M13

FUZE SETTING AND RAMMING EQUIPMENT

TM 9—1635 .....Ordnance Maintenance, Fuze Setter M8
SNL F—177 .....Fuze Setter M8
TM 9—1641 .....Ordnance Maintenance, Fuze Setter M13
Base Shop Data— ...Remote Control System M2
SNL F—211 .....Fuze Setter M13
Base Shop Data— ...Remote Control System M6 with Cable System M3 and Fuze Setter M19
SNL F—288 .....Fuze Setter M19
TM 9—370 .....90mm Gun Materiel M1 and M1A1
TM 9—1370A .....90mm Gun M1 and Mounts M1 and M1A1
SNL D—28 .....Gun 90mm M1 & M1A1 Mount
TM 9—372 .....90mm Gun M2 and 90mm Gun Mount M2
TM 9—1372B .....Ord. Maint. Combination Fuze Setter Ramm M20
SNL D—38 .....Gun 90mm M2 Mount
TM 9—372 .....90mm Gun M2 and 90mm Gun Mount M2
TM 9—1372B .....Ord. Maint. Combination Fuze Setter Ramm M20
SNL F—274 .....Amplifier Torque M1 for 90mm AA gun Mount M2
TM 9—380 .....4.7-inch Gun M1 and Mount
TM 9—1380 .....Ord Maint., Gun 120mm
Base Shop Data— ...Gun 4.7-in. M1 and Mount Gun AA 4.7-in. M1
SNL D—32 .....Gun 4.7-in. M1 on Mount M.

GENERATING UNITS

TM 9—2300 .....Standard Artillery and Fire Control Materiel
TM 9—616 .....Generating Units M5 and M6
TM 9—1616 .....Ordnance Maintenance, Generating Units M5 and M6
TM 9—2616 .....Instruction Guide, Generating Unit M5
TM 9—618 .....Generating Unit M7
TM 9—1618 .....Ordnance Maintenance, Generating Unit M7
TM 9—617 .....Generating Unit M18
SNL F—226 .....Unit, Generating, M7, M7A1, and M15
SNL F—291 .....Unit, Generating, M18

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General Instrument Shop Inspection Forms. The following pages are sample inspection forms which may be used in an instrument shop when inspecting or adjusting fire control instruments. Forms are given for elbow telescopes, aiming circles, panoramic telescopes, B.C. telescopes, binoculars, and gunner's quadrants. Similar forms may be devised for other instruments.

INSPECTION FORM

Binocular M———

Serial No. ———— Date ————

A. GENERAL	CONDITION	REQUIREMENTS FOR SERVICEABILITY
Completeness	————	As listed in S.N.L.
Painting	————	Paint must be in good condition.
Sealing	————	Must indicate proper sealing with the authorized sealing agents.
B. CONDITION OF OPTICS		
Eye lens	————	Check all the optical elements for presence of dirt, grease, moisture, cracks and chips.
Field lens	————	Check all compound optical elements for possible deterioration of the Canada Balsam.
Reticle	————	
Prisms	————	
Objective lens	————	
C. OPTICAL INSPECTION		
Parallax	————	(No tolerance)
Diopter movement		
Left telescope	————	From the point where clear definition of the reticle is obtained with a collimating telescope there must be a full plus 4 and minus 4 diopter movement.
Right telescope	————	From the point where clear definition of the field is obtained with a collimating telescope there must be a full plus 4 and minus 4 diopter movement.
Scales		
Left telescope	————	Must be at 'O' when definition of the reticle is clear with a collimating telescope.
Right telescope	————	Must be at 'O' when definition of the field is clear with a collimating telescope.
Tilt of field	————	(No tolerance.)
Collimation		
Vertical position	————	At normal setting of the interpupillary scale there should be no double-vision. From one extreme to the other extreme the allowed tolerance is ½ mil.
Horizontal position	————	Same as for vertical position.
D. MECHANICAL INSPECTIONS		
Eyepieces	————	2 diopters when scales set at 'O'.
Objectives	————	1/32 inch tolerance.
Hinge joint	————	Movement must be tight and smooth.
Focusing nut	————	Movement must be smooth and firm from one extreme to the other.
Interpupillary scale	————	Must read the same as distance between centers of the eyelens.
E. ACCESSORIES		
Carry case	————	Must be clean, with stitching and supports in good condition.
Carrying strap	————	Leather clean. Buckle sturdy and safe.
Neck strap	————	Leather clean. Button fasteners sturdy and safe.
F. DISPOSITION		
Arsenal	————	State to which echelon of maintenance this instrument be sent for repair.
Base shop	————	
Field shop	————	
Repairman	————	

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INSPECTION FORM

TELESCOPE B.C. M

Serial No. _____ Date _____

GENERAL	CONDITION	REQUIREMENTS FOR SERVICEABILITY
Completeness	_____	All major items should be in the carrying case.
Painting	_____	Must be painted.
TRIPOD CHECKS		
Lower Legs	_____	Must be painted and free from dents.
Wing Nut Clamp	_____	Must hold lower leg tight.
Hinge and Clamp	_____	With lower leg extended and clamp tight, it must support its weight in a horizontal position.
Mount Key	_____	(a) Must hold mount securely in place. (b) Attached to tripod with chain.
Mount Clamp	_____	Must not come above the horizontal position when tight.
CHECKS FOR THE MOUNT		
Ball and Socket Joint	_____	(a) Must support weight of the mount in any position with clamp loose. (b) Must support weight of mount and 'scopes in any position with clamp tight.
Dust Cover	_____	Free from holes and tears. Also pliable.
Packlash in Orienting Mech.	_____	Reduce to a minimum and operate smoothly.
Backlash in Azimuth Mech.	_____	Should not exceed 1½ mils and operate smoothly.
Setting of the Scales:		
a. Azimuth scale reads	_____	With aid of an eye loupe set the azimuth scale to zero. The micrometer must read zero.
b. Azimuth micrometer reads	_____	
Operation of the Throw-Out Circular Level Vial		Should completely disengage the worm from the worm-wheel. Bubble must stay within the index when rotated thru 6400 mils.

TELESCOPE CHECKS	CONDITION	REQUIREMENTS FOR SERVICEABILITY
Locating Bushing	_____	Must fit snugly to upper vertical spindle and fit tightly to elevating worm-wheel.
Backlash in Elevation	_____	Reduce to a minimum and operate smoothly.
Extent of Elevating Movement	_____	Must be smooth and have at least 600 mils movement.
Fit between Telescopes	_____	Must support their own weight in any position.
Fit of Telescopes to Eccentric:	_____	Must support their own weight in any position.
Fit of the Angle of Site Housing of the Telescopes	_____	Must support its own weight in any position.
Backlast in the Angle of Site Mechanism	_____	Should not exceed ½ mil and operate smoothly.
Horizontal Travel	_____	Should not exceed 1 mil Total.
Vertical Travel	_____	Should not exceed ½ mil Total.
Optics:		
Objective windows	_____	
Large 90° prism	_____	
Objective lens	_____	All optics are to be checked for dirt, scratches and breaking down of Canada balsam in compound lenses.
Small 90° prism	_____	
Porro prism	_____	
Field lens	_____	
Eye lens	_____	
Reticle	_____	
Parallax	_____	No tolerance.
Double Vision		
a. Vertical position	_____	½ mil tolerance.
b. Horizontal position	_____	½ mil tolerance.
Setting of the Diopter Scales:		
Right Telescope:		
1. Definition of Reticle	_____	¼ of a diopter tolerance.
2. Full movement from point of clearest definition of the reticle	_____	Must have at least plus and minus 4 diopter movement.
Left Telescope:		
1. Definition of field of view	_____	¼ of a diopter tolerance.
2. Full movement from point of clearest definition of the field of view	_____	Must have at least plus and minus 4 diopter movement.
Stagger	_____	Tolerance up to 2 diopters.
Setting of the horizontal line of site	_____	No tolerance.
a. High	_____	
b. Low	_____	

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INSPECTION FORM

TELESCOPE, ELBOW _____

Serial No. _____ Date _____

A. GENERAL	CONDITION	REQUIREMENT FOR SERVICEABILITY
Completeness	_____	Instrument and rubber eyeguard.
Appearance	_____	Bent or damaged mechanical parts.
Painting	_____	Must be painted (Acts as a sealer).
Sealing	_____	Must be sealed (To increase serviceability of instrument).
B. OPTICAL CHECK		
Objective Lens	_____	Check optics for dirt, scratches and breaking down of Canada Balsam in compound lenses.
Erecting System	_____	
Ray Filters (M6, M17 and M22	_____	
Reticle	_____	
Field Lens	_____	
Collective Lens (M6)	_____	
Eye Lens	_____	
C. TILT OF RETICLE	_____	The reticle should be placed in the instrument with the etching being in a perfect vertical or horizontal position, according to the usage of the instrument.
D. DEF. OF RET.	_____	Use collimating Tel. Target sky or some similar background. (For M6, M17 and M22, after the **clearest** def. of ret. is obtained the diopter scale should read "O".)
E. DEF. OF FIELD	_____	Use collimating Tel. Target about 150 yds. away. (For M6, M17 and M22 obtain "clear" def. of ret. or set the diopter scale at "O" before making this check.)
F. PARALLAX	_____	Use naked eye. Tarket about 150 yds. away or more. (For M6, M17 and M22 set diopter scale to own reading.) No Tolerance.
G. MECHANICAL CHECK		
Diopter movement	_____	Should have a full + 2 and — 4 movement.
Movement of focusing nut	_____	Should have smooth movement. Free from burrs.
Movement of filter mech.	_____	Should have smooth movement. Free from burrs.
Legibility of diopter scale	_____	Should be filled with **scale filler** or **white lead.**
H. OPTICAL AXIS*		(Fixed Focus) Bore-Sighting. (M6, M17 and M22) Alinement of telescopes.
I. DISPOSITION		
Arsenal	_____	Check where instrument should be sent for repairs or adjustments.
Shop	_____	
Field	_____	
Repairman	_____	

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INSPECTION FORM

TELESCOPE, PANORAMIC _____

Serial No. _____ Date _____

A. GENERAL	CONDITION	REQUIREMENTS FOR SERVICEABILITY
Completeness	_____	As listed in S.N.L.
Appearance	_____	General appearance of instrument.
Painting	_____	Paint must be in good condition.
Sealing	_____	Must indicate proper sealing with the authorized sealing agents.
B. CONDITION OF OPTICS		
90° prism	_____	Check all the optical elements for presence of dirt, grease, moisture, cracks and chips.
Dove prism	_____	
Objective lens	_____	Check all compound optical elements for possible deterioration of the Canada Balsam.
Amici prism	_____	
Reticle	_____	
Field lens	_____	
Eye lens	_____	
C. OPTICAL INSPECTIONS		
Parallax	_____	Target 88 yards distance. (No tolerance).
Definition of reticle	_____	Reticle must appear clear and sharp using a collimating telescope. (No tolerance).
Definition of field	_____	Field of view must appear clear and sharp using a collimating telescope.
Tilt of reticle	_____	Must be erect to the field of view. (No tolerance).
Tilt of field	_____	Must be erect to within ½ mil.
Horizontal travel	_____	(Tolerance 1 mil).
Vertical travel	_____	(Tolerance 1 mil).
Optical axis	_____	(No tolerance).
D. MECHANICAL INSPECTIONS		
Stop rings	_____	Must have at least 300 mils elevation and depression from '0' (horizontal). Total turns must not exceed 650 mils.
Backlash in azimuth	_____	(Tolerance 1½ mils).
Backlash in elevation	_____	(Tolerance 1½ mils).
Azimuth smoothness	_____	Worm should turn smoothly and freely without binding.
Elevation smoothness	_____	Must be able to elevate and depress line of sight to limits of movement with free and smooth action.
E. MISCELLANEOUS INSPECTIONS		
Legibility of scales	_____	Scales must be in legible condition.
Throw-out lever tension	_____	Must not stick or bind.
Missing screws	_____	Drawing number of missing screws as listed in pertinent S.N.L.
1. _____		
2. _____		
F. DISPOSITION		
Arsenal	_____	State to which echelon of maintenance this instrument be sent for repair.
Base shop	_____	
Field Shop	_____	
Repairman	_____	

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INSPECTION FORM

CIRCLE AIMING MI

Serial No. _____ Date _____

GENERAL	CONDITION	REQUIREMENTS FOR SERVICEABILITY
Completeness	_____	Major items listed in case carrying cover must be there.
Painting	_____	Painting must be in condition.
Sealing	_____	Sealed complete with proper agencies.
Legibility of Scales	_____	Easily read and distinguished.
Optics		
Objective lens	_____	
Porro prisms	_____	
Reticle	_____	All optics must be checked for dirt, scratches, and breaking down of Canada Balsam in compound lenses.
Field lens	_____	
Eye lens	_____	
Needle reticle	_____	
Magnifier	_____	
Definition of reticle	_____	Reticle should be sharp and clear with focusing nut in center of its movement. Using a collimating telescope. Tolerance none.
Tilt of reticle	_____	Must be a plumb vertical line.
Tilt of field of view	_____	Must be erect. No tolerance.
Definition of field of view	_____	Aided by collimating telescope with focusing nut centered. Clear field of view must be had. No tolerances.
Parallax	_____	Testing distance 150 yards. Tolerance none.
Reticle window	_____	Alignment with adapter and reticle cell windows.

MECHANICAL		
Throw-out mech.	_____	Should completely disengage the worm from azimuth worm wheel without binding.
Circular level	_____	Bubble must stay within index when instrument is rotated thru 6400 mils.
Angle of site vial	_____	Check bubble for size. Breakage.
Declinator cover glass	_____	Check stud fit and condition of glass.
Needle clamp release	_____	Must provide definite stoppage of needle. Red plunger—locking. Green—releasing.
Dip and balance of needle	_____	Needle must balance true.
Backlash in elevation	_____	Reduced to minimum and operate freely.
Backlash in the orienting mech.	_____	Operate smoothly and have no backlash. Tolerance none.
Setting of scales		The outer mic. should read 0, the inner mic. 100 when the scale is set at 0 with a jeweler's eye-loupe.
Azimuth scale 0	_____	
Azimuth mic.	_____	
Backlash in azimuth	_____	Operate smoothy. Tolerance 1 mil. Check in all 4 quadrants.
Horizontal travel in azimuth	_____	Should not exceed 1 mil total.
Horizontal travel in orienting	_____	Should not exceed 1 mil total.
Vertical travel	_____	Plumb vertical. Tolerance ½ mil total.
Line of site	_____	Low No
	_____	High tolerances.
Declination	_____	South end reticle no tolerance. North index 5 mil tolerance.

TRIPOD		
Appearance	_____	Painting and parts missing, etc.
Wing Nut Clamps	_____	Must clamp and hold firmly.
Legs	_____	Smooth telescoping, no dents.
Hinge Tension	_____	Leg extended. Must support weight horizontally.
Support Tube	_____	Telescoping easily and not dented.
Vertical Spindle	_____	Must support its own weight in any position with clamp loose.
Case Carrying	_____	No. and type case noted.
Appearance	_____	Condition at a glance.
Straps	_____	Well-preserved and tight.
Supports	_____	Cushions must absorb shock and must be held rigid.
Lid.	_____	Tight fitting with lugs.

INSTRUMENT LIGHT		
Clamps	_____	Clamp tightly.
Wiring	_____	Condition of insulation and test for shorts.
Batteries	_____	Not weak or corroded.
Bulbs	_____	Test for strength condition and (4) number supplied.
Switch	_____	Check for shorts. Must turn both lights on at once.

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INSPECTION FORM

GUNNER'S QUADRANT MI

Serial No. _____ Date _____

INSPECT	CONDITION	CHECK
Completeness	_____	Instrument with packing chest or carrying case. Remarks:
Appearance	_____	Paint__broken, missing or bent parts. Remarks:
Legibility of scales	_____	All scales and indices. Remarks:
Micrometer	_____	Full 10 mil movement—scales zero—operates smoothly. Remarks:
Plunger	_____	Worn in arm. Remarks:
Plunger spring	_____	Sufficient tension of plunger against frame. Remarks:
Pivot	_____	Worn (up and down looseness). Remarks:
Notches	_____	Burrs and dirt (use eyeloop—remove one plunger index plate and check mesh of notches). Remarks:
Shoes Rock	_____	Each set of shoes (place instrument on a true surface—should not rock on either set of shoes). Remarks:
Surface	_____	Each set of shoes (use Prussian blue on a true surface to check percentage of surface on shoes). Remarks:
Level vial accuracy Reference surface (0-800)	_____	Micrometer black 'O'—plunger index 'O'—black auxiliary indices in coincidence. (Place instrument on a leveled surface—bubble must indicate a level position). Remarks:
Reference surface (800-1600)	_____	Micrometer Red 'O'—plunger index '1600'—Red auxiliary indices in coincidence. (Place instrument with shoes corresponding to 800 to 1600 mil scale against a true vertical plate. Bubble should indicate a level position). Remarks:

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CHAPTER 4

AVIATION ORDNANCE

ORDNANCE SERVICE IN THE ARMY AIR FORCES

The long-range striking arm of the Army is its air force. In the final analysis, a fighter plane is nothing more than a flying platform upon which guns are mounted in order to get those guns closer to our enemy's planes and troops. The bomber, on the other hand, is a flying delivery wagon, with which we are able to dump tons of explosives and incendiaries on our enemy's troops and strategic installations.

When considering an air force as an active weapon of either offense or defense, it is necessary to consider simultaneously the time and space factors under which it operates. Flying echelons are mobile, of course, whereas the supporting ground units are relatively static. The weight and volume of essential vital supplies such as fuel, bombs, and ammunition, consumed on each mission, is enormous. The activity of the air echelons directly governs the logistical requirements. The mobility of air echelons makes the air arm an ideal reinforcing weapon, inasmuch as it can be moved with relative ease from one front to another or even from one theater to another. Thus, these time and space factors prevent the air forces from depending either directly or completely upon ground force supply points. This is not from choice, but from necessity, inasmuch as ground forces and the air forces are geared to a different tempo.

The air forces, because of their flexibility and mobility, must rely on their own supply and maintenance establishments if their maximum efficiency is to be reached and maintained. Because of the tremendous amount of ordnance materiel used only by the air forces, such as the bomb service trucks, aircraft pyrotechnic projectors, flak suits, and aircraft cannons, and because of the other ordnance items which are common to air forces, ground forces, and army service forces, the necessity has arisen for special ordnance troops to supply, maintain, and advise in the use of this materiel.

How is aviation Ordnance organized to accomplish its responsibilities? Aviation Ordnance organizations are of two general types: those which are assigned to the tactical echelons of an air force and those ordnance supply and maintenance units assigned to an air force service command.

Ordnance Sections Assigned to Tactical Echelons. Ordnance sections assigned to the tactical echelons higher than the squadron, namely, group, wing, division, command, and air force, are mainly staff sections. The ordnance officers of each of these ordnance sections are technical advisors to the air force commanding officers and to their staffs on the tactical use of ordnance materiel. They further coordinate all ordnance activities within the jurisdiction of their commands. Most of these sections are small, varying from one to three officers and from two to thirteen enlisted men.

The work of the squadron ordnance section differs somewhat from that of the higher tactical echelons. The squadron ordnance officer has as his responsibility the maintenance and major repair of ordnance materiel within the squadron, and the supervision of transportation of ordnance ammunition and bombs, assembled and fuzed, from the squadron ammunition dump to the planes. At the plane itself, the squadron armament officer and his section assume charge. Ordnance, therefore, relates directly to the distribution of ammunition and bombs and the replacement and repair of guns. Armament deals exclusively with minor maintenance of ordnance supplies and arming of combat aircraft. A general distinction must be drawn, however, as the functions of ordnance and armament officers so often overlap; these two officers must work in very close cooperation. It is at the squadron ammunition dump (DP) that the ordnance section begins its work. At the DP, belted ammunition is loaded on trucks. The ammunition train then proceeds to the revetment area where bombs are loaded onto the bomb service trailer or into a M27 2½-ton bomb service truck. The bombs are then hauled to a fusing point near the plane where they are removed from the trucks or trailers, placed

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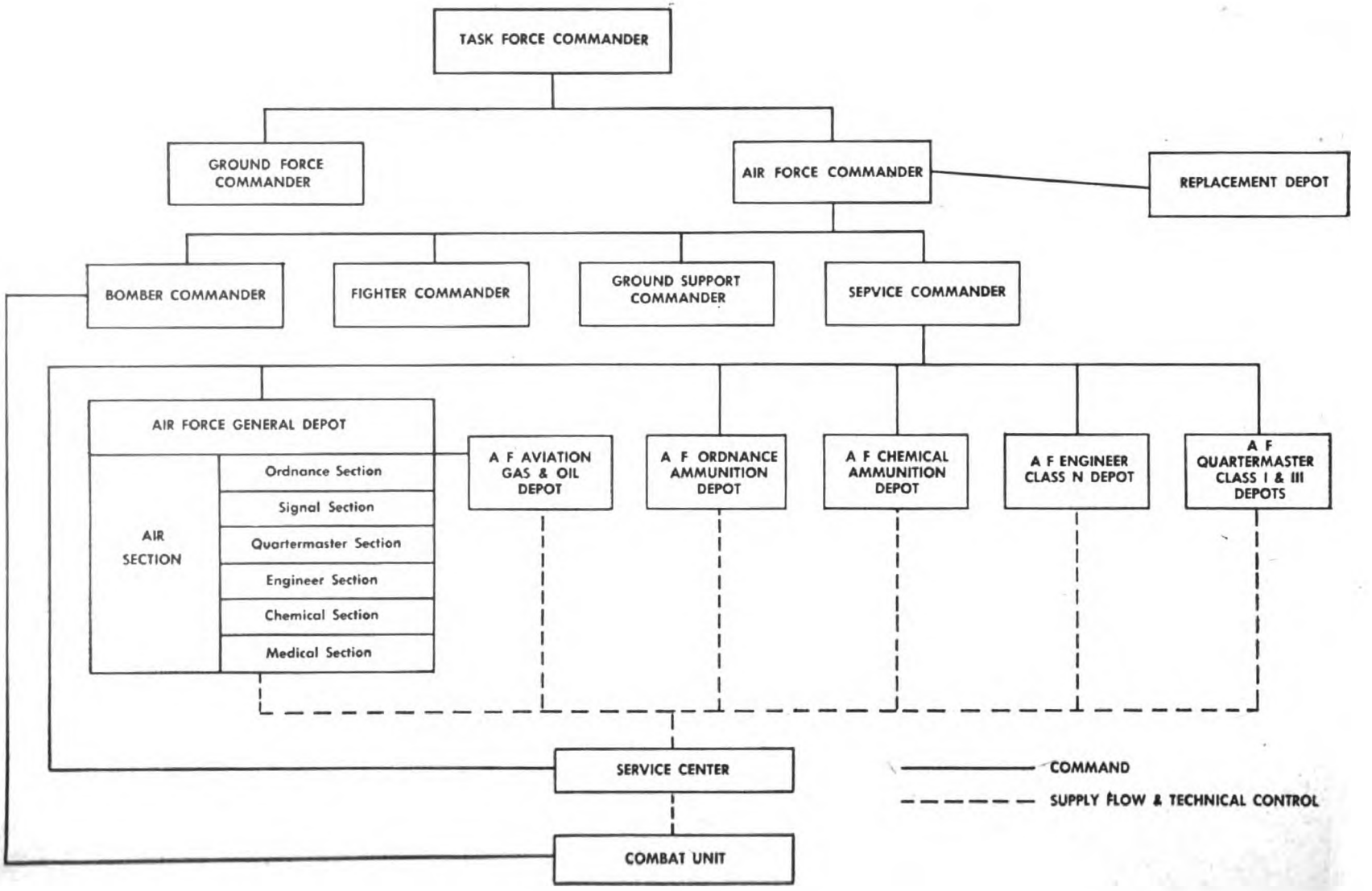

Chart I.

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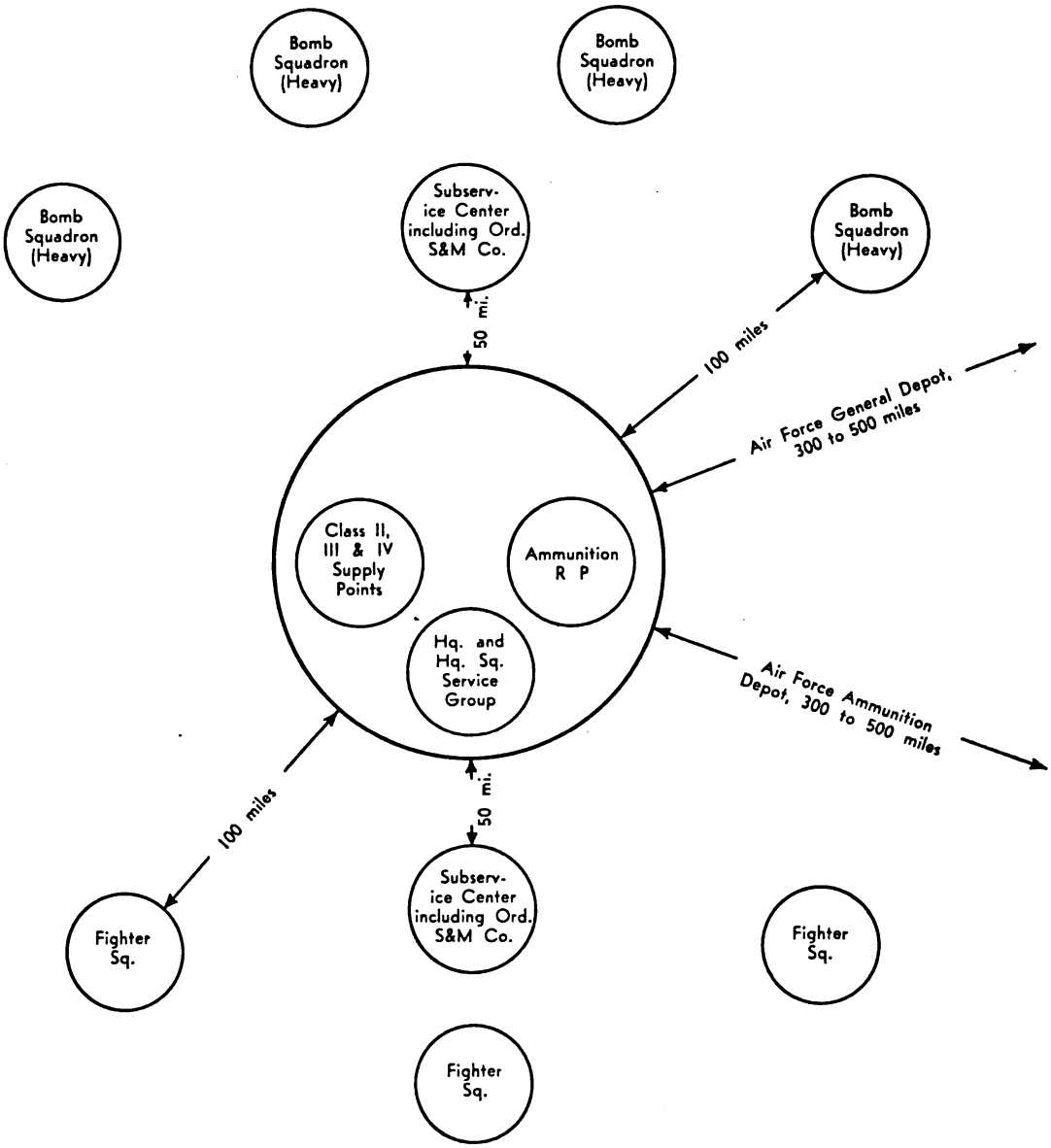
on cradles, finned, and fuzed. The bombs are then rolled under the airplane. At this point the ordnance function ceases and the armament personnel takes over. In some air forces fuzing is done after the bombs are loaded into the plane. Questions invariably arise in maintenance as to the point where the armament section takes over from ordnance. If the truth were known, there is no clear-cut line of demarcation. In the last analysis, maintenance will be done by whatever personnel is available. It may be said, however, that the function of ordnance is usually concerned with major second echelon repair and supply of parts needed for the servicing of guns and small arms in squadron use. Thus, a squadron ordnance officer, besides his advisory duties, has a working ordnance section—one that repairs the guns and handles the ammunition for the squadron.



SCHEMATIC DIAGRAM OF AIR FORCE SERVICE COMMAND
Chart II

Chart 2.

Ordnance Units at Installations of the Airforce Service Commands. The Airforce Service Command's responsibility is to supply and maintain one or more air forces in operation. Normally within a theater of operations, the Air Force

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Service Command will establish such supply and maintenance installations as air force general depots, air force ammunition depots, air depots and service centers and will supervise the activities of all assigned technical service organizations. The ordnance officer of the Air Force Service Command directly supervises the ordnance units. The following are the probable ordnance units which are assigned to one of the installations of the Air Force Service Command.

Ordnance Depot Company. The ordnance depot company operates the ord-

1	1	2	3	4	5	6	7	8	9	10	11	12	13
			Headquarters platoon				2 supply platoons (each)						
1	Unit	Technician grade	Company headquarters	Depot headquarters section	Service section	Total headquarters platoon	Platoon headquarters section	Receiving and shipping section	Storehouse section	Total supply platoon	Total company	Enlisted cadre	Remarks
2	Captain		1			1					1		[1] Insert number of company.
3	First lieutenant			1		1	1			1	2		[2] Administrative, motor, mess, and supply officer.
4	Second lieutenant			1		1					2		[3] Also assists in operation of vehicle replacement pool.
5	Total commissioned		1	2		3	1			1	5		[4] Armed with carbine, cal. .30, unless otherwise indicated.
6	Warrant officer		[2] 1			1					1		[5] Drives truck, ¾-ton.
7	Master sergeant, including			1		1			1	1	3	3	[6] Armed with rifle, cal. .30, M1903.
8	Chief clerk (502)			(1)		(1)					(1)	(1)	[7] Armed with gun, submachine, cal. .45.
9	Chief storekeeper (769)								(1)	(1)	(2)	(2)	Normal Assignment: Component of Ordnance Service, Army (or independent corps) or Air Force.
10	First sergeant (585)		1			1					1	1	Function: Supply of all items of Ordnance including vehicles and complete ammunition.
11	Technical sergeant, including			2	1	3		1		1	5	5	Capacity: One company can perform army supply for an average of 3,000 men. This is subject to variations depending on the type of units in the force.
12	Chief parts clerk (348)			(1)		(1)					(1)	(1)	
13	Receiving and shipping (186)							(1)		(1)	(2)	(2)	
14	Section chief (813)				(1)	(1)					(1)	(1)	
15	Truckmaster (668)			([6] 1)		(1)					(1)	(1)	
16	Staff sergeant, including		2	1		3	1	1	1	3	9	4	
17	Assistant chief parts clerk (348)			(1)		(1)					(1)		
18	Assistant storekeeper (769)								(1)	(1)	(2)		
19	Mess (824)		(1)			(1)					(1)	(1)	
20	Receiving and shipping (186)							(1)		(1)	(2)		
21	Rigger (189)						(1)			(1)	(2)	(2)	
22	Supply (821)		(1)			(1)					(1)	(1)	
23	Sergeant, including		1	2		3			1	1	5	1	
24	Clerk, parts (348)								(1)	(1)	(2)		
25	Clerk, stock record (323)			(1)		(1)					(1)		
26	Inspector, motor parts (413)			(1)		(1)					(1)		
27	Motor (813)		(1)			(1)					(1)	(1)	
28	Corporal, including		1	2		3					3	2	
29	Clerk, company (405)		(1)			(1)					(1)	(1)	
30	Motor (813)			(2)		(2)					(2)	(1)	
31	Technician, grade 4										25	5	The serial number symbol shown in parentheses is an inseparable part of the specialist designation. See AR 615-26.
32	Technician, grade 5 } including		24	11	7	42	1	16	40	56	50	1	
33	Private, first class										32		
34	Private										47		
35	Carpenter (050)	} 5						(2)		(2)	(1)		
36	Carpenter (050)										(3)		
37	Clerk, parts (348)	4						(1)	(4)	(5)	(10)	(1)	
38	Clerk, parts (348)	5						(1)	(4)	(5)	(10)		
39	Clerk, parts (348)							(2)	(8)	(10)	(20)		
40	Clerk, file (355)	5		(1)		(1)					(1)		
41	Clerk, file (355)			(1)		(1)					(1)		
42	Clerk, general (055)	4		(1)		(1)					(1)		
43	Clerk, general (055)	5						(1)		(1)	(2)		
44	Clerk, general (055)							(1)	(1)	(2)	(4)		
45	Clerk, receiving and shipping (186)	4						(1)		(1)	(2)	(1)	
46	Clerk, receiving and shipping (186)	5						(1)		(1)	(2)		
47	Clerk, receiving and shipping (186)							(2)		(2)	(4)		
48	Clerk, stock, control (374)	4		(1)		(1)					(1)	(1)	
49	Clerk, stock control (374)	5		(1)		(1)					(1)		
50	Clerk, stock control (374)			(1)		(1)					(1)		
51	Clerk, stock record (323)	4							(1)	(1)	(2)		
52	Clerk, stock record (323)	5							(1)	(1)	(2)		
53	Clerk, stock record (323)								(3)	(3)	(6)		
54	Clerk, requisition (186)	4		(1)		(1)					(1)		
55	Clerk, typist (405)	4					(4 1)			(1)	(2)		
56	Clerk, typist (405)	5		(1)		(1)					(1)		
57	Clerk, typist (405)			(1)		(1)					(1)		
58	Cook (080)	4	(2)			(2)					(2)	(1)	
59	Cook (080)	5	(2)			(2)					(2)	(1)	
60	Cook's helper (521)		(2)			(2)					(2)		
61	Cutter, glass, (368)	5			(1)	(1)					(1)		
62	Driver, truck, heavy (245)	5							(4 2)	(2)	(4)		
63	Driver, truck, light (345)	} 5	(1)	((4 1)2)		(3)					(1)		
64	Driver, truck, light (345)										(2)		
65	Driver, wrecker (529)	5	(1)			(1)					(1)		
66	Mechanic, automobile (014)	4	(1)		(2)	(3)					(3)	(1)	
67	Mechanic, automobile (014)	5			(2)	(2)					(2)		
68	Rigger (189)	5						(1)		(1)	(2)		
69	Rigger (189)							(2)		(2)	(4)		
70	Warehouseman (252)	5							(8)	(8)	(16)		
71	Warehouseman (252)								(8)	(8)	(16)		
72	Welder (256)	4			(1)	(1)					(1)		
73	Welder (256)	5			(1)	(1)					(1)		
74	Basic (521)		(15)			(15)					(15)		
75	Total enlisted		29	19	8	56	2	17	43	62	180	23	
76	Aggregate		31	21	8	60	3	17	43	63	[1] 183	22	
77	O Carbine, cal. .30		26	16	6	48	2	13	33	48	144		
78	O Gun, machine, cal. .50, HB, flexible		2			2					2		
79	O Gun, submachine, cal. .45			1		1	1			1	2		
80	O Launcher, rocket, AT				1	1	1	1		2	5		
81	O Rifle, cal. .30, M1903		5	4	2	11		4	10	14	29		
82	O Semi-trailer, 6-ton								8	8	16		
83	O Trailer, 1-ton, 2 wheel, cargo		1	1		2					2		
84	O Truck, ¾-ton			1		1					1		
85	O Truck, ¾-ton, weapons carrier, w/winch						1			1	2		
86	O Truck, 2½-ton, cargo		1	1		2					2		
87	O Truck, tractor, 4-5 ton								2	2	4		
88	O Truck, 10-ton, heavy wrecker		1			1					1		

T/O 9-57. Ordnance Depot Company.

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1	1	2	3	4	5	6	7	8	9	10	11	12	13
	Unit	Technician grade	Headquarters section	Service and supply platoon		Armament platoon			Automotive platoon		Total company	Enlisted cadre	Remarks
				Service section	Supply section	Artillery section	Small arms section	Instrument section	Automotive section	Recovery section			
2	Captain		1								1		
3	First lieutenant				1	1			1		3		
4	Second lieutenant		1				1		1	1	4		
5	Total commissioned		2		1	1	1		2	1	8		
6	Warrant officer			[a] 1							1		
7	Master sergeant, including		1								1	1	
8	Master mechanic (342)		(1)								(1)	(1)	
9	First sergeant (585)		1								1	1	
10	Technical sergeant, including				1	1	1	1	1	1	6	6	
11	Armorer (511)						(1)				(1)	(1)	
12	Foreman, auto repair shop (337)								(1)		(1)	(1)	
13	Instrument repairman, non-electrical (098)							(1)			(1)	(1)	
14	Mechanic, artillery maintenance (802)					(1)					(1)	(1)	
15	Rigger (189)									(1)	(1)	(1)	
16	Supply NCO (821)				(1)						(1)	(1)	
17	Staff sergeant, including		3	1		1		1	2		8	2	
18	Assistant foreman, auto repair shop (337)								(2)		(2)		
19	Instrument repairman, non-electrical (098)							(1)			(1)		
20	Machinist (114)			(1)							(1)		
21	Mechanic, artillery maintenance (802)					(1)					(1)		
22	Mess sergeant (824)		(1)								(1)	(1)	
23	Motor transportation NCO (813)		(1)								(1)		
24	Supply NCO (821)		(1)								(1)	(1)	
25	Sergeant, including				1		1			4	6		
26	Armorer (511)						(1)				(1)		
27	Automobile mechanic (014)									(4)	(4)		
28	Parts clerk, automobile (348)				(1)						(1)		
29	Corporal, including		1								1	1	
30	Clerk-typist (405)		(1)								(1)	(1)	
31	Technician grade 3										13	6	
32	Technician grade 4										42	6	
33	Technician grade 5 including		16	14	24	20	10	10	53	14	58	1	
34	Private, first class										30		
35	Private										50		
36	Automobile body repairman (040)	4							(1)		(1)		
37	Automobile body repairman (040)	5							(1)		(1)		
38	Automobile mechanic (014)	3							(6)		(6)	(1)	
39	Automobile mechanic (014)	4							(10)	(2)	(12)	(1)	
40	Automobile mechanic (014)	5							(10)	(2)	(12)		
41	Automobile mechanic (014)								([a] 10) 18)		(18)		
42	Automobile radiator man (172)	4							(1)		(1)		
43	Automobile radiator man (172)	5							(1)		(1)		
44	Blacksmith (024)	5							(1)		(1)		
45	Bugler (893)		(1)								(1)		
46	Carburetor specialist (414)	3							(1)		(1)	(1)	
47	Carburetor specialist (414)	4							(2)		(2)		
48	Carburetor specialist (414)	5							(2)		(2)		
49	Carpenter, construction (050)	5		(1)							(1)		
50	Clerk, general (055)		(1)								(1)		
51	Clerk-typist (405)	5	(1)		(1)						(2)		
52	Clerk-typist (405)				(2)						(2)		
53	Cook (060)	4	(2)								(2)	(1)	
54	Cook (060)	5	(2)								(2)	(1)	
55	Cook's helper (521)		(3)								(3)		
56	Electrician (028)	5		([b] 1)							(1)		
57	Electrician, automotive (012)	3							(1)		(1)	(1)	
58	Electrician, automotive (012)	4							(2)		(2)		
59	Electrician, automotive (012)	5							(2)		(2)		
60	Instrument repairman, non-electrical (098)	3						(1)			(1)	(1)	
61	Instrument repairman, non-electrical (098)	4						(3)			(3)		
62	Instrument repairman, non-electrical (098)	5						((b 1) 4)			(4)		
63	Instrument repairman, non-electrical (098)							([b] 1)			(1)		
64	Machinist (114)	3		(1)							(1)		
65	Machinist (114)	4		(1)							(1)		
66	Machinist (114)	5		([b] 1)							(1)		
67	Machinist (114)			(2)							(2)		
68	Mechanic, artillery maintenance (802)	3				(2)					(2)	(1)	
69	Mechanic, artillery maintenance (802)	4				(4)					(4)		
70	Mechanic, artillery maintenance (802)	5				(5)					(5)		
71	Mechanic, artillery maintenance (802)					([b] 2) 7)					(7)		
72	Mechanic, automotive engine (909)	3							(1)		(1)	(1)	
73	Mechanic, automotive engine (909)	4							(2)		(2)		
74	Mechanic, automotive engine (909)	5							([b] 1)		(1)		
75	Motor inspector (413)	4							(2)		(2)		
76	Motorcycle mechanic (138)	5							(1)		(1)		
77	Motorcycle mechanic (138)								(3)		(3)		
78	Orderly (695)		((b 1) 2)								(2)		
79	Painter, automobile (143)	5							(1)		(1)		
80	Painter, general (144)	5		(1)							(1)		
81	Parts clerk, automobile (348)	4			(2)						(2)	(1)	
82	Parts clerk, automobile (348)	5			(2)						(2)		
83	Parts clerk, automobile (348)				(5)						(5)		
84	Stock record clerk (323)	4			(1)						(1)	(1)	
85	Stock record clerk (323)	5			(1)						(1)		
	Private—Continued.												
86	Stock record clerk (323)				(1)						(1)		
87	Storage battery electrician (215)	5							(1)		(1)		
88	Truck driver, heavy (245)	5								(4)	(4)		
89	Truck driver, light (345)	5	(1)								(1)		
90	Truck driver, light (345)		(2)	(1)	(7)				(2)		(12)		
91	Weapons mechanic, aircraft (902)	4					(2)				(2)	(1)	
92	Weapons mechanic, aircraft (902)	5					((b 1) 5)				(5)		
93	Weapons mechanic, hand and shoulder (903)						([b] 2)				(2)		
94	Welder, combination (256)	4		(2)					(3)		(5)	(1)	
95	Welder, combination (256)	5		([b] 1)						(4)	(5)		
96	Basic (521)		(1)	(2)	(2)	(2)	(1)	(1)	(9)	(2)	(20)		
97	Total enlisted		22	15	26	22	12	12	88	19	216	24	
98	Aggregate		24	16	27	23	13	12	90	20	225	24	
99	O Carbine, cal. .30		18	11	20	16	10	9	69	14	167		
100	O Gun, machine, cal. .50, HB, flexible [c]		1		2				4		7		
101	O Gun, submachine, cal. .45		2	2	1	2	1		2	1	11		
102	O Launcher, rocket, AT		1		1	1			1		4		
103	O Rifle, cal. .30, M1903		4	3	6	5	2	3	19	5	47		
104	O Trailer, 1-ton, 2-wheel, cargo		1	3	6	1	2	2	11		26		
105	O Trailer, 1-ton, 2-wheel, water tank, 250 gal		1								1		
106	O Truck, ¼-ton		1	1		1			1	1	5		
107	O Truck, ¾-ton, command, w/winch		1								1		
108	O Truck, ¾-ton, weapons carrier, w/winch			1	1	1	1	1	1		6		
109	O Truck, 2½-ton, cargo, w/winch		1						11		12		
110	O Truck, 2½-ton, cargo, wo/winch		1		6			1			8		
111	O Truck, artillery repair, M9					1					1		
112	O Truck, heavy wrecker, M1									1	1		
113	O Truck, instrument repair, M10							1			1		
114	O Truck, machine shop, M16, Load A			1							1		
115	O Truck, small arms repair, M7						2				2		
116	O Truck, welding, M12			1							1		
117	O Truck, 4-ton, wrecker, w/winch									2	2		

[a] Insert number of company.
[b] Munitions: armament machinist 9923.
[c] Also drives truck.
[d] These guns are mounted 1 per 4 1½-ton trucks (or heavier) in this table.

Assignment.—As required, normally to an air force general depot.

Function.—Performs 4th echelon maintenance and overflow 3rd echelon maintenance of vehicles and armament of an air force.

For specification serial numbers shown in parentheses, see AR 615-26.

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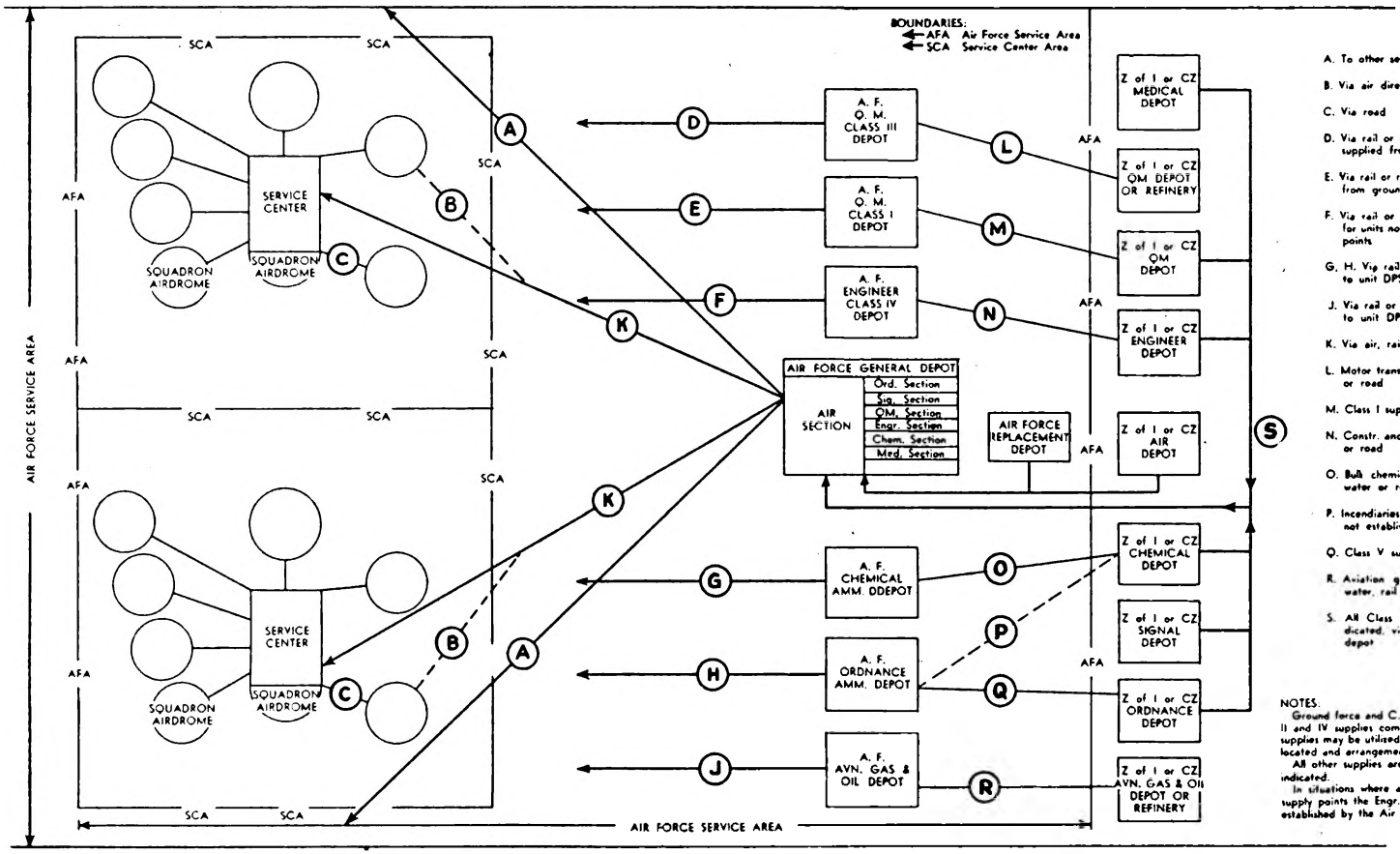

LEGEND

A. To other service centers

B. Via air direct

C. Via road

D. Via rail or road to Class III RPS for units not supplied from ground troop supply points

E. Via rail or road to Cl. I RPS for units supplied from ground force supply points

F. Via rail or road to Engr. Cl. IV RPS or DPS for units not supplied from ground force supply points

G, H. Via rail or road to Class V RPS or direct to unit DPS

J. Via rail or road to Class III (A) RPS or direct to unit DPS

K. Via air, rail or road

L. Motor transport gasoline and oil via water, rail or road

M. Class I supplies only via water, rail or road

N. Constr. and Cam. materials only via water, rail or road

O. Bulk chemicals and incendiaries only via rail, water or road

P. Incendiaries when Air Force Chem. Amm depot not established

Q. Class V supplies only via water, rail or road

R. Aviation gas and oil only Class III (A) via water, rail or road

S. All Class II and IV Supplies, except as indicated, via water, rail or road to Air Force depot

NOTES:

Ground force and C.Z. supply points for Class I supplies, articles of Classes II and IV supplies common to both ground and air forces and for Class III supplies may be utilized to supply air force units when these points are suitably located and arrangements are made by the air force commander.

All other supplies are normally supplied through air force supply points as indicated.

In situations where all air force units are served by ground force or C.S. supply points the Engr. Class IV and Q.M. Class I and III depots will not be established by the Air Force Commander.

Chart 3.

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nance section of the air force general depot. It maintains the necessary stock levels of ordnance general supplies in order to supply all ordnance supply and maintenance points of the air force. The number of ordnance depot companies assigned to an air force general depot is determined by the ordnance load. By the same token, ordnance depot companies may not be required if Army Service Forces facilities within the air force area are adequate to serve its units.

Ordnance Maintenance Company (Air Force) operates a fixed or mobile repair shop for the fourth echelon maintenance, inspection, and renovation of ordnance materiel in the hands of air force units. This company has trained personnel and equipment capable of performing fourth echelon maintenance on all ordnance equipment including automotive. It is responsible for the evacuation to Army Service Forces base shop of all ordnance equipment unserviceable beyond repair with available facilities. This company furnishes the most specialized ordnance maintenance available in an air force. Its location is usually at or adjacent to the air force general depot.

Ordnance Ammunition Company operates the air force ammunition depot. It supplies all ammunition including bombs and pyrotechnics to the service center refilling points (RP's) and airdrome distributing points (DP's) depending on local conditions and routes of communication. Actual movement of the ammunition will be by rail, water, or truck, which transportation is provided by assigned

1	1	2	3	4	5	6	7	8	9	10	11
	Unit	Technician grade	Company headquarters	Ammunition section	Armament section	Automotive section	Supply section	Total company	Enlisted cadre	Torpedo section[a]	Remarks
2	Captain		1					1			† Insert number of company.
3	First lieutenant				[b] 1	1		2		1	
4	Second lieutenant			1				1			*Assignment.*—2 Companies per Service Center (1 per Service Squadron). Provides Ordnance General Supply and Ammunition Supply. Also third echelon maintenance on automotive and armament equipment of combat group.
5	Total commissioned		1	1	1	1		4		1	
6	Master sergeant, including	[c]				1		1	1	1	
7	Aerial torpedo mechanic (662)									(1)	
8	Foreman, auto repair shop (337)					(1)		(1)	(1)		
9	First sergeant (585)		1					1	1		
10	Technical sergeant, including			1	1	1	1	4	3		
11	Ammunition (505)			(1)				(1)	(1)		
12	Armorer (511)				(1)			(1)	(1)		
13	Motor inspector (413)					(1)		(1)			
14	Supply (821)						(1)	(1)	(1)		
15	Staff sergeant, including		2			1		3	2	1	
16	Aerial torpedo mechanic (662)									(1)	
17	Automobile mechanic (014)					(1)		(1)			
18	Mess sergeant (824)		(1)					(1)	(1)		
19	Supply (821)		(1)					(1)	(1)		
20	Sergeant, including			1	1	1	1	4			
21	Administrative clerk (501)					(1)	(1)	(2)			
22	Ammunition (505)			(*1)				(1)			
23	Weapons mechanic, aircraft (902)				(1)			(1)			
24	Corporal, including		1					1	1		
25	Clerk-typist (405)		([d]1)					(1)	(1)		
26	Technician, grade 3							1			
27	Technician, grade 4							9	2	2	
28	Technician, grade 5 including		6	16	9	25	6	21	5	2	
29	Private, first class							12		2	
30	Private							19		2	
31	Administrative clerk (501)	5	(*1)	(1)			(2)	(4)	(1)		
32	Administrative clerk (501)		(*1)	(1)	(1)		(1)	(4)			
33	Aerial torpedo mechanic (662)	4								(2)	
34	Aerial torpedo mechanic (662)	5								(2)	
35	Aerial torpedo mechanic (662)									(*4)	
36	Artillery mechanic, light (913)	4			(1)			(1)			
37	Automobile mechanic (014)	3				(1)		(1)			
38	Automobile mechanic (014)	4				(2)		(2)	(1)		
39	Automobile mechanic (014)	5				(3)		(3)	(1)		
40	Automobile mechanic (014)					(*6)		(6)			
41	Automobile radiator man (172)	4				(1)		(1)			
42	Carburetor specialist (414)	4				([e]1)		(1)			
43	Carburetor specialist (414)	5				(*1)		(1)			
44	Carburetor specialist (414)					(1)		(1)			
45	Carpenter, construction (050)	5				(*1)		(1)			
46	Cook (060)	4	(1)					(1)	(1)		
47	Cook (060)	5	(1)					(1)			
48	Cook's helper (521)		(1)					(1)			
49	Crane operator (063)	5		([f]1)				(1)			
50	Machinist (114)	4				(1)		(1)			
51	Machinist (114)	5				(1)		(1)			
52	Munitions worker, aviation (901)	5		([g]4)				(4)	(2)		
53	Munitions worker, aviation (901)			(*7)				(7)			
54	Parts clerk, automobile (348)	5					(1)	(1)			
55	Parts clerk, automobile (348)						(*1)	(1)			
56	Receiving or shipping checker (186)						(*1)	(1)			
57	Sheet metal worker (201)	5				(1)		(1)			
58	Shop clerk (457)					(1)		(1)			
59	Weapons mechanic, aircraft (902)	4			(1)			(1)			
60	Weapons mechanic, aircraft (902)	5			(1)			(1)	(1)		

[a] Additional qualification as aerial mines mechanic.
[b] Company clerk.
[c] Additional qualification as truck driver (345)
[d] Additional qualification as storage battery electrician (215).
[e] Additional qualification as automotive electrician (012).
[f] Additional qualification as painter (144).
[g] Additional qualification as truck driver (245).
[h] 2 to have additional qualification as aerial mines mechanic.
[i] These guns are mounted 1 per 4 trucks, 2½-ton (or heavier) in this table.
[j] To be used as 2½-ton wrecker.

For specification serial numbers shown in parentheses, see AR 615-26.

T/O 9-417. Ordnance Supply and Maintenance Company, Aviation.

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	1	2	3	4	5	6	7	8	9	10	11
	Unit	Technician grade	Company headquarters	Ammunition section	Armament section	Automotive section	Supply section	Total company	Enlisted cadre	Torpedo section[a]	Remarks
61	Weapons mechanic, aircraft (902)	...	...	...	(2)	...	...	(2)	...	...	
62	Weapons mechanic, hand and shoulder (903)	...	...	...	(*1)	...	...	(1)	...	...	
63	Welder, combination (256)	4	...	...	...	(1)	...	(1)	...	...	
64	Welder, combination (256)	5	...	...	(1)	...	...	(1)	...	...	
65	Wrecker operator (529)	5	...	...	...	(1)	...	(1)	...	...	
66	Basic (521)	...	(1)	(2)	(1)	(2)	...	(6)	...	...	
67	Total enlisted	...	10	18	11	29	8	76	15	10	
68	Aggregate	...	11	19	12	30	8	80	15	11	
69	O Carbine, cal. .30	...	8	13	9	24	6	60	...	8	
70	O Gun, machine, cal. .50, HB, flexible[b]	...	...	...	...	1	1	2	...	...	
71	O Gun, submachine, cal. .45, M3	...	1	1	1	...	...	3	...	1	
72	O Launcher, grenade, M1	...	2	5	2	6	2	17	...	2	
73	O Launcher, rocket, AT, M1	...	...	1	...	1	...	2	...	...	
74	O Rifle, cal. .30, M1903A3 or M1903A1	...	2	5	2	6	2	17	...	2	
75	O Tractor crane, 2-ton, M5	...	...	1	...	...	...	1	...	...	
76	O Trailer, bomb, M5	...	...	4	...	...	...	4	...	...	
77	O Trailer, 1-ton, 2-wheel, cargo	...	1	...	...	...	2	3	...	...	
78	O Trailer, tractor crane	...	...	1	...	...	...	1	...	...	
79	O Truck, automotive repair	...	...	...	...	1	...	1	...	...	
80	O Truck, bomb service, M6	...	...	2	...	...	...	2	...	...	
81	O Truck, machine shop, M16, Load A	...	...	...	...	1	...	1	...	...	
82	O Truck, small arms repair, M7	...	...	...	1	...	...	1	...	...	
83	O Truck, welding, M12A1	...	...	...	...	1	...	1	...	...	
84	O Truck, ¼-ton	...	...	1	...	...	...	1	...	...	
85	O Truck, ¾-ton, command, w/winch	...	1	...	...	...	...	1	...	...	
86	O Truck, ¾-ton, weapons carrier w/winch	...	...	...	1	...	...	1	...	1	
87	O Truck, 2½-ton, cargo	...	1	...	...	...	2	3	...	...	
88	O Truck, 2½-ton, cargo, w/winch	...	...	...	...	1	...	1	...	1	
89	O Truck, 4-ton (For air compressor)	...	...	...	...	...	...	...	...	1	
90	O Truck, 4-ton, wrecker	...	...	...	...	1	...	1	...	...	
91	O Truck, 6-ton, prime mover, w/winch	...	...	1	...	...	...	1	...	...	

T/O 9-417. Ordnance Supply and Maintenance Company, Aviation. (Continued)

Quartermaster and Transportation Corps units. The ammunition company is not sufficiently equipped with vehicles to move ammunition to forward points. Normally, deliveries are made directly to advanced airdromes, the service center refilling point being maintained in cases of temporary breakdown in this service. The number of ammunition depots will depend on the size and activity of the air force. The set-up and organization for this company is included in chapter 9.

Ordnance Section Headquarters and Headquarters Squadron Air Depot Group is located at an air depot overseas and is responsible for the inspection, maintenance, and repair of ordnance items, except automotive, at the air depot. This is a specialized section set up for third echelon repair and provides service only at the air depot. It is not a regular third echelon maintenance shop for second echelon units, but functions at the air depot only. Present plans provide for the augmentation of this section to provide automotive maintenance personnel now furnished by the ordnance medium automotive maintenance platoon (aviation).

Ordnance Section Headquarters and Headquarters Squadron, Service Group is a small ordnance section assigned to service group headquarters. It coordinates and supervises the various ordnance activities within the service center area, which is mainly accomplished by the ordnance supply and maintenance company (aviation). In the new tentative organization of the service group into an engineering squadron, materiel squadron, and headquarters and base services squadron, Ordnance has been integrated into the air forces. This is the first indication of actual amalgamation of arms and services assigned or attached to the air forces into the air forces.

Ordnance Supply and Maintenance Company, Aviation. Usually two ordnance supply and maintenance companies, aviation, are furnished per service group. These companies are responsible for supply, maintenance, storage, issue, and inspection of all ordnance items, including automotive, to units located at the service center, and also for the operation of service center ammunition stocks (RP).

In the text following, description, function, inspections, and preventive mainte-

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nance of the various types of bombs and their fuzes, pyrotechnics, aerial mines and torpedoes, bomb handling equipment, and aircraft armament are discussed separately. Maintenance and inspection data generally include too large a field to be included in a single volume; however, the complete descriptive bibliography at the close of this chapter will afford ready references to officers with field problems of this nature. To avoid duplication of treatment the broad subject of aircraft ammunition is omitted here since the necessary information is included in chapter 3, Vol. III Ammunition. Similarly, Browning Machine Guns are covered in considerable detail in chapter 1, Small Arms, and although prominently employed as aircraft armament these have also been omitted to avoid duplication.

Aerial bomb ballistic data, Altitude of Release tables and tactical employment charts which follow are particularly directed to the reader's attention. The information shown is capable of many uses and will materially assist Ordnance staff officers with the Air Force.

AERIAL BOMBS

Definition. A bomb is a cylindrical metal container filled with high explosive which is dropped from aircraft.

Classification of Demolition Bombs

Demolition (M Series)
General Purpose (GP Series)
Semi-Armor-Piercing, (SAP Series)
Armor-Piercing, (AP Series)
Light Case, (LC Series)

DEMOLITION BOMBS (M SERIES)

General. This type of demolition bomb is designed to reduce targets chiefly by the violence of the detonation of the bomb, although fragments may cause additional damage, particularly when the detonation occurs above the surface of the

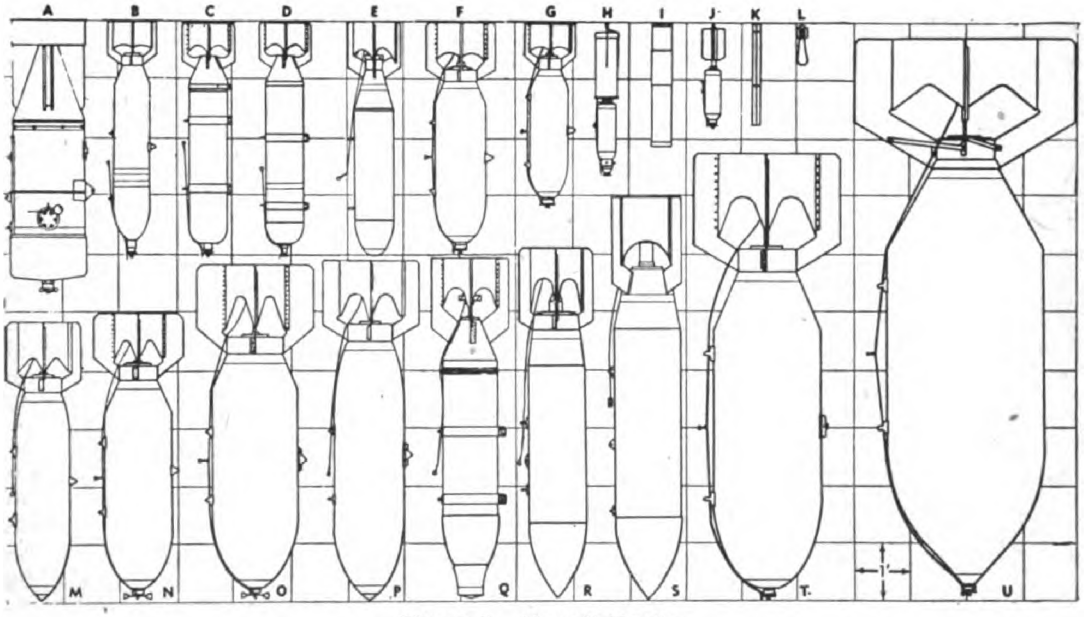

Figure 1. Aircraft Bombs.

ground. In order that the maximum violence of detonation may be achieved, the steel case of the bomb is made as light as possible consistent with the structural strength required to withstand impact and penetration of the target.

Description. This bomb is manufactured from a section of seamless steel tubing with the nose heated and swaged to form a curved ogive, and the tail drawn to a convenient diameter to fit the rear cap. A pair of suspension lugs are welded on

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top of the bomb along the longitudinal axis. On bombs up to and including the 1,000-pound bomb, these lugs are 14 inches apart. On the 2,000- and 4,000-pound bombs the lugs are welded 30 inches apart. The nose end of the M series demolition bomb is much heavier than any other section of the bomb body. This type of construction insures that the bomb body will not rupture upon impact with material targets which it is designed to destroy, and thereby eliminates the possibility of a low order detonation. A fuze seat liner is assembled to the nose of the bomb. The base is closed with a large ring-shaped cap, which has a threaded extension for attaching the fin assembly. The center of the cap is closed with the adapter booster for the tail fuze.

The M series bombs are readily recognized by the external threads on the rear end of the bomb body and the ring-shaped cap internally threaded to be assembled to the rear end of the bomb body. Also they have only two suspension lugs.

Size and Nomenclature

1. 100 lb — M30
2. 300 lb — M31
3. 600 lb — M32
4. 1,100 lb — M33
5. 2,000 lb — M34

Standardization. In order to standardize bombs between the Army and Navy, the next change in Army bomb sizes was to adopt a 500- and 1,000-pound bomb to replace the 600- and 1,100-pound bombs. This change in size was due to the fact that the 600- and 1,100-pound bombs would not fit in installations of Navy bombers. The 500- and 1,000-pound bombs were standardized as follows:

1. 500 lb — M43
2. 1,000 lb — M44

Tactical Use. Refer to section on tactical use of bombs and fuzes.

GENERAL PURPOSE (GP SERIES)

General. The British were using large numbers of our bombs, and it was found that our 300-pound M31 bomb would not conveniently fit the British bomb racks. It was also discovered that the lip of the tail base cap would catch as the bomb penetrated targets, pulling off the cap and the tail fuze so as to result in a low order detonation or a dud. To satisfy the British and to overcome the difficulty with the tail cap, the 250-pound GP AN-M57 bomb was made. The tail cap was replaced by a tail base plug which screws into the bomb case. A simple suspension lug is welded to the bomb case 180° from the two suspension lugs. This was the first step toward the present GP series bombs. To standardize all bombs used by the Army, Navy, and the British, a new nomenclature series was used.

Description. This series of bombs is identical with the M series of bomb with the exception of a third suspension lug and the tail base plug which screws into the bomb.

Size and Nomenclature

1. 100 lb GP AN-M30
2. 250 lb GP AN-M57
3. 500 lb GP AN-M43
4. 1,000 lb GP AN-M44
5. 2,000 lb GP AN-M334

Tactical Use. Refer to section of tactical use of bombs and fuzes.

Standardization of the Bombs, GP AN-M64, AN-M65, and AN-M66. The AN-M64 (500 lbs.) replaces the AN-M43 (500 lbs.), the AN-M65 (1,000 lbs.) replaces the AN-M44 (1,000 lbs), and the AN-M66 (2,000 lbs.) replaces the AN-M34 (2,000 lbs.). These three bombs are essentially the same as the three they replace except that they permit the use of the fuze, Navy, hydrostatic, AN-MK 230 or an Army tail fuze. This series of bombs use the M115 adapter booster which has a removable inner sleeve. When using a Navy fuze, the sleeve is removed; and when using an Army fuze, the sleeve remains in the adapter. It is obvious that the fuzing alternative permits a wide range of adaptability of various targets and that, by the use of different settings in the nose and tail fuzes, the bombardier of a plane equipped for selective arming can make some choice of fuze setting while in the air.

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A1 Modification of GP Series Bombs. All standard GP series of bombs incorporate a locking device in order that the base plate may be securely locked to the bomb body and the adapter booster may, if desired, be locked to the base plate.

The modification consists of two studs fastened to the under side of the base plate in order that the TNT tail surround will hold the base plate firmly and prevent the removal of the plate. An annular groove is milled into the base plug located below the adapter booster seating surface and cut into the adapter booster mating threads of the base plate. The adapter booster also has a hole drilled through it in order that the locking pin may be inserted prior to installation of the tail fuze, which will securely lock the adapter booster to the base plate.

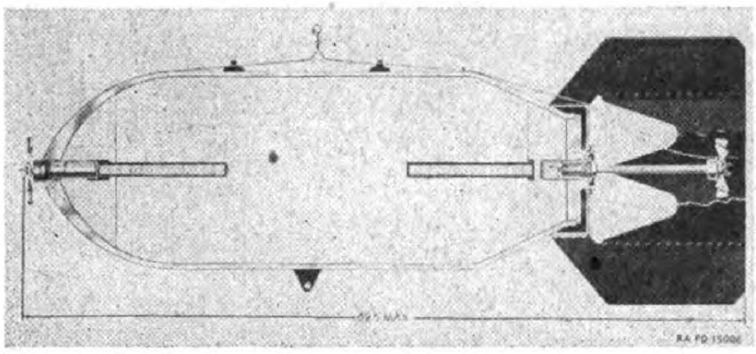

Figure 2a. General Purpose Bomb.

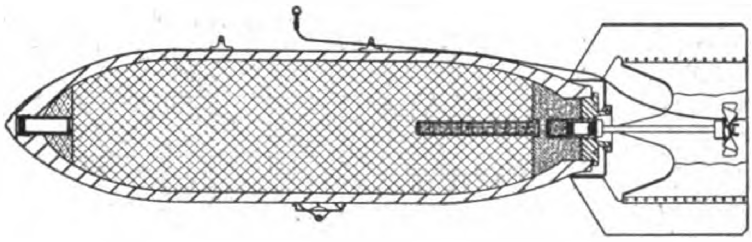

Figure 2b. SAP, 100-lb. Bomb, AN-M59.

The above mentioned modifications were made primarily to prevent the circumvention of the antiwithdrawal device of the long delay series of fuzes. The locking pins, mentioned above, will be shipped with the long delay fuzes, one pin per each fuze.

SEMI-ARMOR-PIERCING (SAP SERIES)

General. A semi-armor-piercing bomb was developed at the same time as the bomb, GP, 250 pounds AN-M57 for the specific purpose of penetrating the reinforced floors of factory buildings and functioning on ground floors. These bombs can be identified by the sharply pointed nose and pointed steel nose plug.

A1 Modification of AN-M58. 9.5 pounds of explosive filler was removed, and 31.5 pounds of steel was added to the nose to increase the penetrating ability of the bomb.

A2 Modification of AN-M58, and A1 Modification of AN-M59. This modification is identical to the A1 modification of the GP series bombs (see above).

1. 500 lb AN-M58
2. 1,000 lb AN-M59
3. 500 lb AN-M58A1
4. 1,000 lb AN-M59A1
5. 500 lb AN-M58A2

Tactical Use. Refer to section on tactical use of bombs and fuzes.

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ARMOR-PIERCING BOMBS AP SERIES

General. Armor-piercing bombs are thick-walled bombs intended for penetrating reinforced concrete targets. Because of their heavy walls, they contain only a small percentage of explosive charge, approximately 15 per cent by weight. The first armor-piercing bombs of the Army were converted 10-inch, 12-inch, and 14-inch seacoast mortar projectiles. The suspension lugs are attached to the body by means of metal bands that surround the circumference of the shell and are bolted in place. A tail base plug has been added to adapt the shell for a tail fuze and a box type fin assembly.

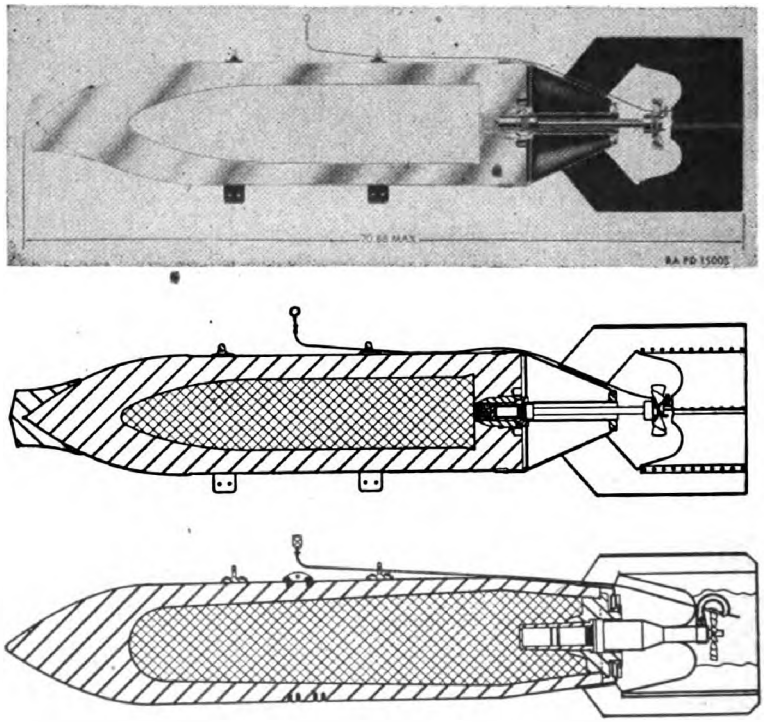

Figure 3. Armor-Piercing Bomb; Bomb, AP, 1000-lb., M52; and Bomb, AP, 1000-lb., AN-Mk. 33.

Explosive Filler. Unlike the rest of modern bombs, the armor-piercing bombs are filled with Explosive D (ammonium picrate). Since armor-piercing bombs are subject to great shock, Explosive D is used because it is very insensitive to shock and will not detonate upon impact of the bomb.

Size and Nomenclature

1. Converted seacoast-mortar shells.
   a. 600 lb AP M62
   b. 800 lb AP M61
   c. 1,000 lb AP M52
   d. 1,400 lb AP M63
2. Navy development.
   a. 1,000 lb AP AN-MK 33
   b. 1,600 lb AP AN-MK I, Mod. I

Tactical Use. Refer to section on tactical use of bombs and fuzes.

LIGHT CASE BOMB (LC SERIES)

General. This bomb was developed to be used primarily against residential areas, factories, and lightly constructed buildings.

Description. The body is made of several cast pieces welded together. The

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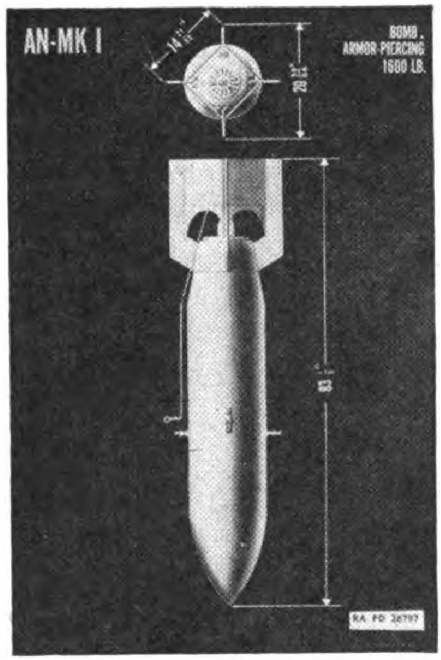

Figure 4a. Bomb, AP 1600-lb., MK 1.

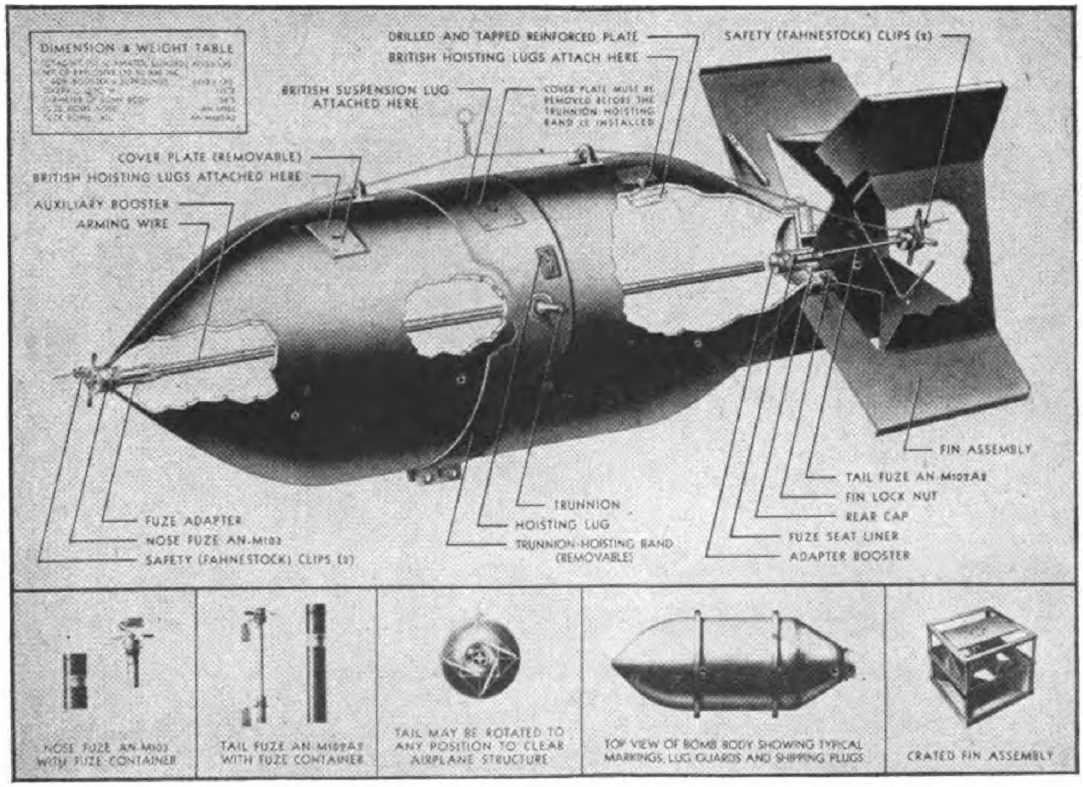

Figure 4b. 4,000-lb. Light Case Bomb AN-M56A1.

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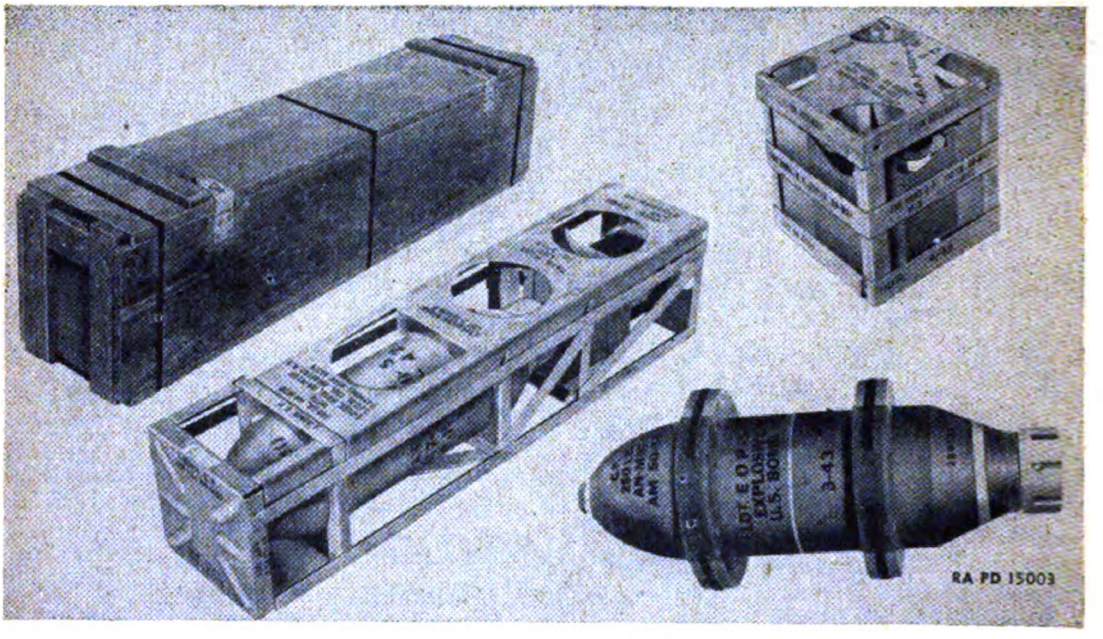

Figure 5. Packing Bombs.

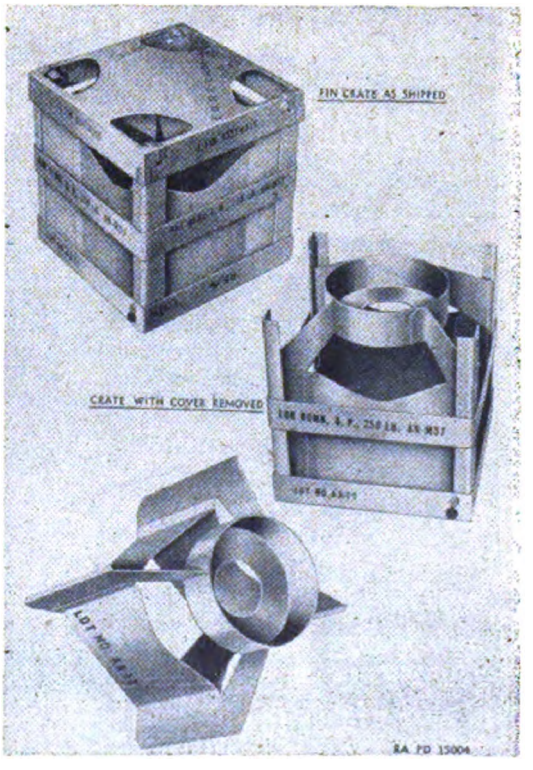

Figure 6. Packing Components.

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side walls have a minimum thickness of .3 inch and a maximum thickness of .5 inch. It is closed at the base by a female cap. Two lugs are welded to the case, 15 inches on either side of the center of gravity. The normal box-type fin assembly is modified on this bomb by eight additional strut rods to give increased stability for this large bomb.

Size and Nomenclature

4,000 lb LC AN-M56A1

Tactical Use. Refer to section on tactical use of bombs and fuzes.

PACKING AND SHIPPING

For the purpose of packing and shipping, in general bombs can be divided into two weights: 100-lb bombs, and bombs over 100 lbs.

1. Bombs weighting 100 pounds are packed and shipped in metal crates with fins attached.

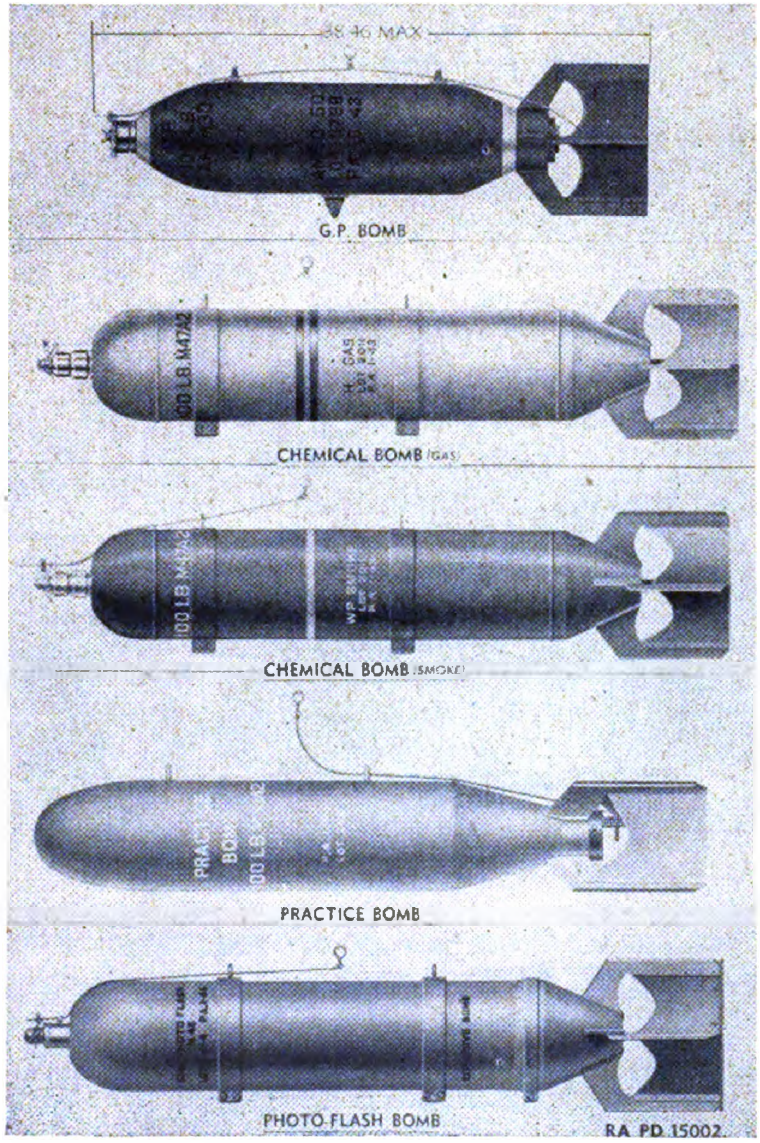

Figure 7. Painting and Marking of Bombs.

2. Bombs weighing over 100 pounds such as GP, AP, SAP, and LC are packed in two parts. One part consists of the bomb body with shipping plugs to protect the nose and tail openings if such are present. Shipping bands are channeled to fit

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over the suspension lugs around the circumference of the bomb. These bombs are provided with slots to attach slings, hooks, or any other means of handling. The shipping band protects the suspension lugs from damage and provides tracks for rolling the bombs on hard surfaces. Shipping bands are made of metal, or, more recently, of layers of paper glued together. The second unit of the packing of bombs over 100 pounds is the fin assembly which is packed in a metal crate. The nose and tail fuze assembly and arming wire assembly will be shipped separately in bulk.

PAINTING AND MARKING

General. Bombs are painted for prevention of rust, as a means for identification, and for camouflage. All demolition bombs are painted olive drab, lusterless. High-explosive bombs are painted with one yellow band, one inch wide, located at each end of the bomb body; they may or may not have a ¼-inch yellow band at the center of gravity. See Figure 7.

Marking. The following information is stenciled on the bomb body:

(1) Type. GP, AP, SAP, or LC.
(2) Weight and mark or model of bombs, *e.g.*, 100 lb AN-M30A1.
(3) Type of filler.
(4) Lot number.
(5) Initials of loading plant and date loaded.

COMPONENTS OF A COMPLETE ROUND

A. Bomb body with high explosive.
B. Nose fuze.
C. Tail fuze.
D. Fin assembly.
E. Arming wire assembly.

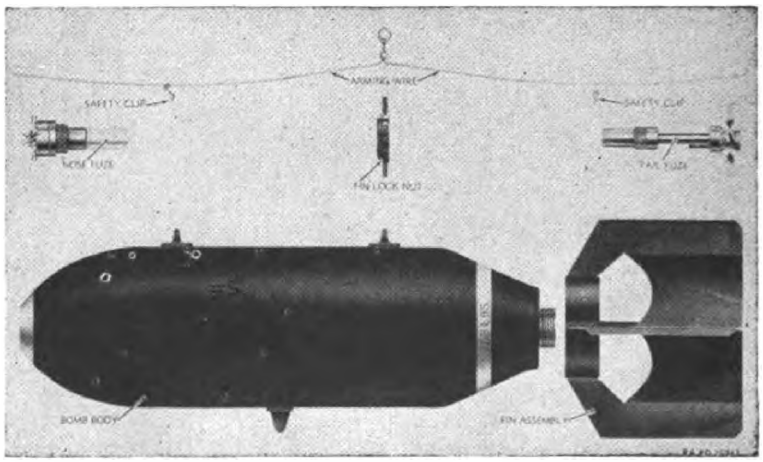

Figure 8. Complete Round Components.

FRAGMENTATION BOMBS AND FUZES

General. Fragmentation bombs are designed for their destructive effect against personnel and light materiel targets. Among the various types of targets they might be used against are truck convoys, troop columns, landing craft, parked airplanes, and bivouac areas. In certain theaters, fragmentation bombs have played a large part in our big offenses, and have generally kept the enemy on the alert at all times.

The name given the bomb indicates its primary use. Where we look for blast effect in other types of bombs, in fragmentation bombs our main objective is to fill the air with countless numbers of high velocity fragments, all with rough jagged edges.

Specifically, fragmentation bombs which have landed and functioned at a

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distance of sixty feet from parked aircraft have perforated all parts of an airplane engine except engine cylinders packed by pistons. At distances of two hundred feet the fragments will perforate wings, gas tanks, other vital spots on planes and will cut tires and control wires. One 20-pound fragmentation bomb will do as much damage as a 3-inch artillery shell placed as close as sixty feet from the target.

Fragmentation bombs will break up into 800 to 1,200 fragments, each weighing .2 to .3 of an ounce—roughly the same bulk as a .30 caliber rifle bullet. The fragments have an initial velocity of 2,300 to 4,900 feet per second. The effect would be similar to firing 800 caliber .30 rifles from one point simultaneously. It must be noted, however, that the fragments lose their velocity much more rapidly than, and do not have the effective range of, a caliber .30 rifle bullet. Under ideal conditions of vertical impact, fragmentation bombs have projected fragments up to a distance of 600 yards from the point of impact and have produced casualties up to a distance of 165 feet.

We have seen that fragmentation bombs perform little damage from blast; it follows logically, therefore, that they will contain much less high-explosive filler than some other types of bombs. The high explosive filler, which may be either TNT, Amatol, or Composition B, is approximately 15% of the total weight of the bomb.

Suspension in Aircraft. Due to various factors, fragmentation bombs are designed to be suspended in aircraft either horizontally or vertically. All types of aircraft can be adapted to carry fragmentation bombs.

Generally fighters and fighter bombers will carry these bombs suspended horizontally in wing racks. Light, medium, and heavy bombers will usually carry these bombs in a horizontal position in clusters of three or six. However, it should be noted that they may be carried by light bombers suspended vertically in internal bomb racks. The larger size fragmentation bombs may also have single horizontal suspension.

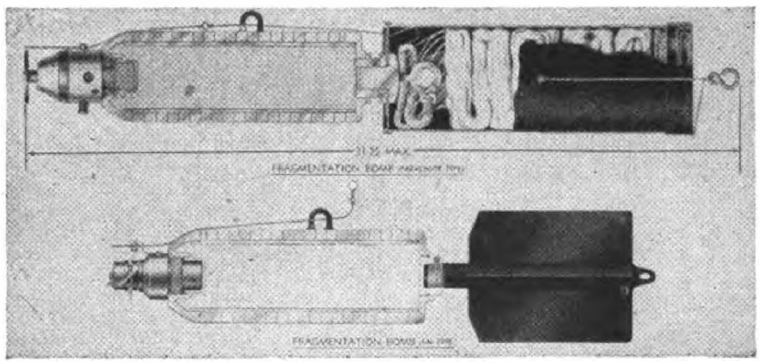

Figure 9. Fragmentation Bombs.

Types of Fragmentation Bombs. Fragmentation bombs can be classified into two broad groups: stabilized fin and parachute. The type of bomb used will depend upon the mission to be flown—either high or low level. The destructive effect of fragmentation bombs depends on the angle of impact. In dropping stabilized fin fragmentation bombs, it is necessary to attain an altitude of release of 8,000 to 10,000 feet before vertical impact can be achieved. By using the parachute type bombs, the altitude of release may be reduced to 150 feet or lower. Thus, the type of bomb used will be determined by the tactical mission to be flown.

In addition to the parachute and stablized fin type bombs, there is a 4-pound antipersonnel bomb, bomb fragmentation, M83, otherwise known as the 'butterfly' bomb. The bomb is cylindrical in shape, is cast in two halves, and is welded together. It is 3 inches long and has a maximum diameter of 3 inches. The walls of the bomb are approximately ¼-inch thick. The filler consists of 7 ounces of cast T.N.T. A vane assembly attached to the bomb consists of four pieces, two semicylindrical surfaces (wings), and two disks (propeller blades).

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CHART IV
FRAGMENTATION BOMBS

Designation	Weight	Type	Fuzes Used	Altitude of Release	Distinguishing Characteristics
AN-M40*	23 pounds	Parachute	AN-M104, AN-M120 or AN-M120A1 (nose)	150 feet or lower	Helical steel spring body, parachute assembly, always clustered in clusters of three, adapted for horizontal suspension only.
AN-M41*	20 pounds	Stabilized fin	M110 or AN-M110A1 (nose)	Above 500 feet	Helical steel spring body, stabilized fin, always clustered in clusters of six, adapted for horizontal suspension only.
M72*	23 pounds	Parachute	AN-M104, AN-M120 or AN-M120A1 (nose)	150 feet or lower	Helical steel spring body, parachute assembly, equipped for single vertical suspension only.
M82	90 pounds	Stabilized fin	AN-M103 (nose)	Above 1000 feet	Helical steel spring body. Nose and tail pieces are partially cut through to afford greater fragmentation. Bomb may be suspended either singly or in clusters.
M81	260 pounds	Stabilized fin	AN-M103 (nose) AN-M100A2 (tail)	Above 1500 feet	Helical steel spring body. Nose and tail pieces are partially cut through to give better fragmentation. Suspended singly in horizontal position.
M83	4 pounds	Vane	M129, M130, or M131	Various altitudes dependent on tactical situation	Small antipersonnel bomb dropped in aimable clusters only. Has four collapsible vanes which are depressed against bomb until time of release. Shipped fuzed and assembled in 100-lb. cluster, but in wafers unassembled in 500-lb. cluster.

* These bombs also have an A1 modification which consists of a half-inch collar added to the nose end forging to enable the bomb to fit in the modified adapters which enable the bombs to be fuzed just prior to use rather than at the loading plants. This gives increased safety in shipping.

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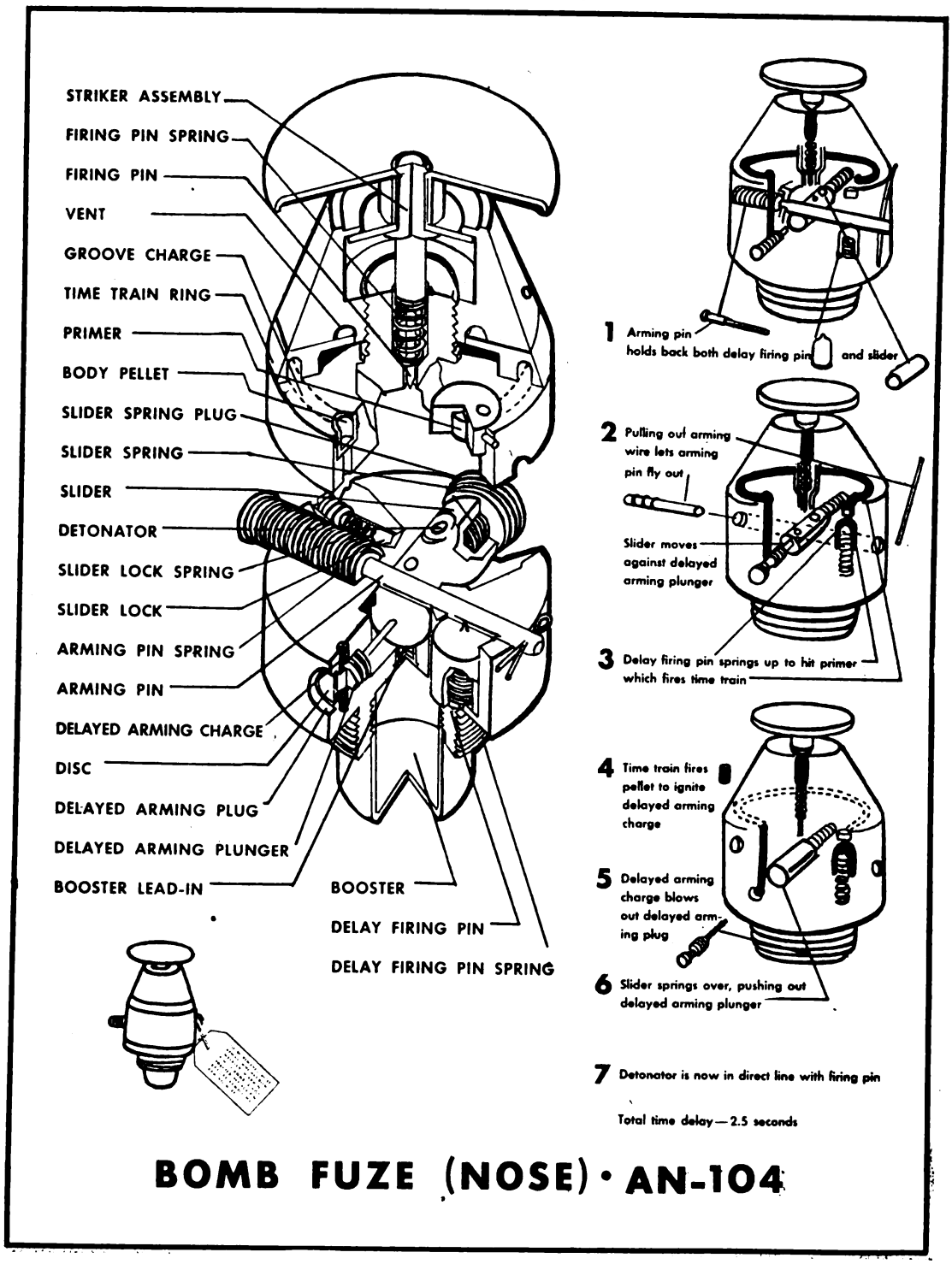

Figure 10. AN-M104 Fuze (Nose).

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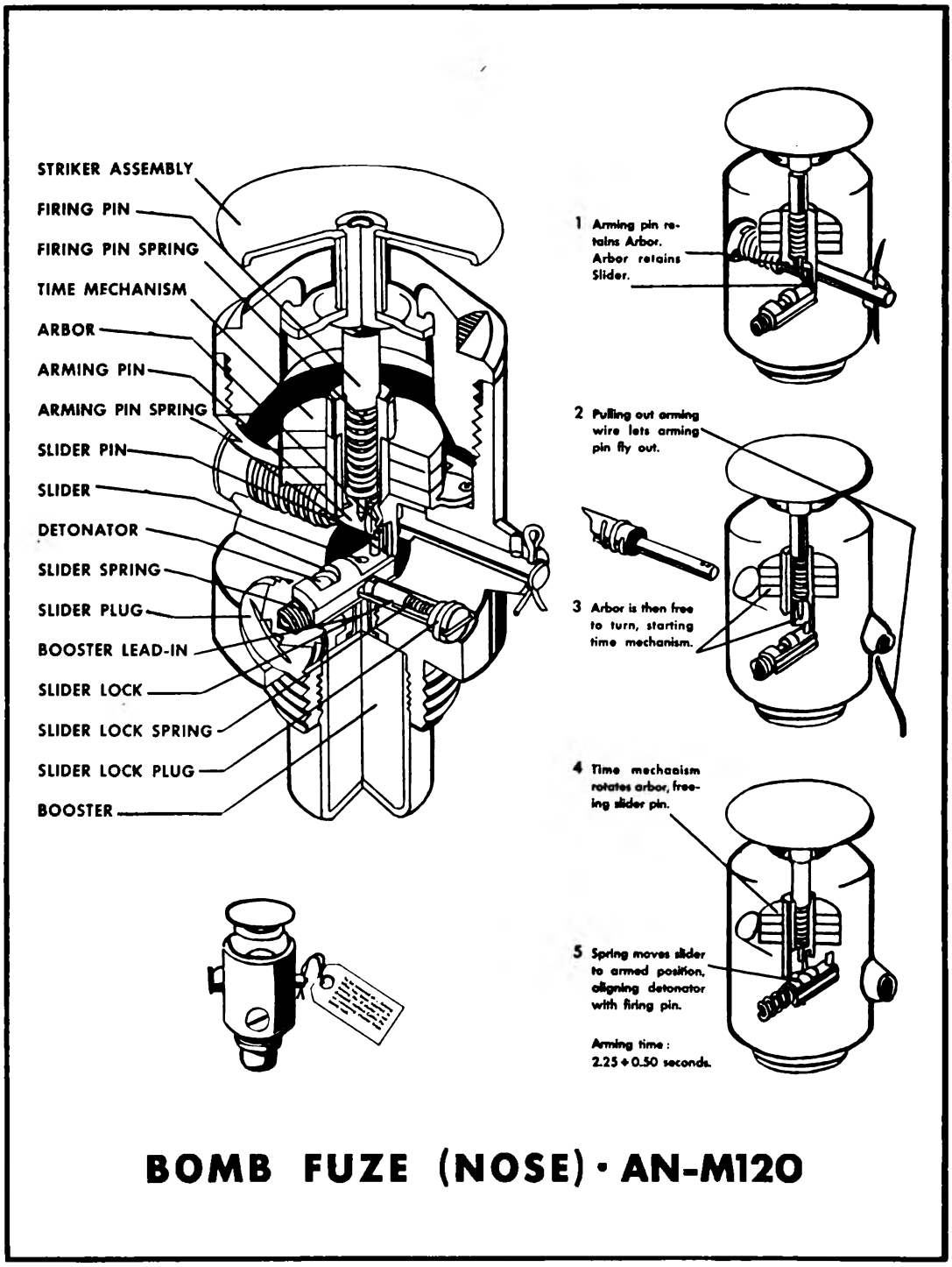

Figure 11. Fuze, Bomb, AN-M120 (Nose) Assembly and Section Views.

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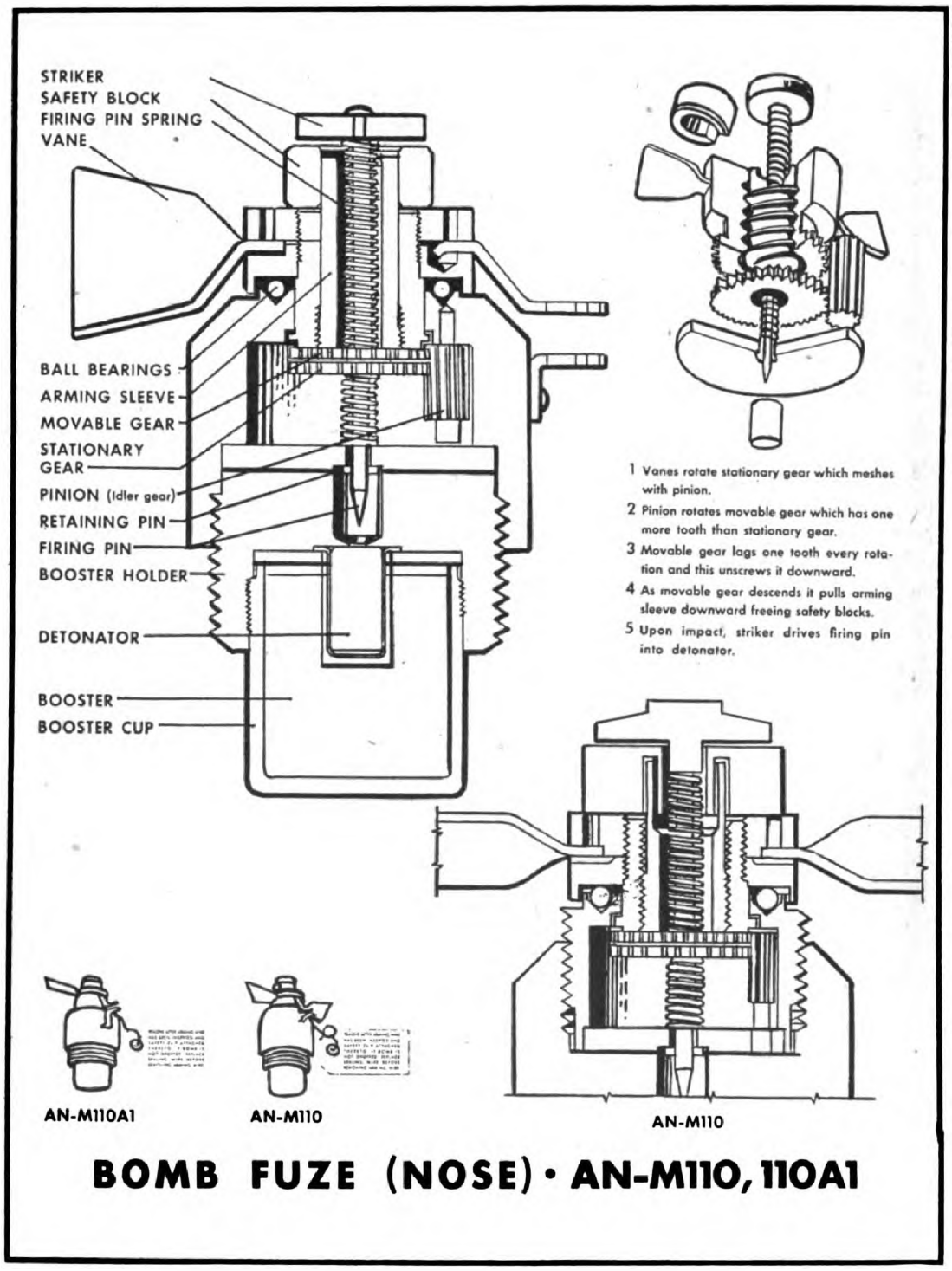

Figure 12. Fuze, Bomb, AN-M110 and AN-M110A1 (Nose).

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While the bomb is in the unarmed position, the vane assembly is folded around the bomb to form a cylindrical casing. In this position, the arming spindle of the fuze projects through the bomb casing. The fuzes used in assembly, release altitude, and identification of fragmentation bombs are listed in Annex A.

Fuzes. Two fuzes, the AN-M104 and the AN-M120 or AN-M120A1, are used with the 23-pound parachute type fragmentation bomb. The 20-pound stabilized fin type bomb is fuzed with the M110 or the AN-M110A1 nose fuze. Both the 90-pound and 260-pound bombs are fuzed with the AN-M103 nose fuze; but whereas the 90-pound bomb uses no tail fuze, the AN-M100A2 tail fuze is used with the 260-pound bomb. The 4-pound butterfly bombs may be fuzed with either the M129, M130, or M131 fuzes.

Fuze, Bomb AN-M104 (Nose). The AN-M104 fuze is an arming pin type fuze with a 2½-second delay arming time. The fuze has a mushroom type striker which insures functioning upon impact at any angle up to 13° from the horizontal.

The fuze incorporates several distinctive safety features: delayed arming by a time train, a safety pin which passes through the arming pin and remains in position until the arming wire is inserted, and inability to begin arming until the parachute to which the arming wire is attached has opened and the bomb is falling through the air.[1]

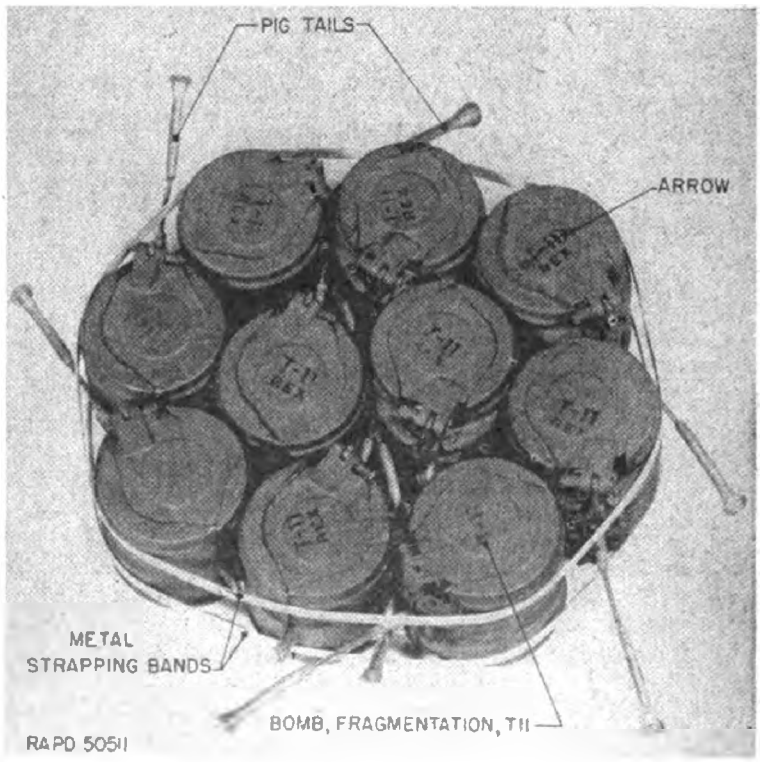

Figure 13. Wafer Containing Ten Fragmentation Bombs M83.

Because this bomb is suspended from a parachute in flight and thus has its rate of descent retarded, and also since it is dropped from such low altitudes, it is impossible to use an arming vane with a mechanical delay type of arming.

When the bombs are released from the cluster or from the racks in case of single vertical suspension, the pilot disk is forced from the parachute case and drags the parachute behind it. The arming wire which is attached to the shroud lines of the parachute is withdrawn from the fuze, initiating the 2½-second black powder time train, which functions the delayed arming blow-out charge and arms the fuze. The fuze will function instantaneously upon impact.

Fuze, Bomb AN-M120, AN-M120A1 (Nose). This fuze is an arming pin fuze with a clockwork delay instead of the black powder delay used in the AN-M104

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fuze. The arbor attached to the escapement projection holds the slider out of line in the unarmed position. When the arming wire is withdrawn as the parachute functions, the arming pin is ejected from the fuze and the clockwork set in motion. At the end of 2½ seconds the arbor has rotated sufficiently to allow the slider to come into the armed position arming the fuze, which will then function instantaneously upon impact.

The AN-M120A1 fuze is identical to the AN-M120 except that the arming time is reduced to 1.9 second ± .15 of a second, which allows the bombs to be dropped from lower levels.

Fuze, Bomb M110, AN-M110A1 (Nose). This arming vane with mechanical delay fuze is used in the 20-pound stabilized fin fragmentation bombs. Arming delay is obtained by a series of reduction gears. In the unarmed position the striker is prevented from impacting the primer by safety disks or a safety collar. As the vane rotates the moveable gear and arming sleeve will rotate and unscrew, stopping upon contact with the end plate. This frees the safety blocks or safety collar and arms the fuze, which will then function instantaneously upon impact.

The M110 and AN-M110A1 differ in that the AN-M110A1 arms in 340 revolutions, while the M110 arms in 570 revolutions. The M110 has a 3 section safety disk, while the AN-M110A1 has a safety collar. The vanes on the AN-M110A1 are smaller and the body is made of steel rather than aluminum as in the M110.

Fuze, Bomb M129, M130, M131. There are three fuzes available for the butterfly bomb: the M129, M130, and M131. The M129 is designed to function approximately 5 seconds after the cluster opens (aerial burst) or upon impact. The setting switch on the top of the fuze body, designated 'ground' or 'air', can be set for the desired functioning. The fuze is set at the factory and the wafers are not disassembled in the field to alter the setting.

The M130 is a mechanical time fuze which can be set to function at various times up to 30 minutes. The time setting is predetermined at the factory and cannot be adjusted in the field.

The M131 is an antidisturbance fuze which arms on impact and will be functioned by vibrations or distrubances in its near vicinity.

The employment of fragmentation bomb fuzes is shown in chart V.

Clustering. In order to increase the loads of bombers and saturate areas more effectively all fragmentation bombs are clustered.

In order to make up the complete rounds, the bomb body together with the fuze is assembled to a cluster adapter which acts as a container for the bombs The complete round is known as a cluster.

Clusters may be functioned in many ways. Some may have a firing mechanism which propels a lead slug through the adapter and cuts the wires, others function by the release of a toggle buckle, while still others are functioned by mechanical time fuzes.

These clusters can all be classified as quick-opening, or non-aimable, and aimable. The quick-opening type functions immediately upon release from the bomb rack, while the aimable may be dropped and armed as any bomb is and be caused to function at the desired altitude by the use of a mechanical time fuze. Figures 13-19 show the principal clusters in use today; see also chart VI.

CHART V
FRAGMENTATION BOMB FUZES

Designation	Type	Arming Time	Functioning Time	Distinguishing Characteristics
AN-M104	Arming Pin	2.5 Seconds	Instantaneous	Mushroom striker head, black powder. Delay in arming, steel body.
AN-M120	Arming Pin	2.5 Seconds	Instantaneous	Mushroom striker head, clockwork delay in arming, steel body, top of body has four cut-away portions.
AN-M120A1	Arming Pin	1.9 Seconds	Instantaneous	Same as above.
M110	Arming Pin	570 Revolutions	Instantaneous	Large vane, aluminum body, and three safety disks.
AN-M110A1	Arming Vane	340 Revolutions	Instantaneous	Smaller vane, steel body, and single safety collar.
M129	Arming Vane	3½ Revolutions	Aerial burst or impact	Assembled to bomb when issued.
M130	Arming Vane	3½ Revolutions or ¼"	5 to 30 minutes	Assembled to bomb.
M131	Arming Vane	3½ Revolutions	Anti-disturbance	Assembled to bomb.

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CHART VI
FRAGMENTATION BOMB CLUSTERS

Designation	Adapter	Type of Bombs	Number of Bombs	Remarks
M1	M1	20-lb. stabilized fin	6	When arming wire is withdrawn, cocked firing pin fires cartridge which propells lead slug through adapter cutting wires and releasing bombs.
AN-M1A1	AN-M1A2	20-lb. stabilized fin	6	Toggle buckle is released when arming wire is withdrawn, which frees bombs.
AN-M1A2	AN-M1A3	20-lb. stabilized fin	6	Identical to AN-M1A1 except cluster is shipped unfuzed.
AN-M4	AN-M3	23-lb. parachute	3	Toggle buckle is released when arming wire is withdrawn, freeing bombs. Three wings under spring tension on adapter help to throw bombs out of adapter.
AN-M4A1	AN-M3	23-lb. parachute	3	Identical to AN-M4, except cluster is shipped unfuzed.
M26	M13	20-lb. stabilized fin	20	Selective quick opening or aimable cluster functioned by toggle buckle release or mechanical time fuze.
M27	M14	90-lb. stabilized fin	6	Selective quick opening or aimable cluster functioned by toggle buckle release or mechanical time fuze.
M28	M15	4-lb. butterfly	24	Aimable cluster functioned by mechanical time fuze.
M29	M16	4-lb. butterfly	90	Aimable cluster functioned by mechanical time fuze.

CHART VII. INCENDIARY CLUSTERS

Model Designation Cluster	Adapter	Bomb	Number of Each	Total
Cluster, incendiary bomb, 100-lb., AN-M6	M5	AN-M50A2 AN-M50XA3* (Type A and B)	28 6	34
Cluster, incendiary bomb, 500-lb., AN-M7	M6	AN-M50A2 AN-M50XA3 Type A* AN-M50XA3 Type B*	102 20 6	128
Cluster, incendiary bomb, 100-lb., AN-M8	M5	AN-M54 AN-M54XA1	28 6	34
Cluster, incendiary bomb, 500-lb., M9	M6	AN-M54 AN-M54XA1	102 26	128
Cluster, incendiary bomb, 100-lb., M10	M5	AN-M52A1 AN-M52XA1 Type A and B	41 10	51
Cluster, incendiary bomb, 500-lb., M11	M8	AN-M52A1 AN-M52XA1 Type A AN-M52XA1 Type B	153 30 9	192
Cluster, incendiary bomb, 100-lb., AN-M12	M4	AN-M69	14	14
Cluster, incendiary bomb, 500-lb., AN-M13	M7	AN-M69	60	60
Cluster, aimable, incendiary bomb, M14	M10	AN-M50TA2 AN-M50XA3	104 6	110
Cluster, aimable, incendiary bomb, AN-M17	M10	AN-M50A2 AN-M50XA3 Type A AN-M50XA3 Type B	88 16 6	110
Cluster, aimable, incendiary bomb, E-28	E6R2	AN-M69	38	38
Cluster, aimable, incendiary bomb, E-46	E23	AN-M69	38	38
Cluster, aimable, incendiary bomb, E-47	E23	E5 (M74)-W.P.	38	38
Cluster, aimable, incendiary bomb, E-48	E23	E5 (M74)-I.M.	38	38
Cluster, aimable, incendiary bomb, E-61	E23	E5 (M74)-H	38	38
Cluster, aimable, incendiary bomb, E-67	E23	M77-H.C.	38	38

* The AN-M50XA1 may be substituted for the AN-M50XA3 in these clusters.

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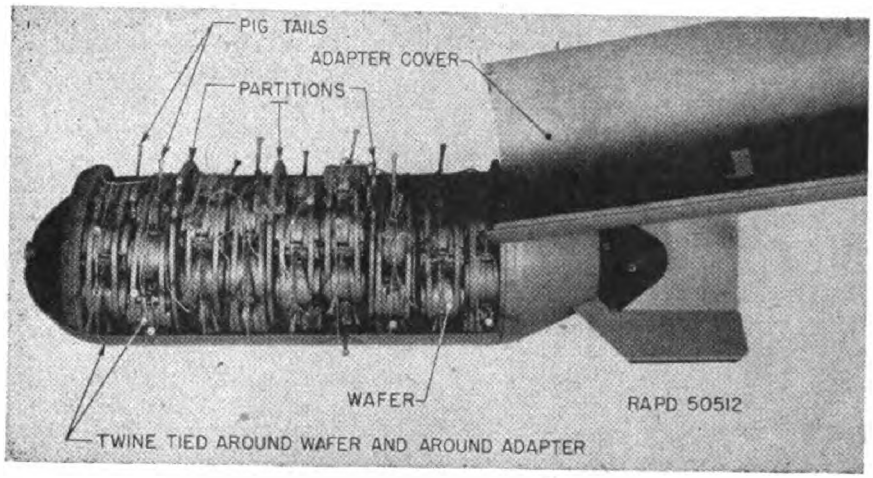

Figure 14. Wafers in Place in Cluster.

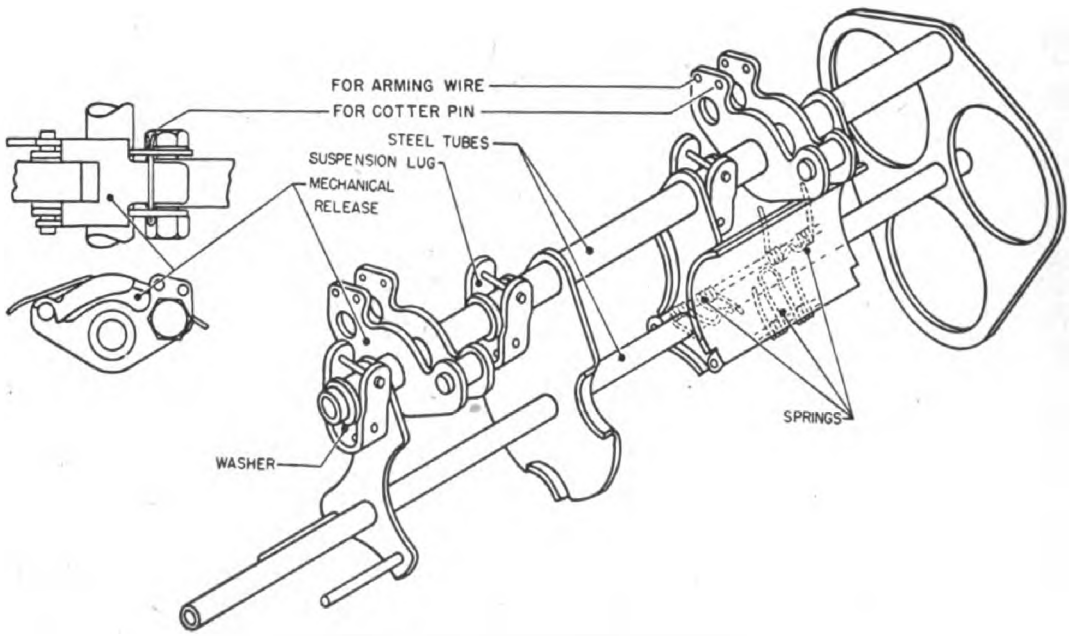

Figure 15. Adapter, Cluster AN-M3.

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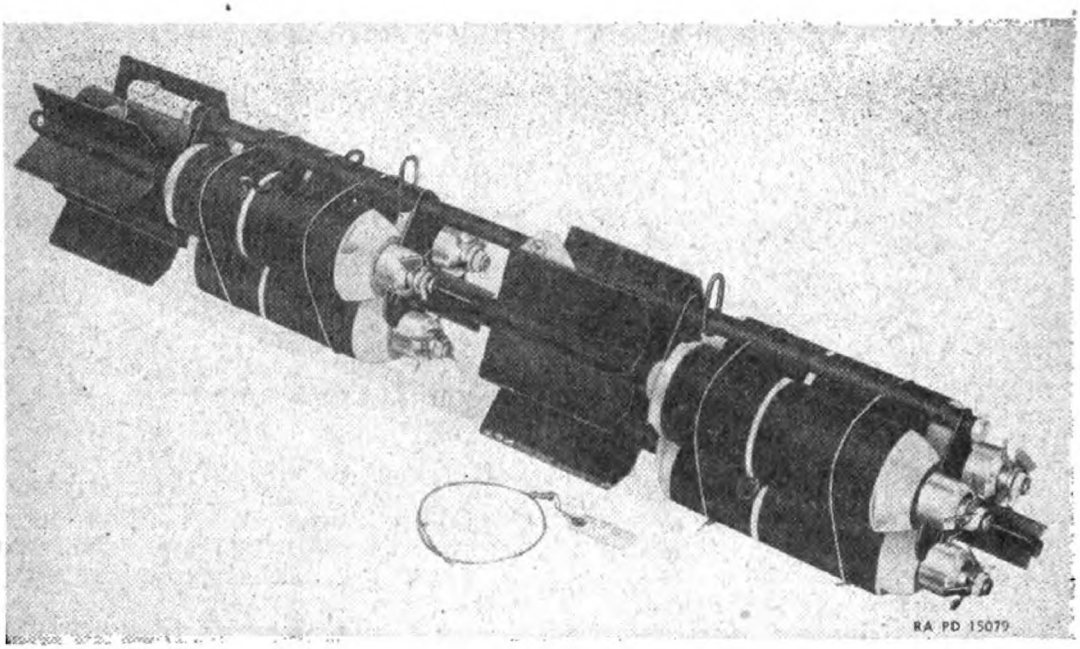

Figure 16. Cluster, Fragmentation Bomb, M1.

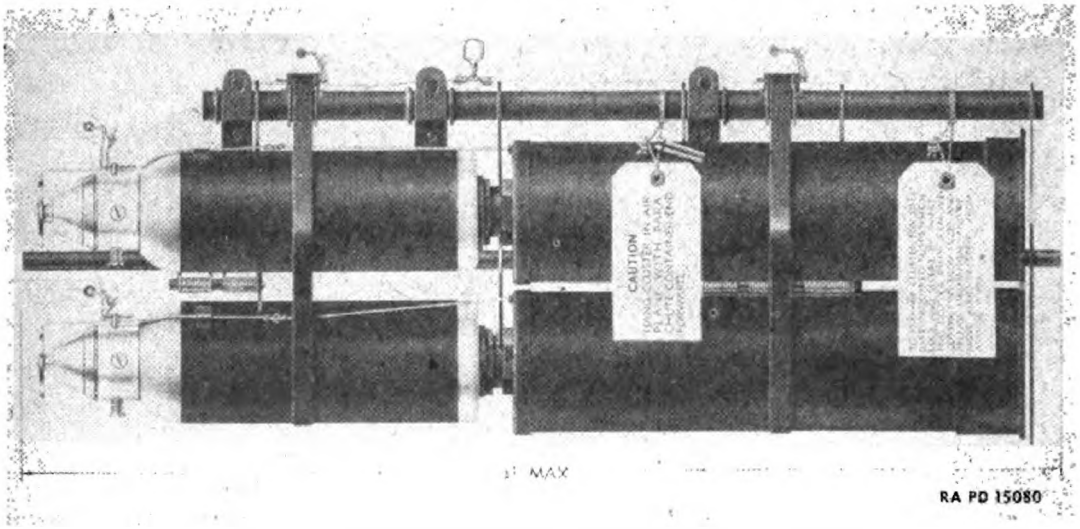

Figure 17. Cluster, Fragmentation Bomb, AN-M4.

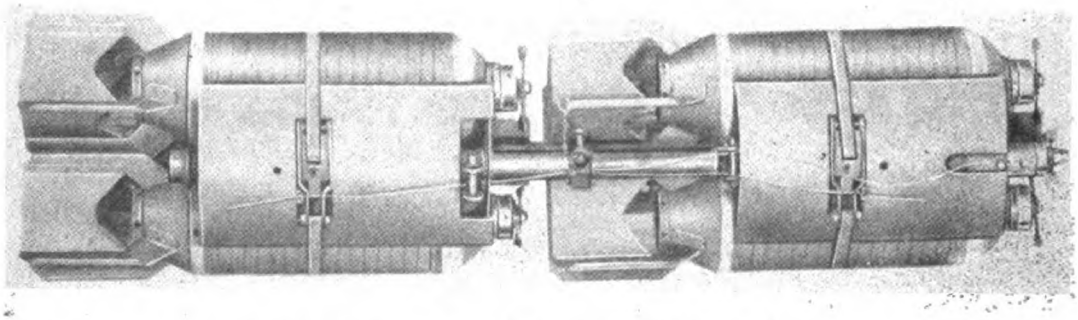

Figure 18. Cluster, Fragmentation Bomb M27, Delay Opening.

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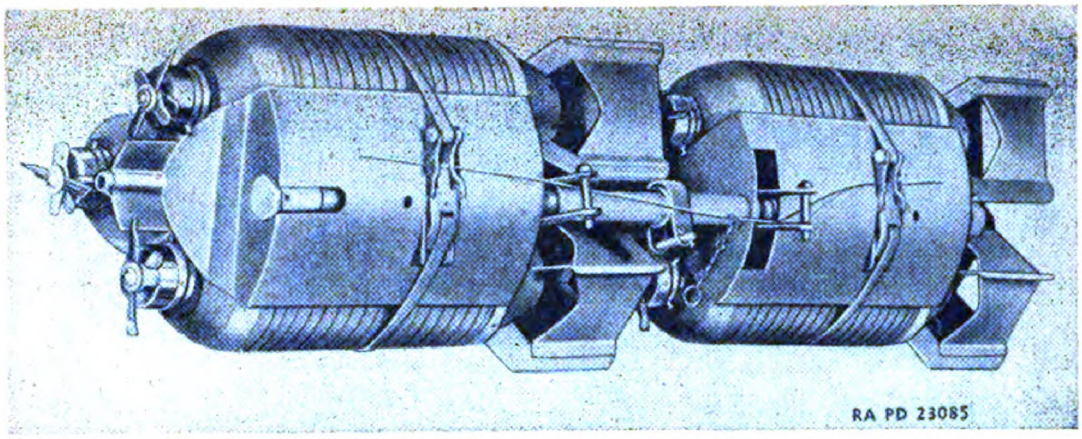

Figure 19. Cluster, Fragmentation Bomb M27, Immediate Opening.

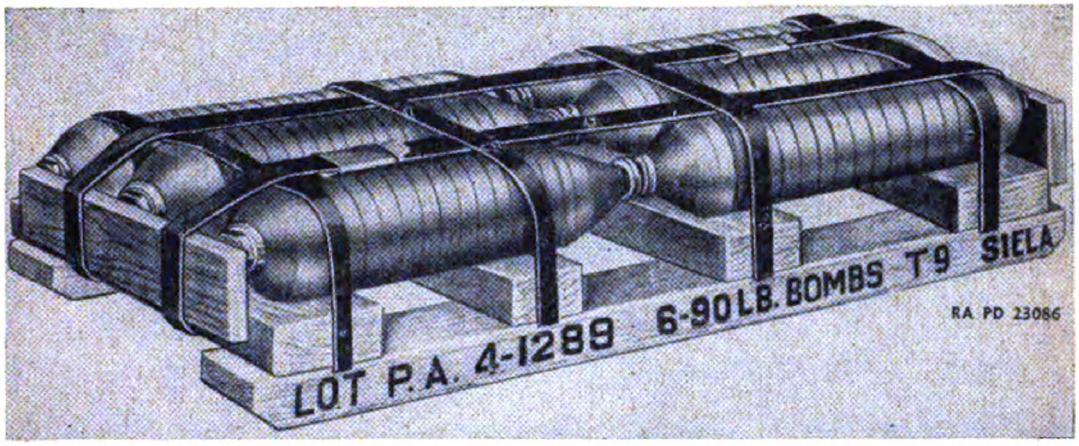

Figure 20. Packing of Fragmentation Bombs—Bomb, Fragmentation 90-lb., M82.

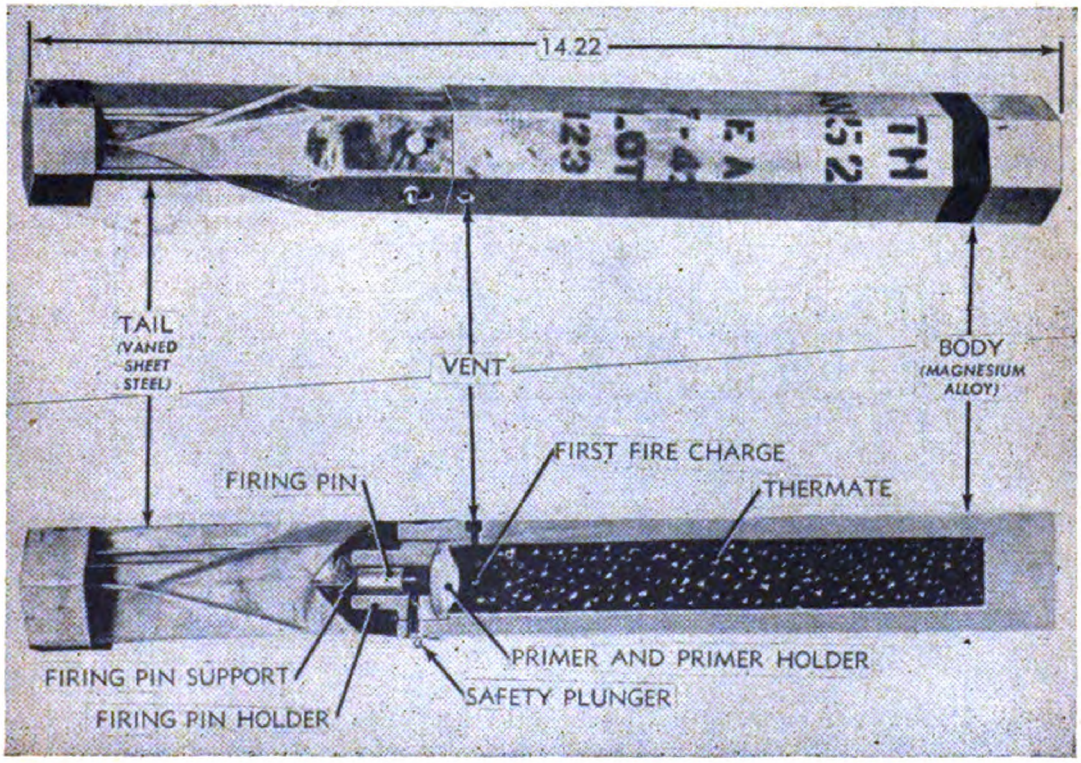

Figure 21. Bomb, Incendiary, 2 lb., AN-M52.

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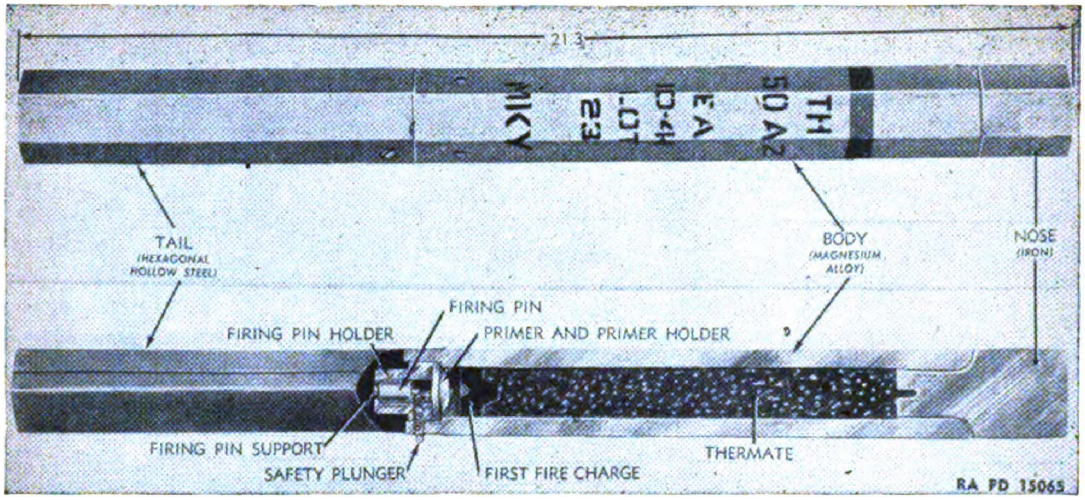

Figure 22. Bomb, Incendiary, 4 lb., AN-M50A2.

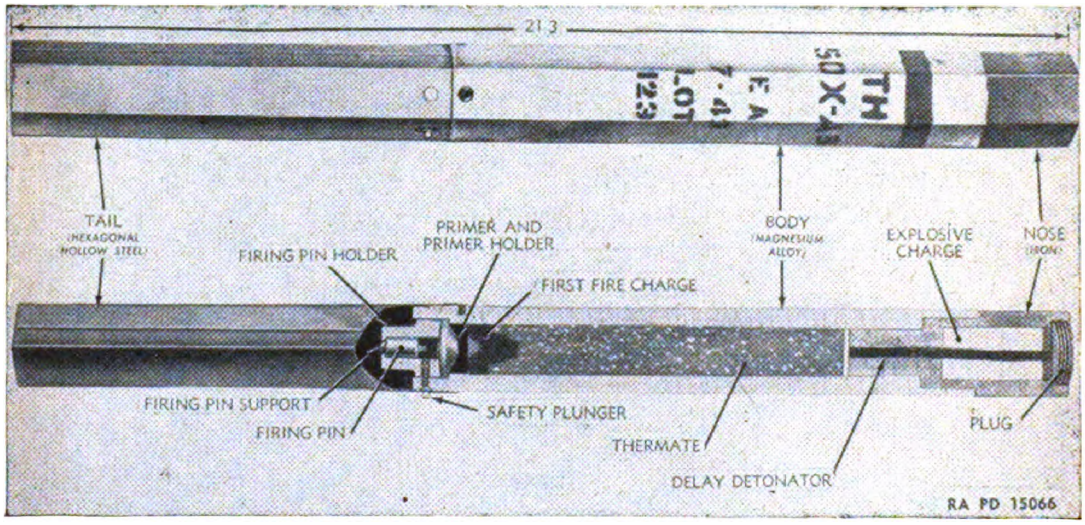

Figure 23. Bomb, Incendiary, 4 lb., AN-M50XA3.

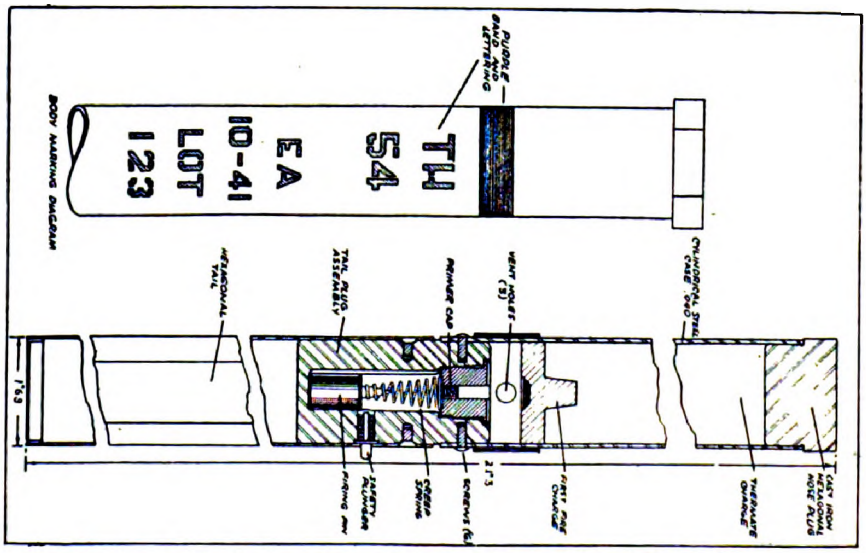

Figure 24. Bomb, Incendiary, 4 lb., AN-M54 (Substitute).

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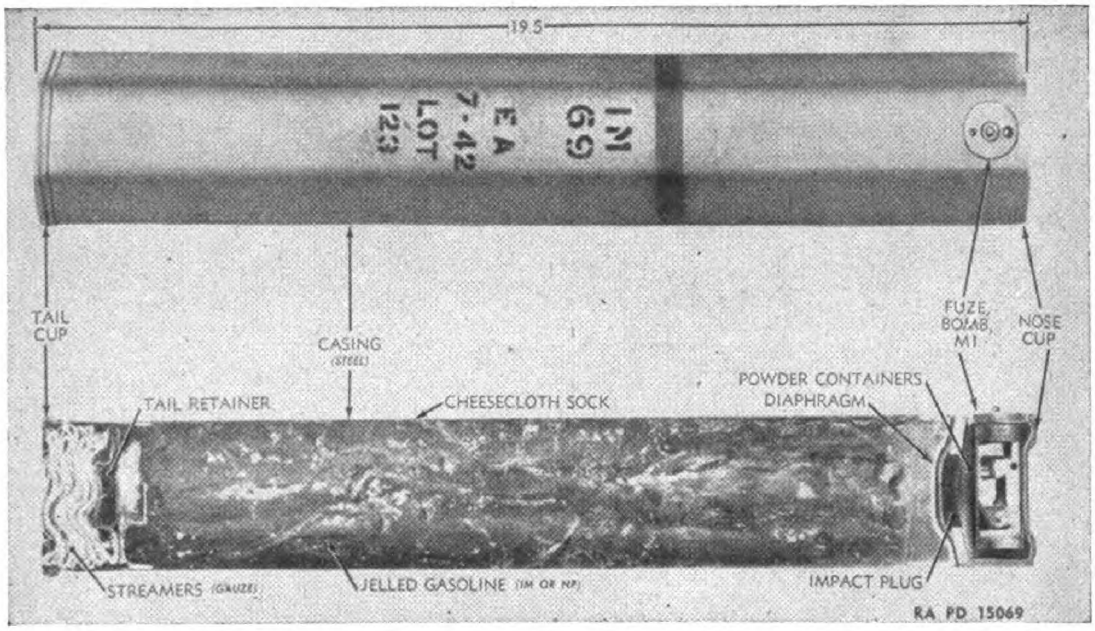

Figure 25. Bomb, Oil, Incendiary, 6 lb., AN-M69.

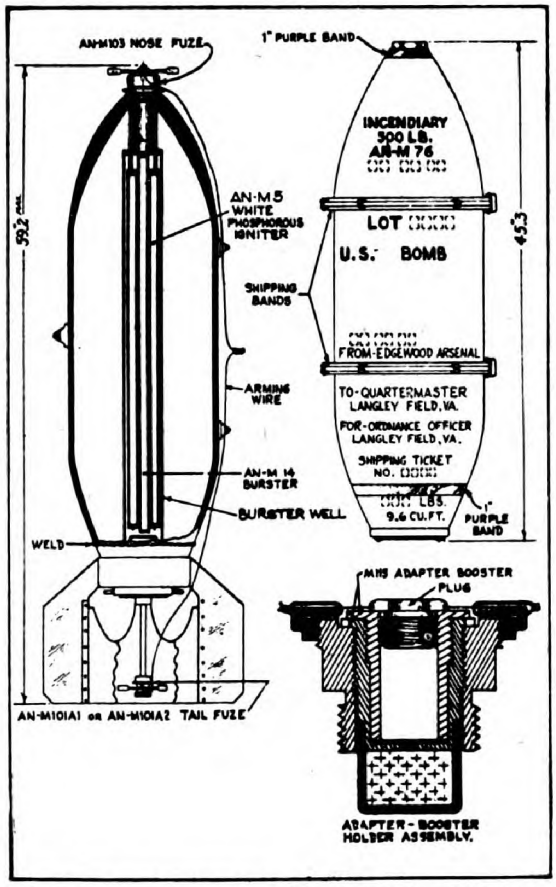

Figure 26. Bomb, Incendiary, 500 lb., AN-M76.

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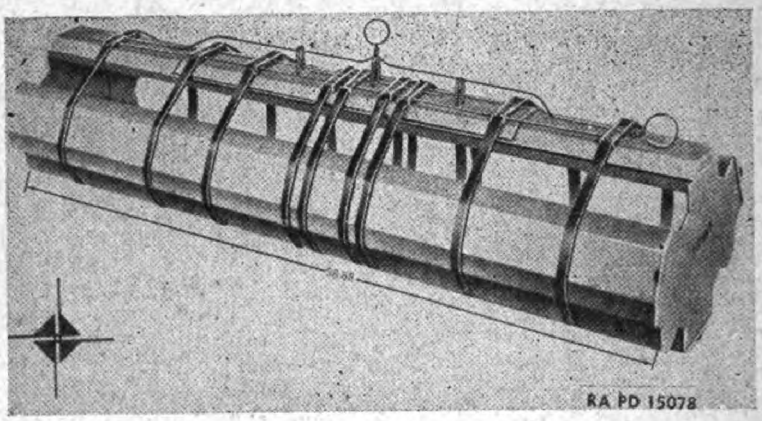

Figure 27. Adapter, Clusters, M7.

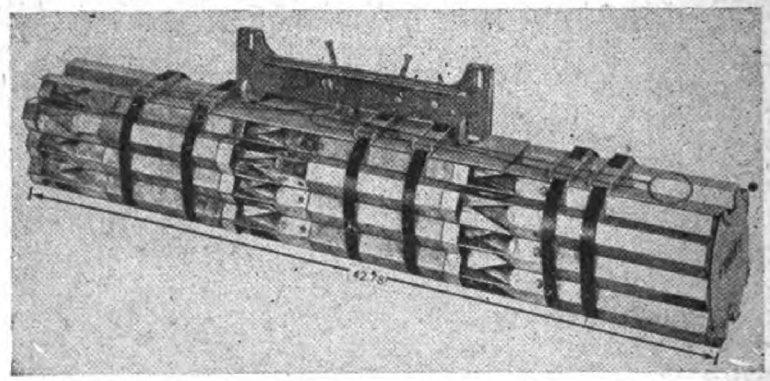

Figure 28. Incendiary Bomb Clusters, M10.

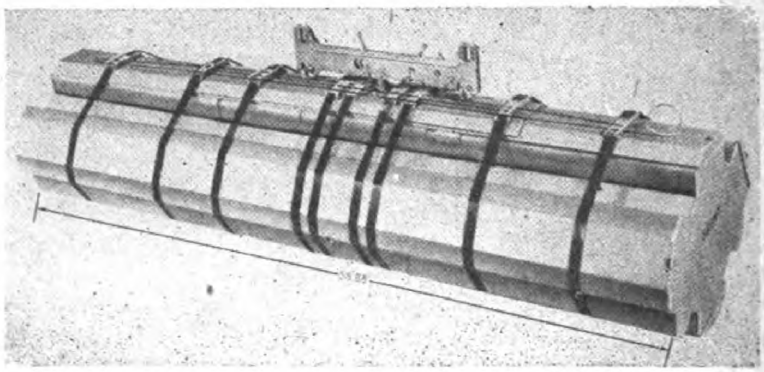

Figure 29. Incendiary Bomb Clusters, AN-M13.

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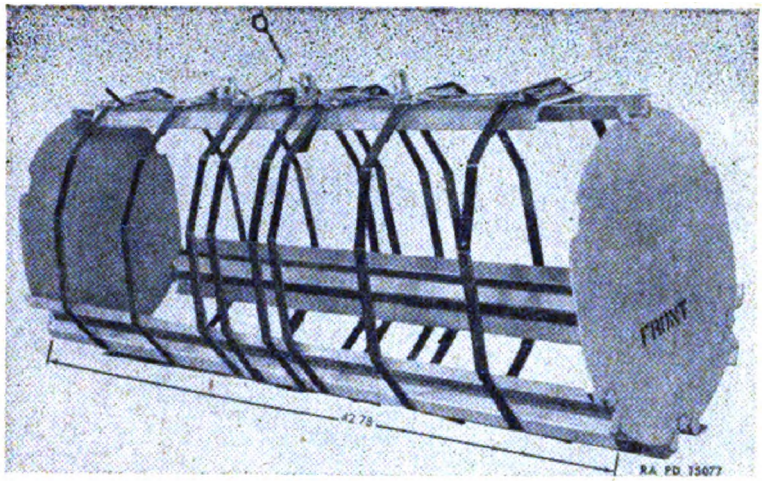

Figure 30. Adapter Cluster M6.

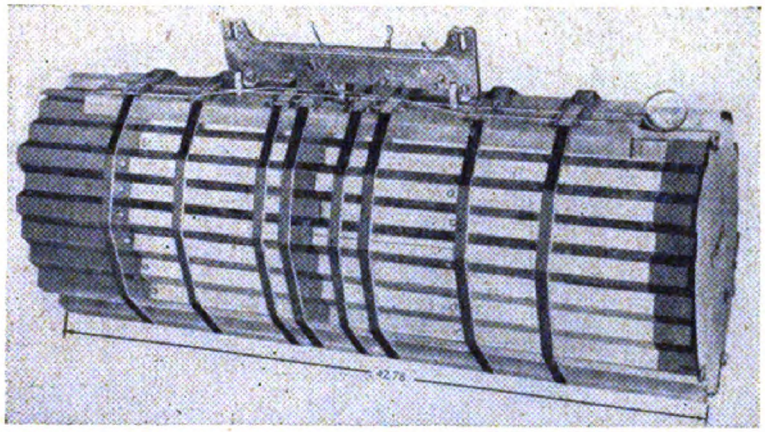

Figure 31. Cluster, Incendiary, M7.

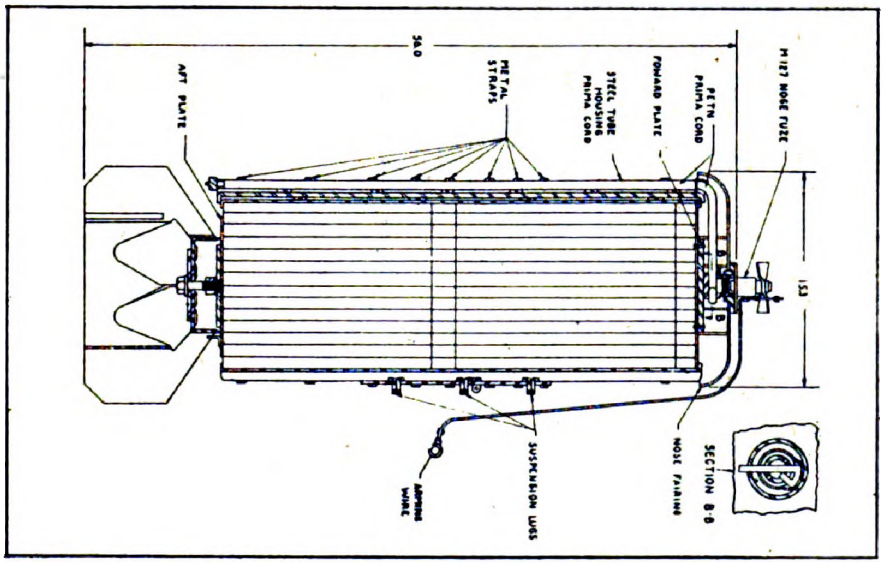

Figure 32. Cluster, Incendiary, 500-lb., M17A1 (Aimable).

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INCENDIARY BOMBS

Incendiary bombs are of two types: those released in clusters for area bombing and those released individually for point bombing. In some of the smaller bombs such as the magnesium alloy incendiaries the metal case serves as the main charge, while in others the charge is contained in a sheet metal body and requires an explosive burster to open the body and distribute the incendiary charge.

It may be said that in general all incendiary bombs designed for use in clusters are similar in many respects.

Their size will range from two to ten pounds and they are usually hexagonal

CHART VIII

CHART VIII. INCENDIARY BOMBS

Mg—Magnesium
Th—Thermate
B.P.—Black Powder

IM & NP {Mixtures of gasoline within an organic compound to form a gel.

Model Designation	Wt. of Bomb Lb.	Incendiary Fillers	Burning Time, Min.	Fuze	Burster	Explosive Charge	Distinguishing Characteristics
M47A1 (2)	66	Gasoline and rubber	5 to 15	AN-M126	M12	B.P., Mg., and castor oil	Coated internally with acidproof black paint.
				AN-M126A1	M13 (3)	M9 Igniter	
M47A2 (2)	66	Gelled Gasoline (Im or NP)	8 to 10	AN-M126	M12	B.P., Mg., and castor oil	Coated internally with SAE 10 oil; bomb body pressure-tested to 400 lb. per sq. in.
				AN-M126A1	M7	B.P.	
AN-M50A1	4	Mg & TH	8 to 10	Part of unit	None	None	Has a brass cross set in head of striker assembly, which is sheared upon impact with target.
AN-M50XA1	4	Mg & TH	8 to 10	Part of unit	Integral part of unit	B.P.	Has a steel capsule filled with 170 grains B.P. located at nose end of bomb body.
AN-M50XA2 Type A and Type B (1)	4	Mg & TH	8 to 10	Part of unit	Integral part of unit	Tetryl	Similar to AN-M50XA1, with nose plug replaced by a steel shell containing a tetryl bursting charge, detonator, and delay fuze which may burn from a few seconds to 6 minutes; this ignites the detonator which explodes the bursting charge, scattering steel fragments and burning Mg.
AN-M50XA3 Type A and Type B (4)	4	Mg & TH	8 to 10	Part of unit	Integral part of unit	Tetrytol	Identical to AN-M50XA2 except that a different explosive is used as the bursting charge.
AN-M50A2	4	Mg & TH	8 to 10	Part of unit	None	None	Improved first fire and thicker detonator are main changes over AN-M50A1.
AN-M52	2	Mg & TH	5 to 8	Part of unit	None	None	Body made in two pieces.

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in shape rather than round, thus permitting more solid packing in the cluster.

Generally they will be equipped with an integral inertia type fuze which becomes armed when the bombs are released from the cluster. The arming mechanism of the fuze consists of a safety plunger or arming plunger which is held depressed against spring action by the adjacent bomb in the cluster. When depressed the plunger prevents the firing pin from moving toward the primer.

In the event that a cluster breaks up in handling or otherwise accidentally releases its bombs, it should be remembered that the bombs are armed and should be handled carefully. A drop from several feet may cause them to function.

Model Designation	Wt. of Bomb Lb.	Incendiary Fillers	Burning Time, Min.	Fuze	Burster	Explosive Charge	Distinguishing Characteristics
AN-M52X	2	Mg & TH	5 to 8	Part of unit	Integral part of unit	Tetryl	Similar to AN-M52, with one-third of TH and Mg alloy body replaced by a steel capsule filled with tetryl; AN-M52X is closed by a nose plug.
AN-M52A1	2	Mg & TH	5 to 8	Part of unit	None	None	Has a one-piece body.
AN-M52XA1 Type A and Type B	2	Mg & TH	5 to 8	Part of unit	Integral part of unit	Tetryl	Has a one-piece body and steel capsule filled with tetryl.
AN-M54	4	TH	1½ to 2	Part of unit	None	None	Cylindical steel body with hexagonal nose plug and hexagonal sheet-steel tail assembly.
AN-M54X	4	TH	1½ to 2	Part of unit	Integral part of unit	B.P.	Similar to AN-M54, with a small part of the TH charge replaced by a steel capsule containing 420 grains B.P.
AN-M54XA1	4	TH	1½ to 2	Part of unit	Integral part of unit	Tetryl	Similar to AN-M54X, with a steel capsule just inside the nose plug, containing a high-explosive charge with short-delay fuze and detonator.
AN-M69	6	Gelled gasoline (Im or NP)	8 to 20	M1	Integral part of unit	B.P. and Mg.	Contains a main charge of 2.6 lb. gelled gasoline and a burster charge of 0.4 lb. B.P. and Mg.
AN-M76	500	PTI	Approx. 8 Min.	AN-M103 AN-M101A2	AN-M14 M5 Igniter (5)	Tetrytol	G.P. Series 500 lb. bomb case sealed at the rear.

(1) Type A functions instantaneously. No delay fuze is incorporated in explosive train.
Type B functions with variable delay from few seconds to 6 minutes.
(2) Normally the M47A1 and the M47A2 are suspended 1 per 100-lb. bomb station, but they may be suspended 2 per 100-lb. bomb station by the use of the M12 adapter cluster.
(3) Uses M9 Igniter which contains .7 lbs. W.P.
(4) Type A functions instantaneously. No delay fuze is incorporated in explosive train.
Type B functions with variable delay from few seconds to 6 minutes.
(5) M5 Igniter contains 7½ lbs. W. P.

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SHIPPING AND PACKING

Small incendiary bombs ranging in size from two to ten pounds are usually clustered in 100 and 500 lb. cluster adapters and are shipped assembled and packed one per crate. Bombs released individually, those of the 100 and 500 pound size, are stored, shipped, and issued individually. The fins may be attached as in the 100 pound bombs or may be shipped separately as in the 500 pound bombs. The bombs are always shipped unfuzed without the burster.

The designation of the smaller type incendiary bombs indicates whether or not they are equipped with an explosive head. All bombs bearing the letter 'X' in the nomenclature contain an explosive in the nose of the bomb. For example, the AN-M50XA3 contains a charge in the nose of the bomb while the AN-M50A2 contains none.

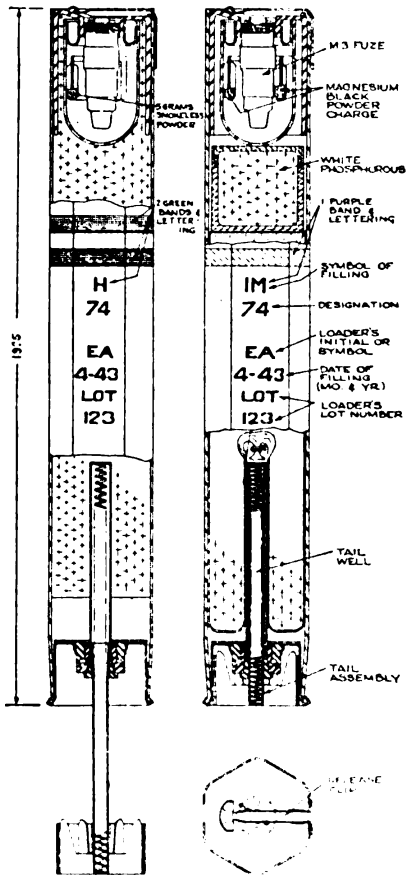

Figure 33. Bomb, Incendiary 10-lb., M74.

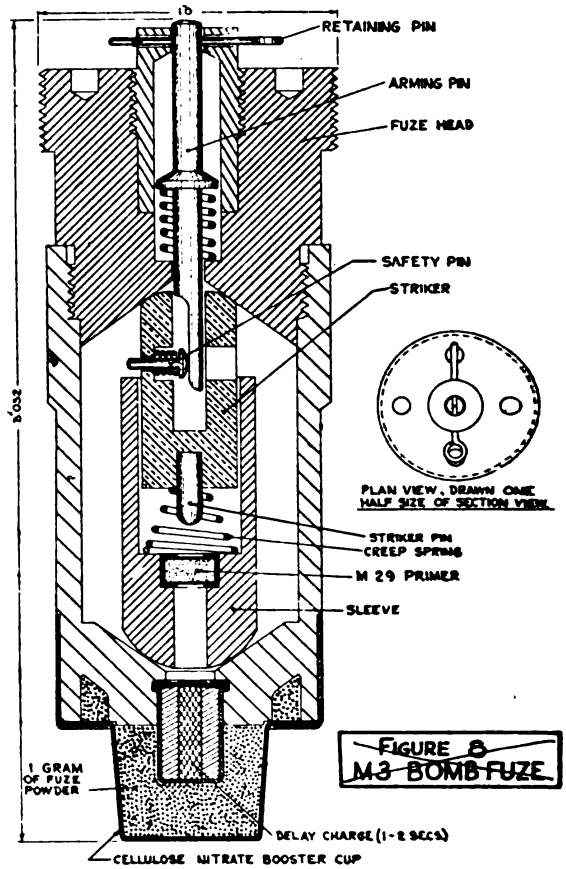

Figure 34. Fuze, Bomb, M3, for M74 Incendiary Bomb.

Aimable clusters are so constructed that they may be set to function at any desired, altitude after release from the plane. They are equipped with the Fuze, Bomb, Nose M127 & M138, which are similar to a Fuze, Flare, Mechanical, Time M111A2 with a tetryl booster. By using this fuze, aerial burst of this cluster is obtained.

At the present time work is progressing toward modifying these aimable clusters so that both nose and tail fuzes may be used with them.

Bomb, Oil, Incendiary, 10-lb., M74. This bomb is a 10-lb. incendiary of the same size and shape as the AN-M69 6-lb. oil incendiary. Hexagonal in shape, it is 19.5 inches long and 2.87 inches in diameter across the flats. It has a telescope type tail which is ejected under spring pressure when the bomb is released from the cluster. The M74 uses the all-ways action fuze M3, which screws into the nose along the long axis of the bomb. In the experimental stage, this bomb is also known as the E5.

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Components of the M74 bomb follow:

A sheet-steel, leak-proof casing extending the entire length of the bomb.

A nose cup which fits into the front of the casing. It has a dome which in turn houses the fuze.

In bombs filled with IM or NP, a small chemical container, located immediately behind the dome, which is filled with white phosphorous. This serves the double purpose or aiding ignition and producing smoke.

In bombs filled with IM or NP, the filling is enclosed in a cheesecloth sack. In bombs filled with white phosphorous, the filling is enclosed in impregnated paper tubes inside the casing.

A tail cup fits inside the rear end of the casing. A threaded hub inside this cup retains a well extending 5 inches into the body of the bomb. This well holds the tail sleeve of the fin when the tail is compressed for clustering. In the compressed position the fin portion fits inside the tail cup.

AN-M3 nose fuze. This is an all-ways action-type fuze. Its safety features consist of a spring-loaded arming pin and a safety pin. The body and head are zinc alloy castings. This fuze incorporates the M29 percussion primer and a built-in delay charge comprised of 60 percent black powder and 40 percent collodion; the delay is from 1 to 2 seconds. The booster cup is made of clear, transparent cellulose nitrate and is filled with 1 gram of fuze powder. The body is 3.032 inches long and 1 inch in diameter.

Operation. The retaining pin is removed when the fuzed bombs are assembled in the cluster. While the bombs are in the cluster, their proximity holds the arming pin in the body of the fuze. When the bombs are released, the arming pin is forced out by its spring, permitting the safety pin to enter the cavity in the striker. Impact forces the striker and sleeve together, piercing the M29 percussion primer, which initiates the delay charge and, subsequently, the fuze powder in the booster cup.

CAUTION: *Once the arming pin jumps out, the fuze is armed and any attempt to reinsert it may cause the fuze to fire.*

CHEMICAL BOMBS

So far during World War II, toxic gases have not been employed by Axis armies in the European theater. On several occasions, Japan has been known to use limited quantities of such gases in China. But it must be remembered that the employment of toxic gases represents only one phase of the modern combat technique of chemical warfare. Screening smoke, incendiaries and flame-throwers have been used many times in many different places by both our enemies and ourselves.

The value of screening smoke has been demonstrated repeatedly during the past few years of the present conflict. Early in the war this device assisted the Germans in their capture of the strategic Fort Eben Emall in Belgium and enabled them to penetrate the heavily fortified Maginot Line of France with relatively few casualties. The Axis again demonstrated the effectiveness of screening smoke in their invasion of Crete when they dropped countless paratroopers under the cover of large clouds of screening smoke. Smoke has also proved itself invaluable in such landing operations as the Dieppe raid and the landings by U. S. forces in North Africa, Sicily, and at the Anzio beachhead. In addition to such examples of tactical use as these, screening smoke is also used to obscure harbor docks and industrial areas when they are subjected to the danger of air raids.

Air raids upon the major cities of the European continent emphasize the importance of incendiary bombs. The use of incendiary bombs and demolition bombs together has wrought the greatest mass destruction of the war. Incendiary bombs form so large a subject in themselves that they must be treated apart from chemical bombs. For this reason they are not discussed in this section.

The tactical value of the flame-thrower against pill-boxes and fixed emplacements is universally recognized. During recent engagements, especially in the Pacific theater, the flame-thrower has been a major offensive weapon. In addition to its destructive effect on fortifications, it also has a devastating effect on enemy morale.

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Definitions. *Chemical bombs.* Chemical bombs are any bombs which are loaded with a chemical filler.

Chemical Agents. Any chemical that will produce one or more of the following effects may be classified as a chemical agent. An example of each type of agent is also shown:

Casualty	Mustard Gas
Harassing	Tear Gas
Screening	White Phosphorous
Incendiary	Thermite

Persistent Gas. A persistent gas may be defined as a gas that will stay in an area for 10 min. or longer in a wind of 15 mph.

Painting and Marking. All chemical bombs are painted gray; their color markings depend on the filler of the bomb. In addition to the color bands, the following information is stenciled on the bomb: the model, weight, filler and the date filled. The following table illustrates the color markings for chemical bombs:

Agent	*Color of Band*	*No. of Bands*
Casualty:		
Persistent	Green	2
Nonpersistent	Green	1
Harassing:		
Persistent	Red	2
Nonpersistent	Red	1
Screening:	Yellow	1
Incendiary:	Purple	1

Procurement. Responsibility for the procurement of chemical bombs is divided as follows. The bomb bodies are procured by the Ordnance Department; the chemical fillers are procured and loaded into the bomb bodies by the Chemical Warfare Service.

Storage, Issue, and Inspection. Chemical bombs are stored by the Chemical Warfare Service at large installations. In forward areas and at airdromes, however, this usually becomes the duty of ordnance personnel. The following precautions should be observed in the storage of chemical bombs:

Thin-case bombs should receive special care in storage so that their body and fins are fully protected

Bursters filled with tetryl should be stored with special care.

Bursters should never be inserted until the bombs are being fuzed for use.

Fuzes should be stored with the same degree of care as fuzes used in demolition bombs.

The following rules should be followed in the inspection of chemical bombs:

Train all personnel in the effects of chemicals and the safety precautions to be followed.

Inspect frequently, preferably every other day.

Inspect for foreign matter in the fuze cavity of the bomb.

Inspect the fin assembly for dislocation or bending.

Assembly of Complete Round. The following is the standard procedure for assembling a complete round of chemical ammunition:

Remove bomb from packing and inspect to be sure there are no leaks or other evidence of unserviceability.

If the fin is shipped separately, assemble it to the bomb by removing the fin lock nut, placing the assembly over the tail of the bomb with one fin in line with the suspension lugs, replacing the fin lock nut, and tightening with a wrench.

Remove the fuze hole plug and adapter sleeve. Inspect the fuze seat and burster well to be sure that the threads are not damaged and that there is no foreign matter present.

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Insert the burster and press it in until the shoulder on the top of the burster seats against the shoulder of the adapter. DO NOT USE FORCE. If the burster will not enter on the seat freely, turn the bomb in for disposal.

Replace the adapter sleeve, seating it firmly against the burster.

Assemble the nose fuze to the round and thread the arming wire through the proper holes.

Place Fahnestock clips or safety clips over the exposed ends of the arming wire.

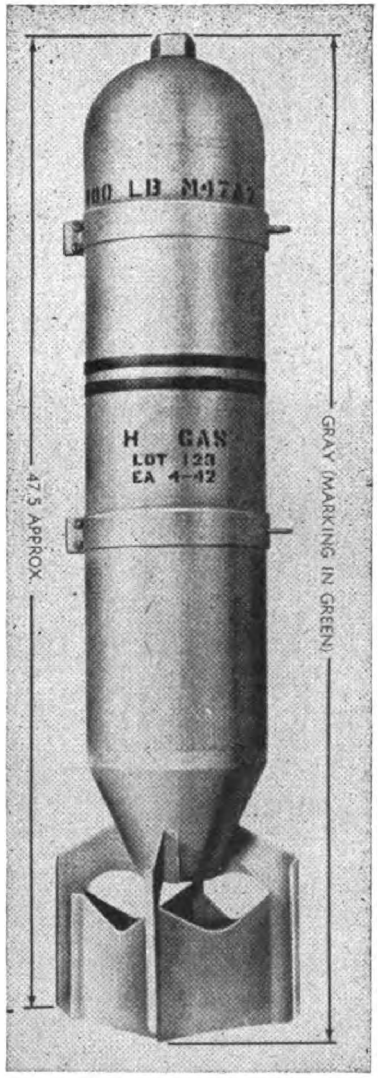

Figure 35. Bomb, Gas Persistent, H, 100-lb., M47A2.

BOMB, gas, persistent, H, 100-lb., M47A1 and M47A2

The A1 modification of this bomb consists of the use of lacquer on the inside of the case. The A2 modification incorporates the use of SAE 10 oil for coating the inside of the bomb body and the additional strengthening of the case to withstand a pressure of 400 lb. per sq. in.

Over-all length: 45.0 in.
Length of body: 32.8. in.
Diameter of body: 8.1 in.
Thickness of wall: 0.06 in.
Material of wall: Sheet steel.

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Construction of body: Tube made of sheet steel with longitudinal seam weld. Nose end is hemispherical; rear end is flat plate, welded to the tube.

Type of suspension: Horizontal.

Construction of suspension lug: Two eyebolts are formed by holes in each half of the suspension bands; the halves are then crimped together to form a complete band. The bands are secured to the bomb body by tightening the bolts on the underside of the body.

Burster: M4.

Length of tail: 12.4 in.

Width of tail: 10.9 in.

Material of tail: Sheet steel.

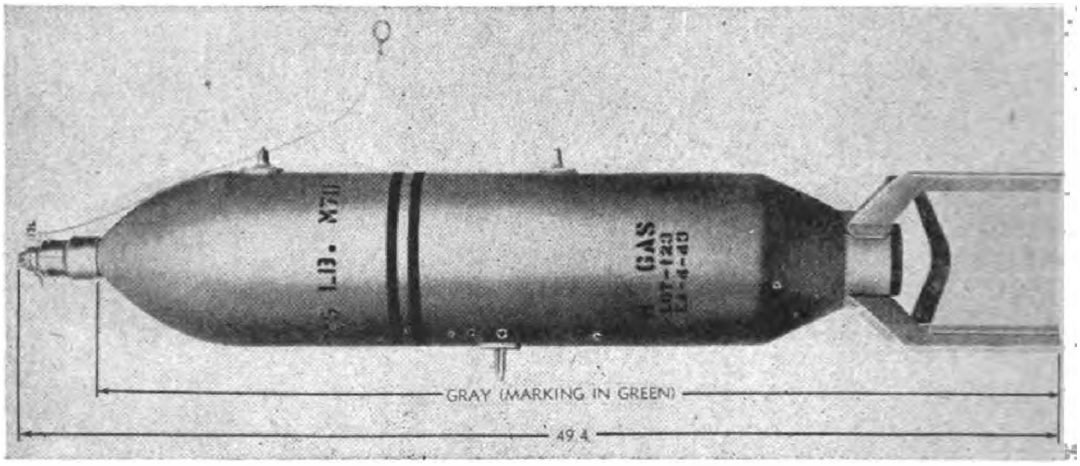

Figure 36. Bomb, Gas, Persistent, H, 115-lb., M70.

Construction of tail: Four vanes welded to truncated cone with box-type interior struts.

Weight of tail: 2.16 lb.

Type of filler: Chemical (H).

Weight of filler: 68.5 lb.

Total weight of bomb: 98.0 lb.

Charge/weight ratio: 70%.

Fuzes: M108, M126, M126A.

BOMB, gas, persistent, H, 115-lb. M70

Over-all length: 48.7 in.

Length of body: 36.95 in.

Diameter of body: 8 3/32 in.

Thickness of wall: 0.19 to 0.224 in.

Construction of body: The body is constructed of seamless steel tubing. A burster well runs the entire length. The nose is spiral.

Type of suspension: Horizontal.

Construction of suspension lug: Steel suspension lugs welded to the body. There are two lugs on one side, 14 in. apart, and one on the other side at the center of gravity.

Burster: M10.

Length of tail: 12.9 in.

Width of tail: 10.9 in.

Material of tail: Sheet steel.

Construction of tail: Four vanes welded to cone with box-type struts.

Type of filler: Chemical (usually H or WP).

Weight of filler: Mustard—57.1 lb.

Total weight of bomb: 122.5 lb.

Charge/weight ratio: 46.6%.

Fuzes: M110 or AN-M110A1.

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BOMB, smoke, 10-lb., WP AN-M67

The M1 and M2 fuzes used with this bomb are of the inertia type. The impact fuze is held in the safe position by a spring detent until the cluster is dispersed. A lacquer coating is also applied to the interior of the bomb body.

Over-all length: 19.5 in.
Length of body: 19.5 in.
Diameter of body: 3.134 in. maximum.
Thickness of body: 0.019 in.
Material of wall: Cold rolled steel.
Construction of body: Rounded hexagonal shape. The M1 or M2 fuze is of the horizontal type and is in the side near the blunt nose end. The tail consists of gauze streamers about 4½ in. long. There is a tail cup and nose cup.
Type of suspension: Suspended in clusters in the following manner: 100-lb. cluster—14 bombs, wt. 151 lb.; 500-lb. cluster—60 bombs, wt. 645 lb.
Material of tail: Gauze streamers about 4½ in. long, folded into a cup. These may have a green tint. They are provided to give stability in flight.
Type of filler: Chemical (usually WP).
Total weight of bomb: 10 lb.
Fuzes: M1 or M2.

BOMB, chemical, 10-lb. M77

Over-all length: 19.5 in.
Length of body: 19.5 in.
Diameter of body: Across flats—2.79 in. Maximum—3.06 in.
Thickness of wall: .0418 in.
Material of wall: Steel.
Construction of body: Steel.
Type of suspension: Clustered.
Length of tail: Four 75-in. streamers, 3 in. wide.
Material of tail: Cloth streamers.
Type of filler: HC, Type E.
Weight of filler: 9.5 lb. (approx.).
Total weight of bomb: 14.1 lb. (approx.).
Charge/weight ratio: 67%.
Fuze: M4.

BOMB, chemical, 500-lb. AN-M78

Over-all length: 59.16 in.
Length of body: 46.7 in.
Diameter of body: 14.8 in.
Thickness of wall: 0.3 in.
Material of wall: Steel.
Construction of body: Steel.
Type of suspension: Horizontal.
Construction of suspension lug: Steel forging.
Burster: M15.
Length of tail: 13.9 in.
Width of tail: 18.9 in.
Material of tail: Sheet steel.
Construction of tail: Box fin.
Weight of tail: 12.3 lb. (fin assembly).
Type of filler: Various chemical agents.
Fuzes: AN-M103 (nose); AN-M101A1 or AN-M101A2 (tail).

BOMB, chemical, 1000-lb. AN-M79

Over-all length: 69.5 in.
Length of body: 53.63 in.
Diameter of body: 18.62 in.
Thickness of wall: Thickens from body to nose, 0.38 in. to 1.5 in.
Material of wall: Steel.

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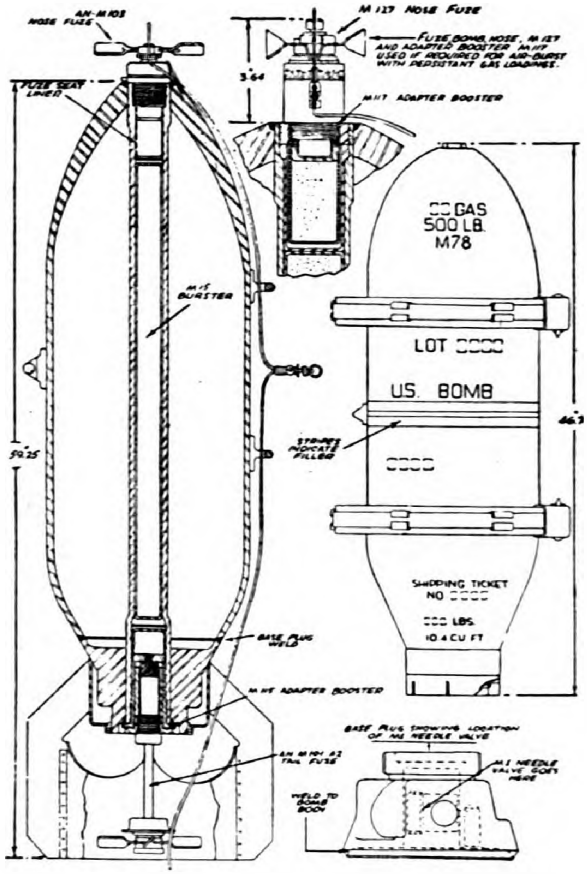

Figure 37. Bomb, Chemical, 500-lb., AN-M78.

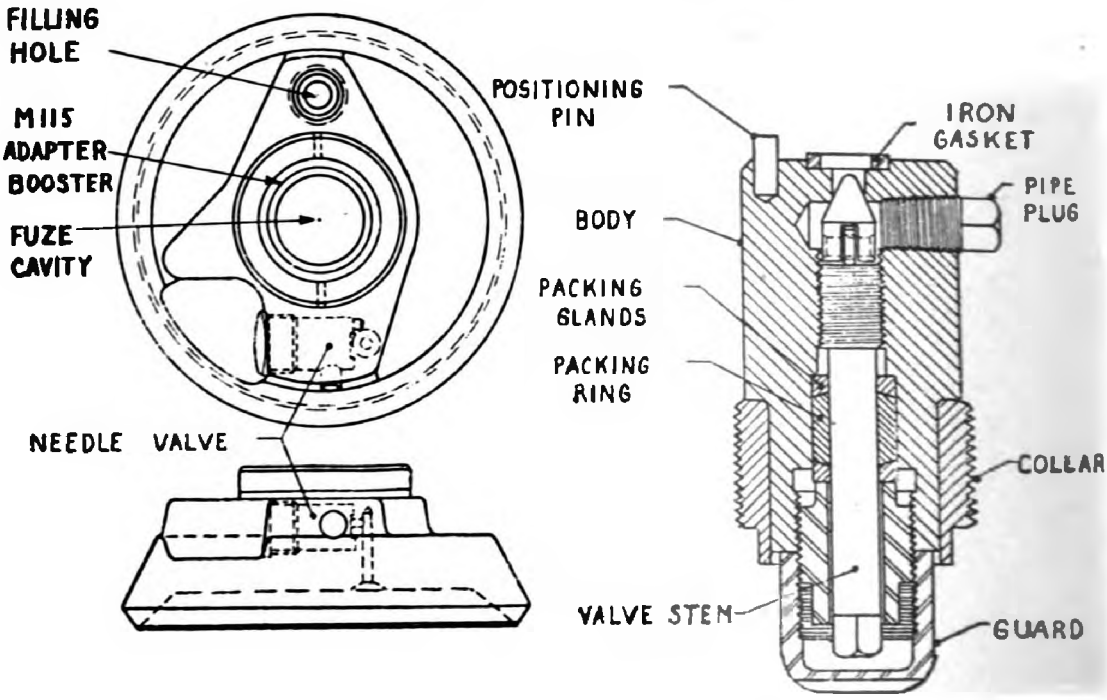

Figure 37a. M1 Needle Valve for AN-M78 and AN-M79 Chemical Bombs.

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Construction of suspension lug: Steel welded.
Burster: M16.
Length of tail: 18.5 in.
Width of tail: 25.4 in.
Material of tail: Sheet steel.
Construction of tail: Box fin.
Weight of tail: 21.5 lb. (fin assembly).
Type of filler: Various chemical agents.
Fuzes: AN-M103 or M127 (nose); AN-M102A1 or AN-M102A2 (tail).

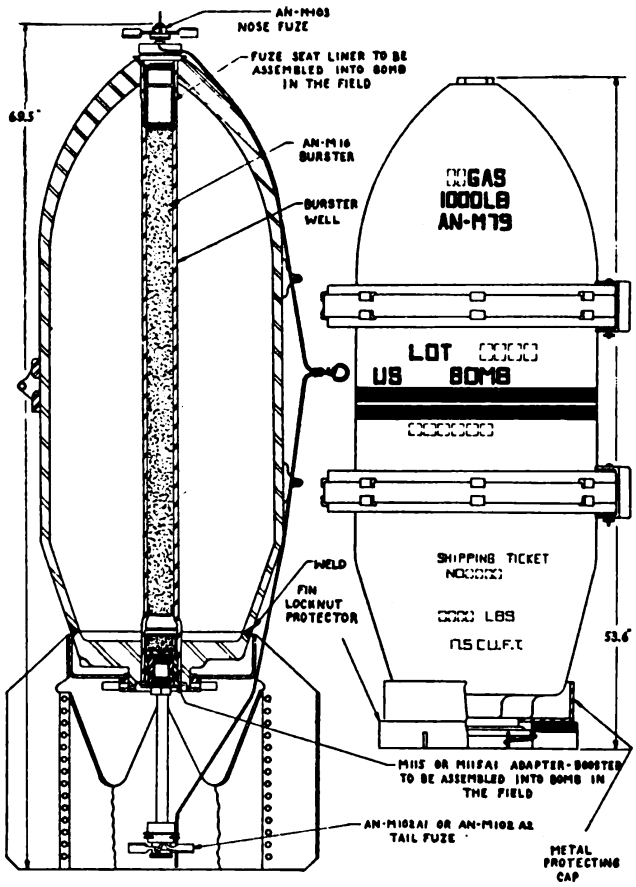

Figure 38. Bomb, Chemical, 1000-lb., AN-M79.

M1 Needle Valve. The valve is located in the base plug (see drawings) of the AN-M78 and AN-M79 chemical bombs. During shipment the valve is protected by a sheet-steel cup over which is fitted a paper fin lock nut protector. The M1 needle valve serves two purposes:

It acts as an air vent when the bomb is being filled with a chemical agent.

It is used for surveillance tests while the bombs are in storage. By unscrewing the pipe plug or the valve and attaching in its place a 2-inch or 3-inch nipple, a sample of the filling may be drawn off into a test tube. The guard cup must be unscrewed and the valve stem turned back to permit the gas to escape.

IMPORTANT: *This test should never be done except in the presence of a chemical warfare service officer or other similarly qualified personnel.*

BOMB, chemical, 10-lb. M74

This bomb is identical to the M74 bomb discussed in the section on incendiary bombs. It is classified as a chemical bomb because the filler is either mustard gas (H) or white phosphorous (WP).

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CLUSTERING

For most economical loading in planes, all chemical bombs weighing 100 lb. or less are clustered in order to facilitate loading of more than one bomb at each 100-lb. station on the bomb racks. Bombs weighing up to 10 lb. are stored, shipped, and issued in clusters of 100-lb. and 500-lb. size. These clusters are ready for installation. Bombs of the 100-lb. size and clusters of this weight are hung two at each 100-lb. station by use of the cluster adaptor M12. The diagrams on pages 431 and 432 will familiarize ordnance personnel with the procedures for loading chemical bombs in heavy bombers.

DEMOLITION BOMB FUZES

A fuze is a mechanical device designed to initiate a detonation under the circumstances desired. Fuzes are classified according to position as nose and tail, and according to function as time and impact. Time fuzes function a predetermined number of seconds after the arming pin is released. Impact fuzes function when the bomb strikes a resistant target. Impact fuzes are classified as delay when they are designed to have a definite time between the impact and explosion of the bomb, and as superquick (nose) or non-delay (tail) when there is no delay element incorporated.

Arming. Both nose and tail fuzes are shipped in a 'safe' condition. They are so constructed that, while they are 'safe' (unarmed), they cannot function. This is accomplished by designing the fuze so that an arming pin passes through the fuze, mechanically restraining the firing pin, or so that parts of the fuze remain out of position until they are moved into functioning position by the rotation of an arming vane. The arming pin or arming vane is held in place by a safety cotter pin. This is replaced by the arming wire when the bomb is placed in the plane. Dropping the bombs causes the arming wire to be withdrawn, which permits the fuze to arm. In the case of arming pin type fuzes, the fuze may arm immediately on withdrawal of the arming wire; or it may have an arming delay element timed by clockwork mechanism or a powder train, which delays arming until a fixed time has elapsed. In the case of arming vane type fuzes, the vane is rotated by the air stream as the bomb falls, and a fixed number of turns is required to arm the fuze. The trend in new fuzes is away from the arming pin type to the arming vane type, since the arming vane type offers more safety in event of a crack-up on take-off or landing.

SPECIFIC DEMOLITION BOMB NOSE FUZES

Fuze, Bomb, Nose AN-M103. This fuze functions on impact with a resistant target. It can be set readily while on the ground for either instantaneous or 0.1 second delay action by means if an external setting pin. This fuze is of the arming vane type and has a mechanical delay arming. This fuze is safe for dive bombing and for take-offs and landings anywhere, including the decks of carriers.

Functioning. When the bomb is released 'armed', the arming wire is withdrawn from the fuze permitting the arming vane to be rotated by the air stream. Rotation of the arming vane unscrews the delay arming mechanism from the striker in the nose of the fuze, thereby successively allowing first, the detonator slider to move over to the delay position, second, the arming discs between the striker flange and the fuze body to be ejected, and finally, the detonator slider to move over to the instantaneous position if the fuze has been so set. When the fuze is set for delay action, the detonator is aligned with the delay element. On impact, the striker is driven into the fuze body, firing the explosive train. When the fuze is set for instantaneous action, the detonator is aligned with the instantaneous firing pin on the striker. On impact the striker is driven into the fuze body, and the instantaneous firing pin is driven into the fuze body, firing the instantaneous explosive train.

Safety Features.

Detonator safe. The explosive train is out of alignment.

Arming discs between the striker head and upper part of the fuze body prevents the striker from moving down when the fuze is in an unarmed state.

Car seal is a shipping seal to prevent the arming vane assembly from rotating

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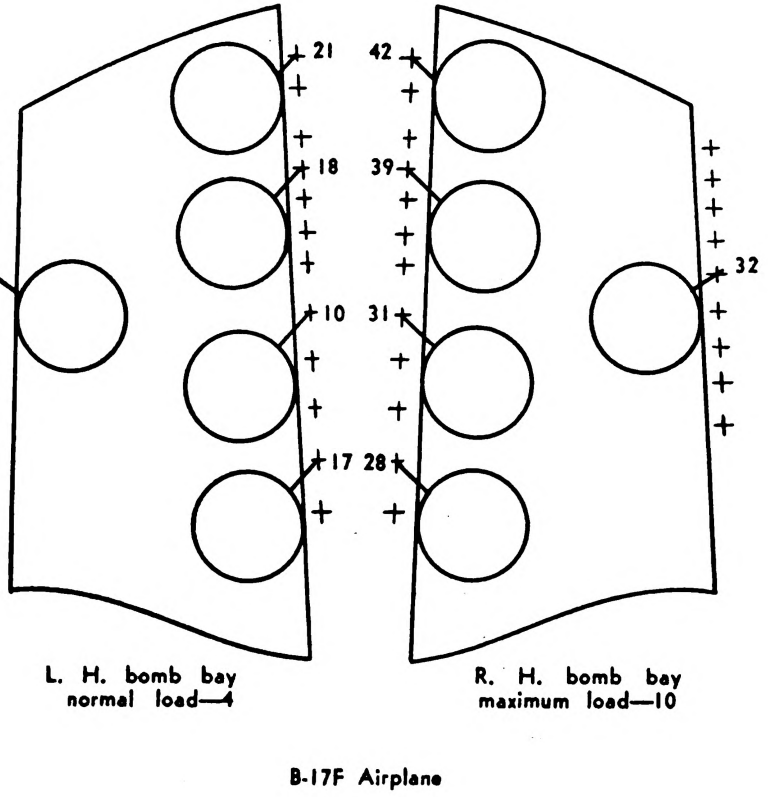

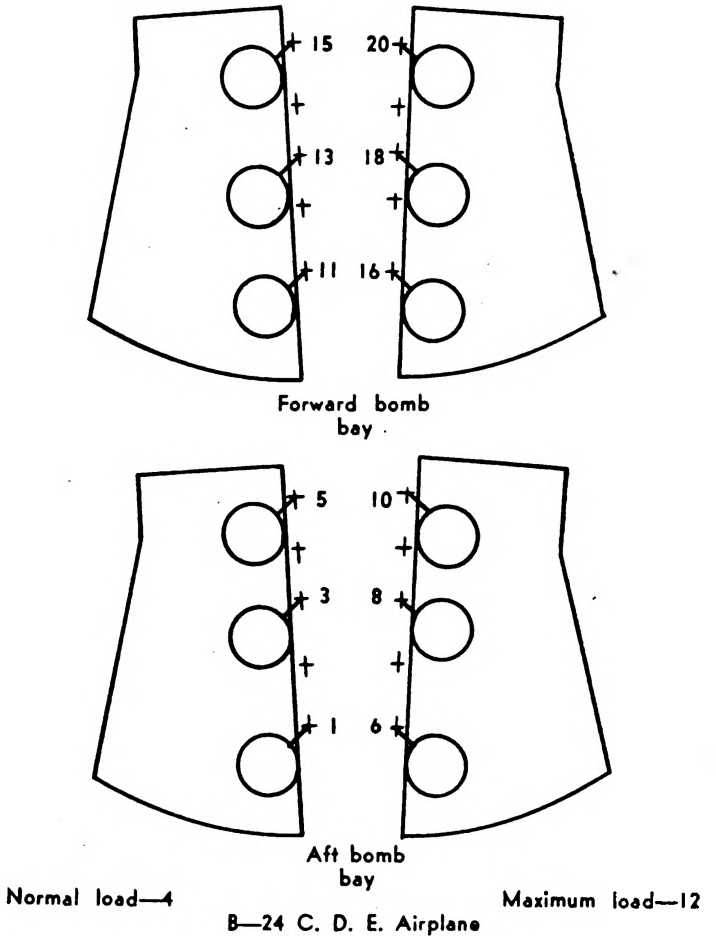

Maximum Load Shown
Bombs Marked "X" Indicate Normal Load
500 lb. Chemical
Bombs and Clusters

Figure 39. Loading Diagram, 500-lb. Chemical Bombs and Clusters.

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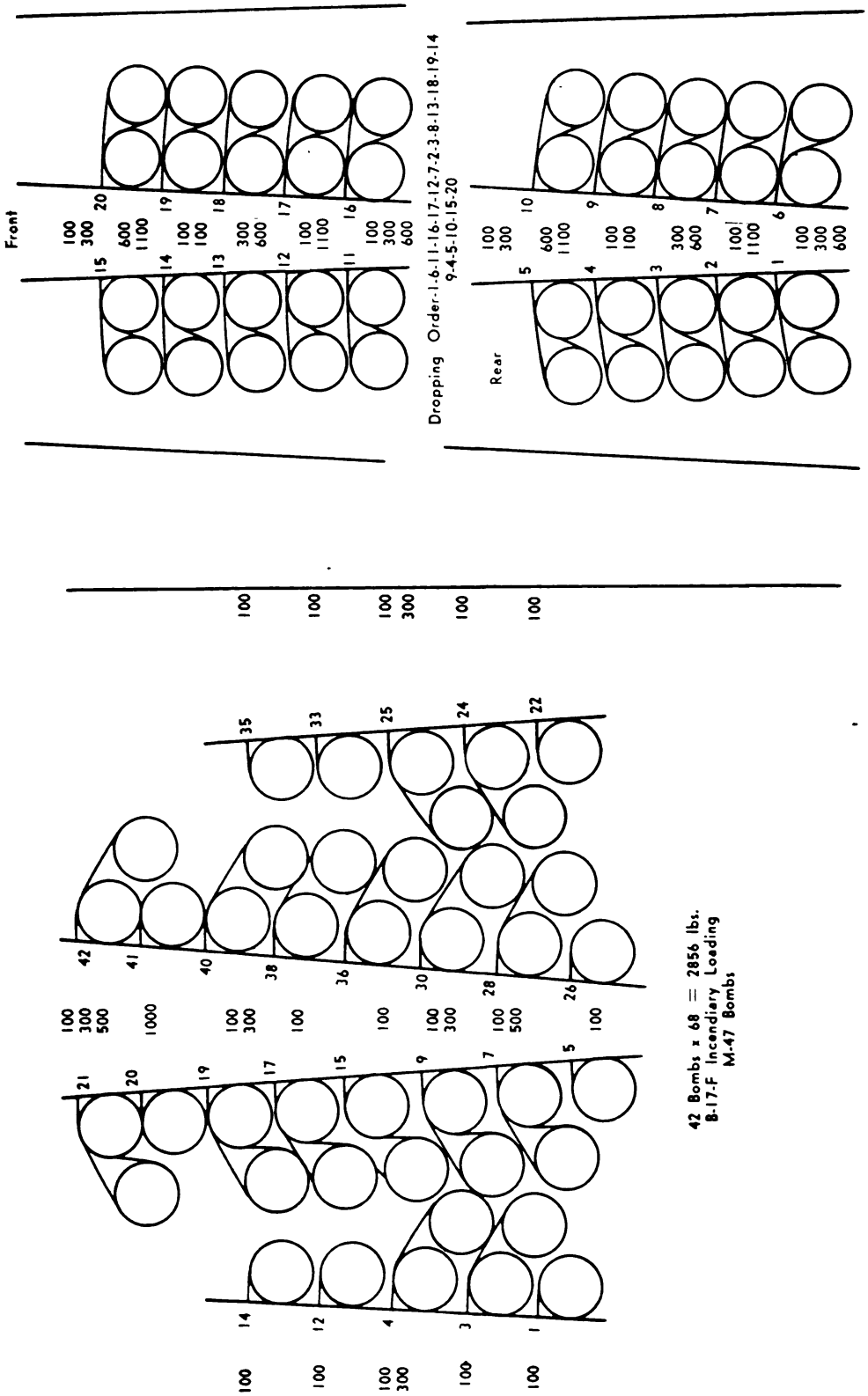

Figure 10 Loading Diagrams Incendiary Bombs M-47

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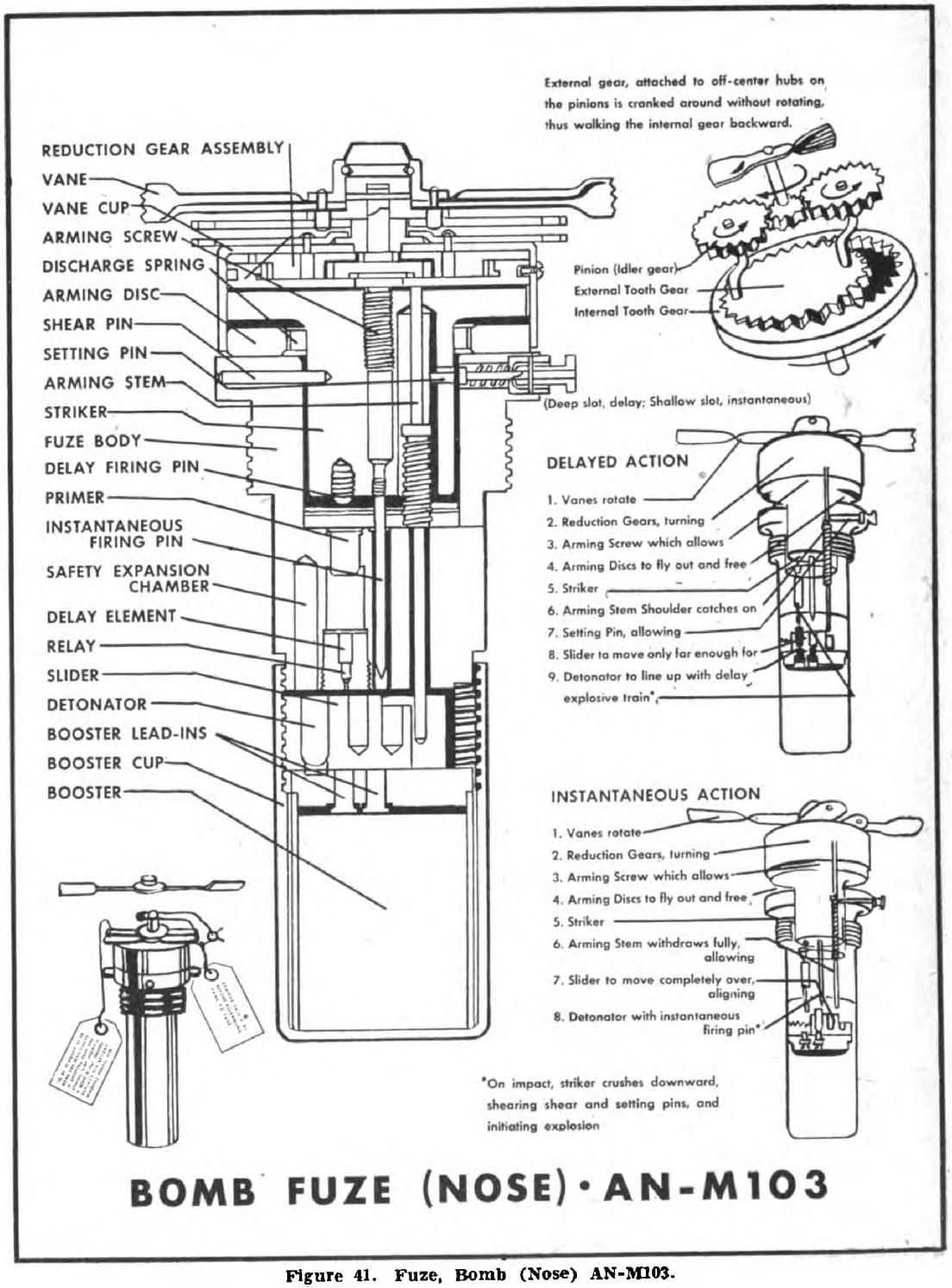

Figure 41. Fuze, Bomb (Nose) AN-M103.

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Cotter pin through the eyelets of the arming vane assembly prevents rotation during the threading of the arming wire.

Mechanical delayed arming.

Use. The fuze, bomb, nose AN-M103 is the standard nose fuze used in all series of bombs.

Fuze, Bomb, Nose M118 and M119. These fuzes are quick-arming fuzes, which may be used for extremely low altitude bombing against unarmored or lightly armored targets. These tactics are called 'masthead bombing'. They contain delay elements which give a time delay of 4 to 5 seconds for the fuze M118, and 8 to 11 seconds for the fuze M119 to provide time for the airplane to leave the effective area of the bomb blast. The delay elements provide the only difference between the models.

Functioning. When the bomb is released armed, the arming wire is withdrawn from the fuze, permitting the arming vane to be rotated by the air stream. The rotating arming vane is directly connected to the arming screw. As the arming screw turns in the striker, it moves the vane cup forward and uncovers the arming discs, which are then ejected by the arming spring. The striker carrying the firing pin is restrained from striking the primer by the shear pin. Upon impact, the shear pin is sheared and the striker carrying the firing pin moves back and strikes the primer, which ignites the delay element of the fuze.

Safety Features.

Car seal.

Cotter key.

Safety discs.

Use. The fuzes, bomb, nose M118 and M119 are used for special tactical mission (skip bombing) as auxiliary fuzes in bombs in which the M112A1, M113A1, and M114A1 bomb tail fuzes are used.

Fuze, Bomb, Nose M139 and M140. These fuzes are recent developments that have functioning times of .01 second and .025 second respectively. They are similar to the standard AN-M103 nose fuze. In order to distinguish these fuzes from the AN-M103 nose fuze, the vane cup will have a segment painted on it which corresponds to the present painting on the base of the M14, detonator. In each case the painted segment will be black, the M139 having a ⅛, and the M140 a ¼ segment.

Functioning. These fuzes function the same as the fuze, bomb, nose AN-M103.

Safety Features. The safety features are the same as the fuze, bomb, nose AN-M103.

Use. These fuzes will be used in conjunction with the fuze, bomb, tail AN-M100A1, AN-M100A2, AN-M101A1, AN-M101A2, AN-M102A1 and AN-M102A2, which have the same available functioning times by making use of the M14 primer detonator.

Fuze, Bomb, Nose T-56 and T-56E1. The T-56 and T-56E1 will be standardized as the M135 and M136. The fuzes are a combination of the M111A2 mechanical time fuze and the AN-M103 nose fuze. The only difference between the two fuzes is that the M135 can be set for a delay of from 5 to 92 seconds, while the M136 has a setting range of from 5 to 30.6 seconds. These fuzes were developed to give aerial burst functioning of the bomb at different altitudes.

Functioning. When the bomb is released 'armed', the arming wire is withdrawn from the fuze permitting the vane to rotate, the arming pin is ejected, and the time mechanism starts to function. The arming stem release pin is ejected, allowing the arming stem to move upwards, thereby permitting the detonator slider to move over into the armed position. After the safety collar is released from the fuze, the time mechanism is then free to function according to the time set on the fuze. The bomb may detonate if it strikes a target prior to completing the function of the time mechanism.

Safety Features.

Safety collar under striker head.

Cotter key.

Snipping seal.

Detonator safe.

Use. These fuzes will be used in any bombs adapted to receive the AN-M103 and will provide an aerial burst of the bomb at different alitudes.

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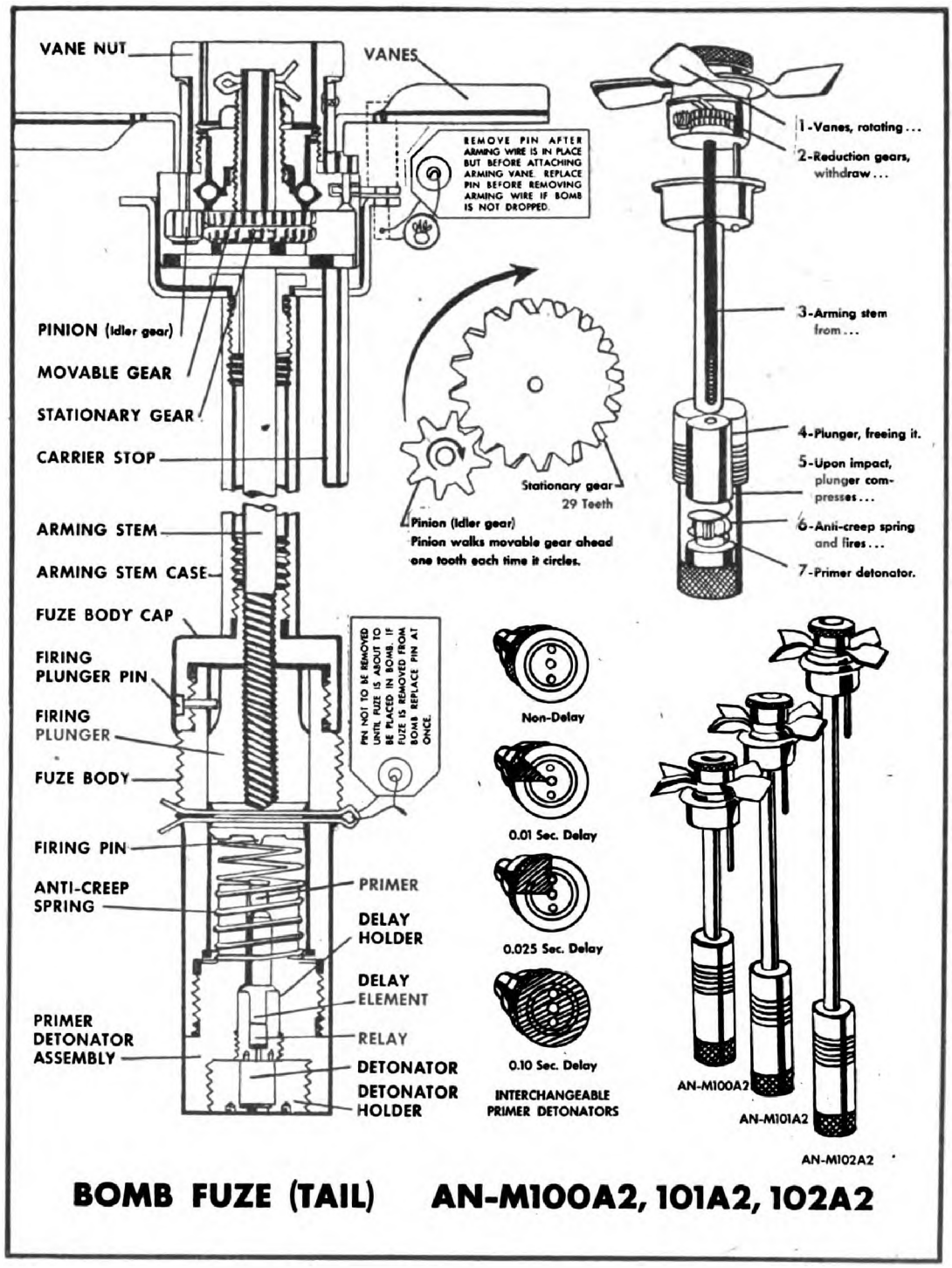

Figure 42. Fuze, Bomb (Tail) AN-M100A2, 101A2, 102A2.

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Fuze, Bomb, Tail AN-M100A1, AN-M100A2, AN-M101A1, AN-M101A2, AN-M102A1, and AN-M102A2. These fuzes function on impact. They are equipped with any one of the following delays: 0.01 second, 0.025 second, 0.1 second, and non-delay by substituting the proper M14 primer detonator. These fuzes are of the arming vane type and have a mechanical delay arming. The two series are identical with the exception of lengths. The variations in lengths are necessary to properly locate the arming vane in the air stream so that the same type of fuze can be used in various size bombs.

Functioning. When the bomb is released armed, the arming wire is withdrawn from the fuze, thereby allowing the airstream to turn the arming vane. The rotating arming vane, acting through the reduction gear train, unscrews the arming stem from the firing plunger, thereby releasing the plunger and arming the fuze. After the fuze becomes armed, the plunger is restrained from striking the primer cap by a retainer spring until impact of the bomb. The retardation imparted to the bomb on impact causes the inertia firing plunger to move forward, striking the primer and initiating the explosive train.

Safety Features.

Cotter key through the eyelets on the vane assembly prevents rotation of arming vane.

Mechanical delayed arming.

Car seal.

A cotter key, which extends through the fuze body and the firing plunger, prevents movement of the plunger.

Primer detonator contained in a solid metal housing that may be screwed out of the fuze during storage.

A1 Modification.

Air interchangeable primer detonator with four different functioning times mentioned above.

A retainer collar to hold the retainer spring in place during the operation of changing primer detonators.

A2 Modification.

Double threads on the arming stem to reduce the arming time to allow the bombs to be dropped from a low altitude.

The arming vane has been strengthened and the number of blades on the arming vane has been decreased from 8 to 4 blades.

Use. These fuzes are used on all series of bombs and are safe to be used on decks of carriers.

Fuze, Bomb, Tail M106, M106A1, M106A2. This fuze is the arming pin type with a time delay. The firing assembly is held in place by an arming pin running through the fuze body and striker, and held in place by the arming wire.

Functioning. When the bomb is released armed, the arming wire is withdrawn from the arming pin, allowing the arming pin to be ejected by the arming pin spring. This operation frees the striker assembly which is restrained from striking the primer by a retainer spring. Upon impact of the bomb with the target, the striker moves downward, compressing the retainer spring and striking the primer which initiates the explosive train.

Safety Features.

Cotter key holding the arming pin in place.

A 45-second delay in the explosive train allows the fuze to drop away from the plane before it would detonate.

A1 and A2 Modifications. These modifications were brought about by a new type of bombing known as 'skip bombing'.

A1 modification. The delay train was cut down from 45 seconds to 8 to 11 seconds.

A2 modification. The delay train was cut down to 4 to 5 seconds.

Use. This fuze may be used on any bomb for which the tactics may call. It is advisable to use the later series of fuzes discussed below.

Fuze, Bomb, Tail M112, M113, M114, M112A1, M113A1, M114A1. These fuzes are of the arming vane type with direct arming. They function with delay action on impact and may be equipped with either a 4 to 5 seconds delay or 8 to 15 seconds delay by installing the M16 primer detonator. These fuzes are identical with the exception of lengths and are used in different size bombs.

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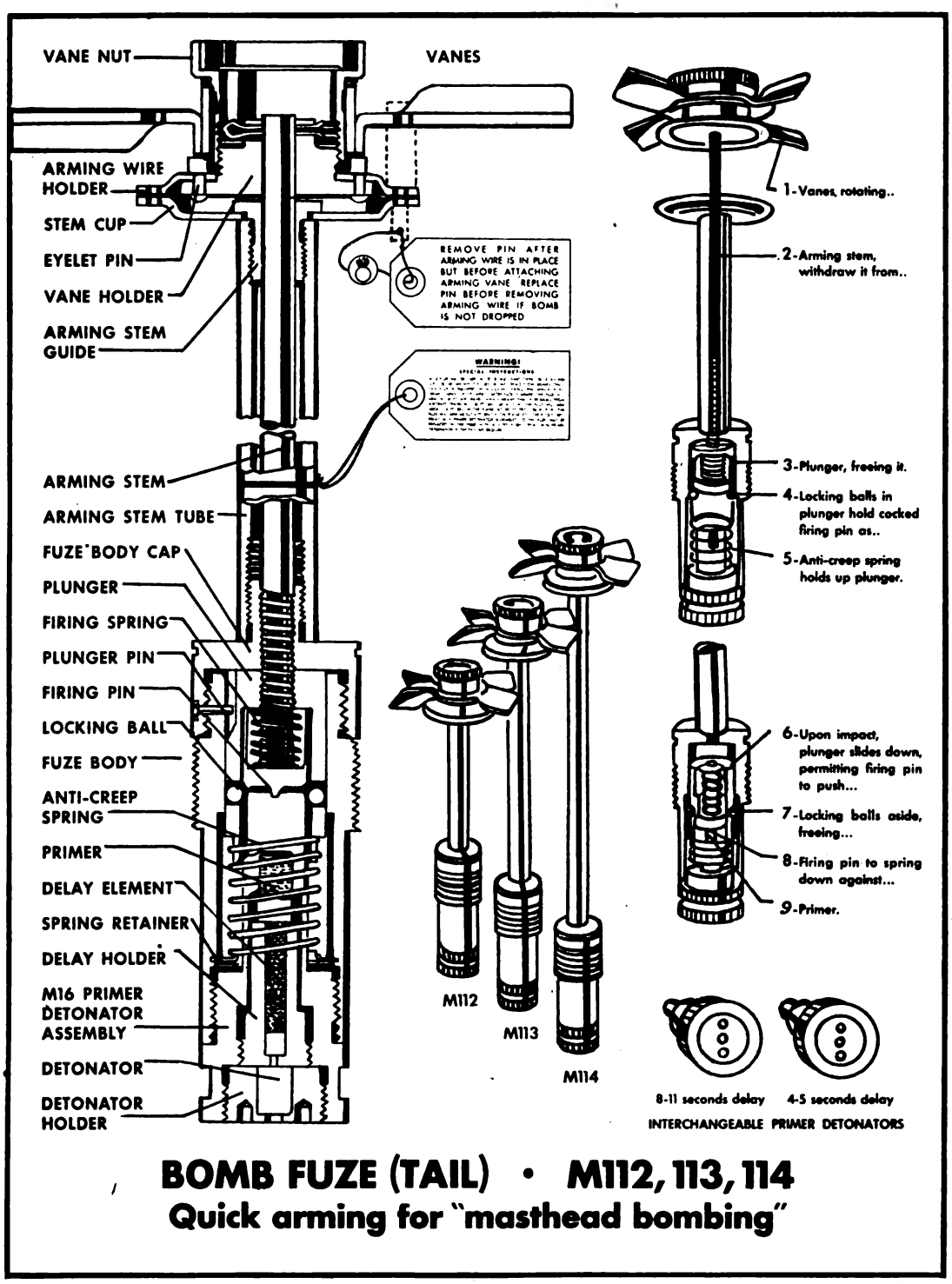

Figure 43. Fuze, Bomb (Tail) M112, M113, M114. Quick Arming for 'Masthead Bombing.'

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Functioning. When the bomb is released armed, the arming vane rotates, arming the fuze. Each turn on the arming vane unthreads one thread on the stem. After a sufficient number of revolutions the arming stem screws from the inertia sleeve, which then is held in position by the retainer spring. The inertia sleeve contains the cocked firing pin, which is held in a cocked position until the bomb impacts a resistant target. Upon impact the inertia sleeve moves forward a distance to allow the locking ball to be ejected into a recess in the fuze body, freeing the cocked firing pin, which impacts the primer that initiates the explosive train.

Safety Features.

Cotter key through the vane assembly prevents rotation of the arming vane.

Car seal.

These fuzes may be stored without the primer detonator.

A1 Modification. The inside diameter of the retainer spring collar has been increased to make the fuze adaptable for the M16A1 primer detonator.

Use. These fuzes are generally used on the 500-lb. and 1,000-lb. bombs for skip and masthead bombing. They will not be used on decks of carriers.

Fuze, Bomb, Tail M115, M116, M117. These fuzes are identical with the fuze, bomb, tail M112, M113, and M114, except that they incorporate a mechanical gear train which increases the arming time so as to make them suitable for use on decks of carriers.

Fuze, Bomb, Tail M123, M124, M125. These fuzes are of the arming vane type with a mechanical delay arming. They are capable of delaying the detonation of the bomb for 1, 2, 6, 12, 24, 36, 72, or 144 hours after impact of the bomb. The amount of delay desired is obtained by choosing a fuze of that particular delay. The delay is caused by a chemical combination of acetone and alcohol reacting on a celluloid disc. These fuzes also contain antiwithdrawal devices, which will function the bombs if attempts are made to withdraw the fuzes from the bombs once they have been inserted.

Functioning. When the bomb is released armed, the arming wire is withdrawn from the fuze, and the vane is rotated by the airstream. The rotation is transmitted through the reduction gears to the arming stem, screwing it into the fuze body a sufficient distance to crush the glass ampoule of solvent. The solvent filters through the delay wad and starts to dissolve the celluloid collar. When the collar has dissolved sufficiently, the firing pin locking balls are released. When the balls are released they are forced outward, and the firing pin is driven downward into the primer initiating the explosive train.

On the antiwithdrawal, the ball groove on the body extension is deep at one end and shallow at the other so that, when the fuze is turned in the adapter in the direction of unscrewing, the ball is forced into the shallow end of the groove and locks the fuze body extension in place. Continued unscrewing of the fuze will unscrew the fuze body from the fuze body extension. After one and a half turns in counterclockwise direction, the sleeve balls move outward releasing the firing pin which is driven downward into the primer, initiating the explosive train.

Safety Precautions.

Detonator holders will not be assembled to fuzes nor fuzes assembled to bombs in advance or in anticipation of future needs.

Particular care must be exercised to protect this type of fuze from heat and shock.

The indicator vials will be examined when the fuze packing box is opened to determine if they are safe to use.

Never unscrew this fuze at any time once it has been screwed into a bomb.

Bombs brought back from a mission will not be stored with fuzes in them, but will be destroyed by demolition.

Safety Features.

Mechanical delayed arming.

Arming block to prevent the arming assembly from moving down.

Cotter key through the vane assembly to prevent the arming vane from rotating.

Thumb screw through the fuze body and fuze body extension to prevent unthreading of the antiwithdrawal device.

Use. These fuzes are used on any standard series of bombs for special missions.

Fuze, Bomb, Tail M132, M133, M134. These fuzes are the arming vane type

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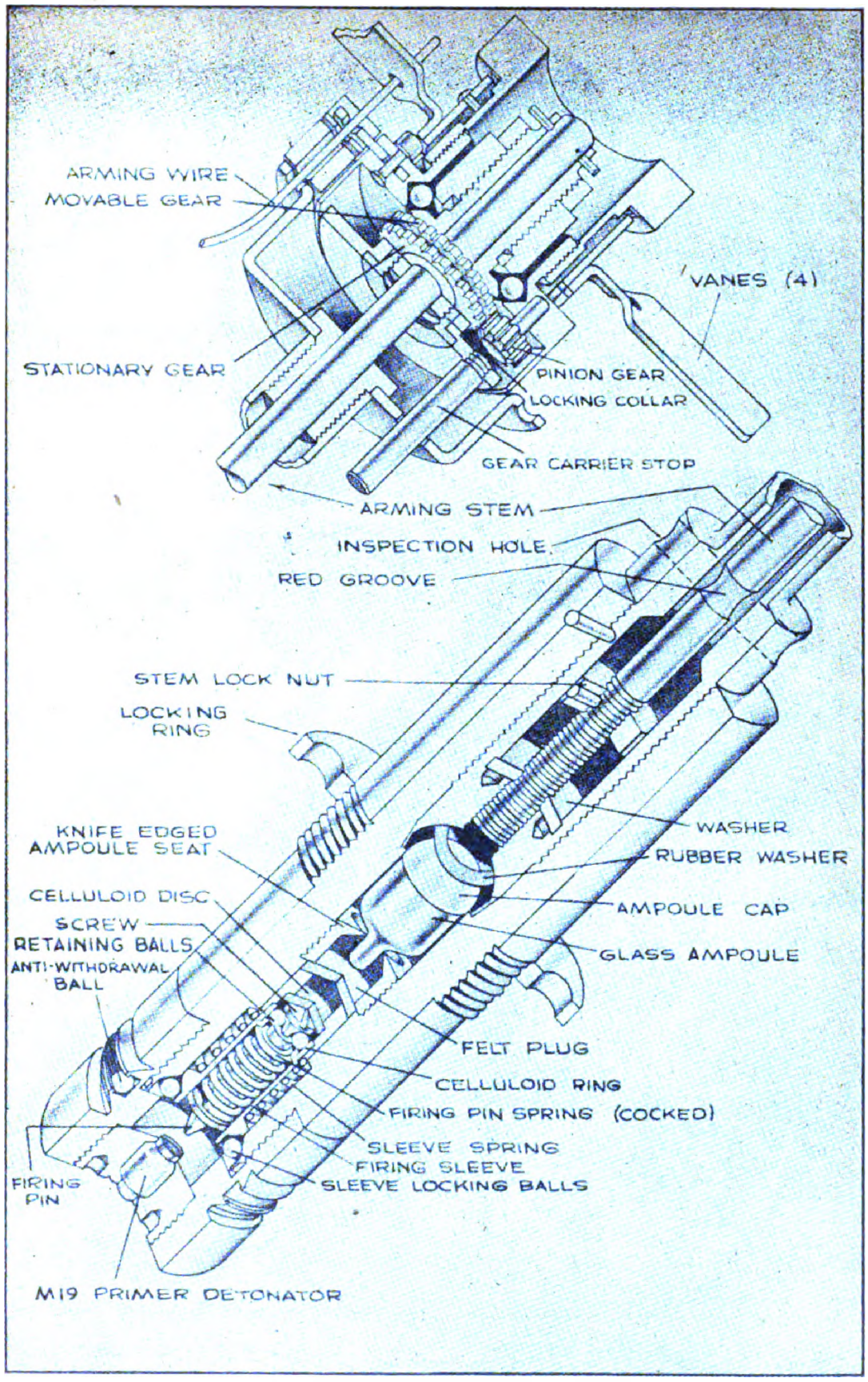

Figure 44. Fuze, Bomb (Tail) M123, 124, 125.

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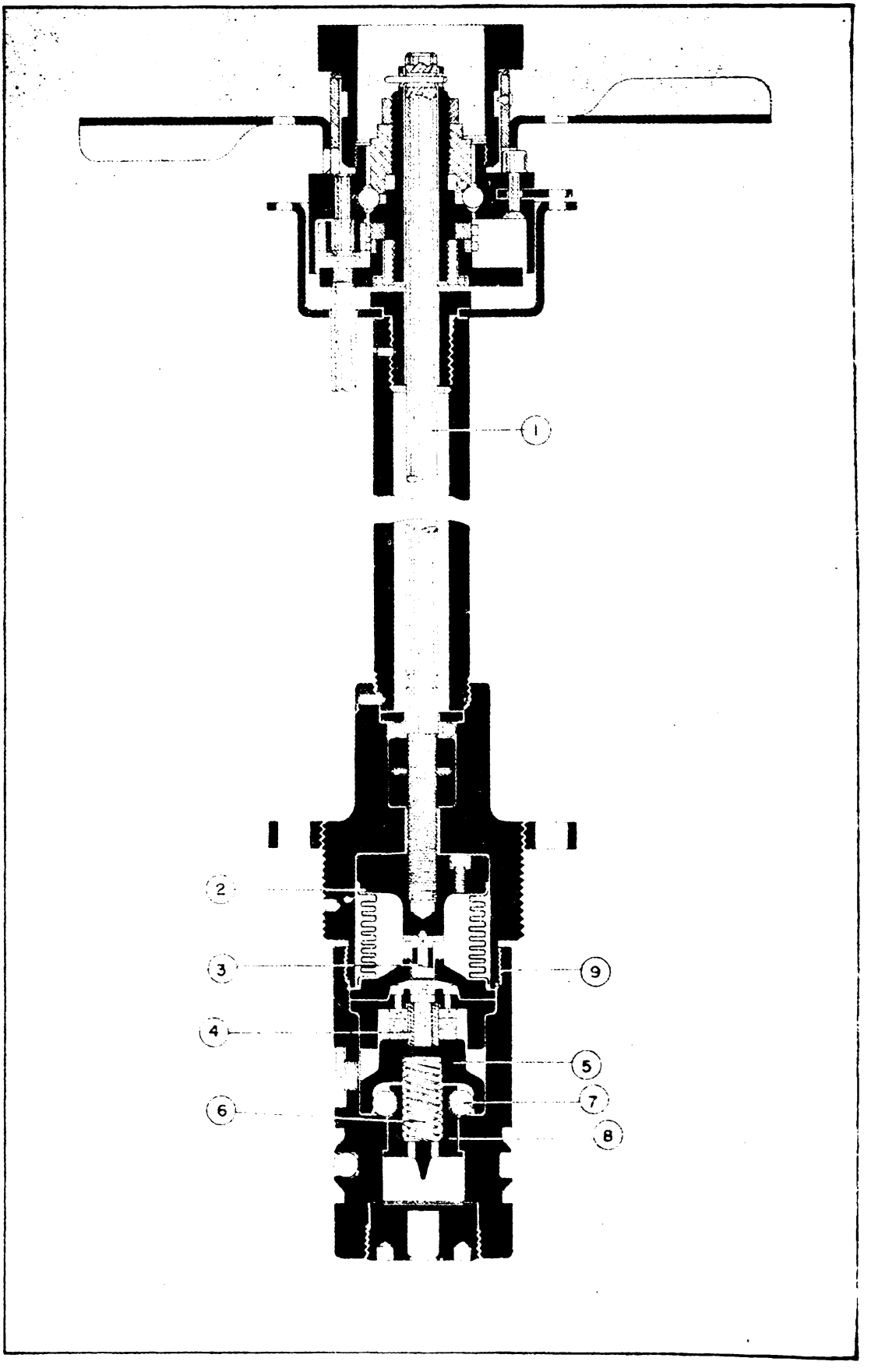

Figure 45. Fuze, Bomb (Tail) M132, 133, 134.

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with a mechanical delay train. They are capable of detonating a bomb from 5 to 10 minutes after impact of the bomb. This delay is identical to the type of delay that is in the fuze, bomb, tail M123, M124, and M125. These fuzes are similar to the M123 series except that the chemical agent is contained in a metal bellows instead of the glass vial, and firing assembly has been modified. The same precautions will prevail in the use of this fuze as for the M123 series.

References: TM9-1980 Bombs and Fuzes
TM9-1904 Amm. Inspect. Guide
OP #988 Fuzes (Navy)
SNL S-1 Parts I and II

TERMINAL BALLISTICS AND TACTICAL USE OF AERIAL BOMBS

The determination of ballistics data is inseparably linked with munitions design and therefore is a responsibility of the Ordnance Department. Obviously a detailed consideration of the many types of testing methods and data calculation

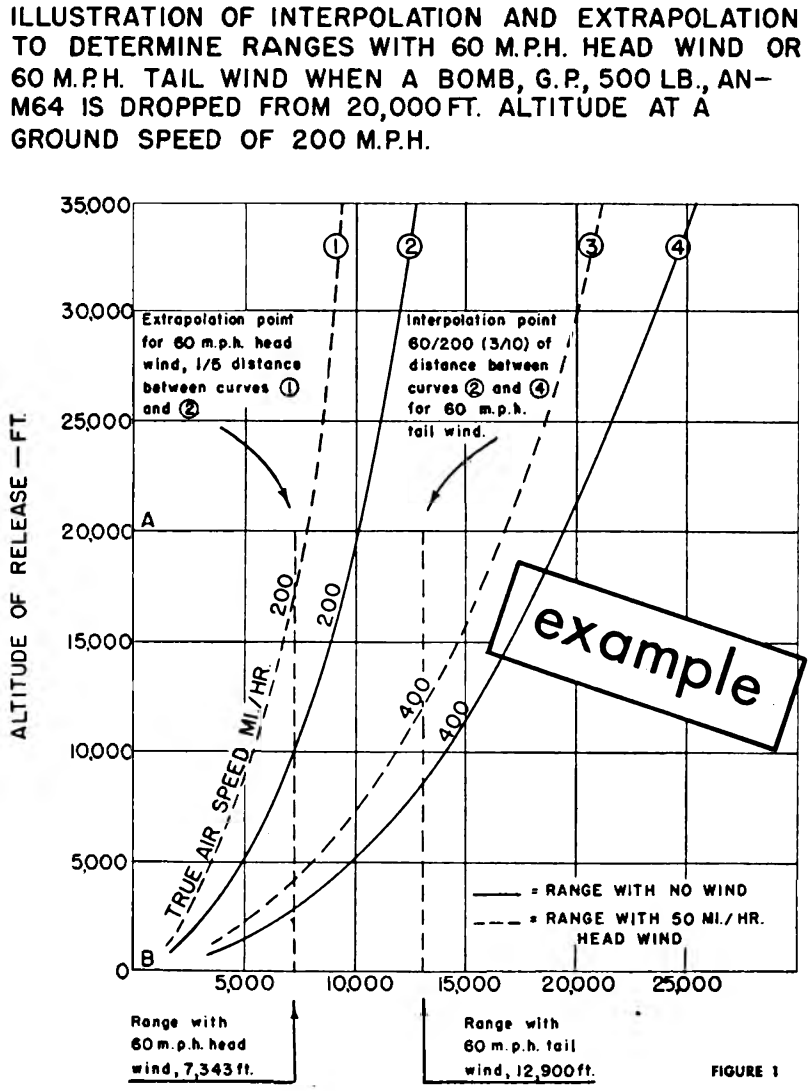

Figure 46. Illustration of Interpolation and Extrapolation to Determine Ranges with 60 m.p.h Head Wind, Etc.

procedures would be impracticable here. The data presented is basic (though largely very recent to the field), and is intended as a basis for more intelligent application of the bombing tables and tactical use of bomb charts which follow.

Wind Effects Upon Range. Range, as considered in aerial bombing, is the

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distance between the point of impact and the point directly under the airplane at the instant of bomb release. With no wind, the true air speeds and ground speeds are the same. For each set of two curves a 50 m.p.h. head wind reduces the ground speeds to 150 m.p.h. and 350 m.p.h. respectively. Effects of other head winds or tail winds may be determined by interpolation. The following examples show the effective use that may be made of the information in figure 46.

Assuming the bomb to be dropped from an altitude of 20,000 ft. with a true air speed of 200 m.p.h. and no wind, a vertical line is extended from the intersection of the solid curve (2) for 200 m.p.h., true air speed, and the horizontal line for 20,000 ft., altitude of release, until it meets the range line at the base of the chart. The range at this point is found to be 10,075 ft.

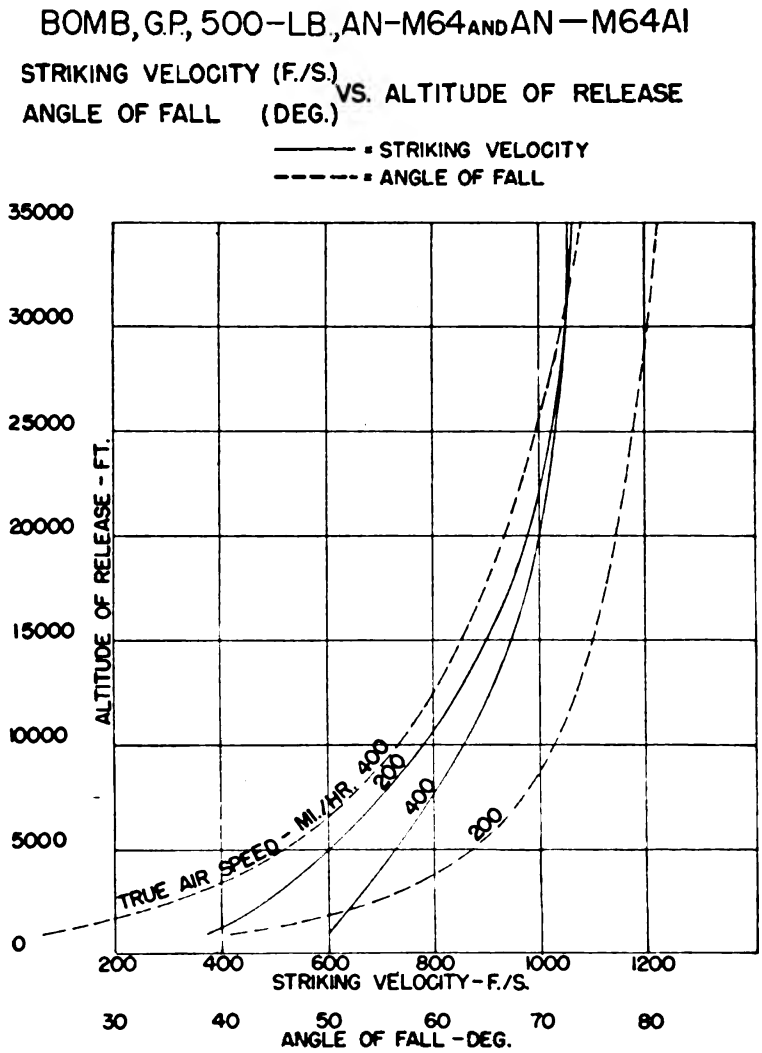

Figure 47. Bomb, GP, 500-lb., AN-M64 and M64A1, Etc.

If a 50 m.p.h. head wind (resulting in a ground speed of 150 m.p.h.) is assumed, the range for a bomb dropped from 20,000 ft. is found from the dotted 200 m.p.h. curve (1) in the same way as in the first example. The range in this instance is 7,600 ft.

In the case of a 60 m.p.h. tail wind with a 200 m.p.h. true air speed, interpolation must be employed. The distance, say X, between the 200 m.p.h. and 400 m.p.h. curves (2 and 4) for range with no wind is measured on the 20,000 ft. altitude of release line. Since there is a difference of 200 m.p.h. between these two curves,

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and the tail wind is 60 m.p.h., 60/200 or 3/10 of the distance (X) from the no wind 200 m.p.h. curve (2) is that from which the vertical line must be extended to the range line to determine the range. Intersection of the range line with the vertical line from the point of interpolation shows the range to be 12,900 ft.

If the wind were a head wind of 60 m.p.h., the interpolation point would be 1/5 the distance between the 200 m.p.h. curve (2) for no wind and the 200 m.p.h. curve (1) corrected for a 50 m.p.h. head wind. This is so because the 10 m.p.h. increase of a 50 m.p.h. wind above the given head wind of 50 m.p.h. is 1.5 the difference between the latter wind and no wind. But the ground speed of a 200 m.p.h. true air speed with a 60 m.p.h. head wind is 140 m.p.h. It is therefore necessary to extrapolate to the left of curve (1) to find the point from which to drop a vertical line to the range line. This is done by measuring to the left (decreasing velocity side) of the 200 m.p.h. curve (1), corrected for a 50 m.p.h. head wind, the distance originally determined by interpolation. This range is found to be 7,343 ft.

Characteristics of Impact. The angle of fall (angle between a line drawn through the main axis of the bomb and the horizontal at moment of impact) and the striking velocity of the bomb at impact may be calculated from figure 47, for any altitude of release up to 35,000 feet for the two plane speeds of 200 m.p.h. and 400 m.p.h. The following examples show the application to planning operations for curves of this type when the angle of fall and striking velocity are required to be known.

A 500-pound bomb is released 20,000 feet from a plane flying at 200 m.p.h. true air speed. From the intersection of the horizontal line for 20,000 feet and the solid 200 m.p.h. line, a reading of 950 feet per second striking velocity is made from the base line. From the intersection of the 20,000 feet line and the dotted 200 m.p.h. line, a reading of 77° angle of fall is made on the known base line.

POWER AND EFFECT OF DEMOLITION BOMBS

Cratering. The diameter and depths of craters formed by detonation of the various size bombs are factors usually desired to be known before scheduling raids on enemy airfields or emplacements. The total amount of earth removed from the runway of an enemy airfield determines the amount of work required by the enemy to effect repairs and therefore bears direct relation to the time it will be denied his use. Combat experience has shown that concrete emplacements are normally not destroyed by a near miss unless the emplacement falls within the radius of a normal crater for the size bomb used. The figures below show crater size and earth displacement caused by various size bombs considering various kinds of earth (soil effect).

Rupture and Deformation of Bombs Upon Impact with Impregnable Targets. General purpose bombs (TNT or Amatol loaded) dropped from a high altitude will upon direct impact with thick concrete deform or break up (see chart 10) and function low order; however, limited tests conducted with TNT and Amatol loaded bombs indicated that when the bombs are fuzed 0.1 sec. or less delay, high order detonation will result. Armor-piercing bombs will not deform or break up regardless of the altitude of release. Semi-armor-piercing bombs weighing less than 1,000 lb. are ineffective against concrete fortifications 5 feet or more in thickness. The 1,000-lb. Semi-Armor-Piercing Bomb AN-M59 or AN-M59A1, and the 1,600-lb. Armor-Piercing Bomb AN-Mk.1 are effective for destruction of pillboxes when it is possible to obtain direct hits. Chart 10 gives the deformation and rupture altitude for bombs falling on very thick concrete.

Penetration and Perforation of Concrete. In this discussion of the effects of bombs upon concrete, perforation of a wall or roof means complete passage of the bomb through concrete, while penetration means making a crater which does not go all the way through the concrete.

Chart 11 gives concrete perforation thicknesses for S.A.P. and AP bombs and the number of bombs required for 50 per cent and 90 per cent probabilities of hitting a 10-yd. by 10-yd. target from various altitudes of release when the true air speed of the airplane is 250 m.p.h.

Attack On Concrete Pill Boxes Utilizing Confined Detonation Close to External Wall. A dirt covering upon concrete considerably reduces the concrete thickness that can be perforated, but in those cases where the dirt cushions a GP bomb

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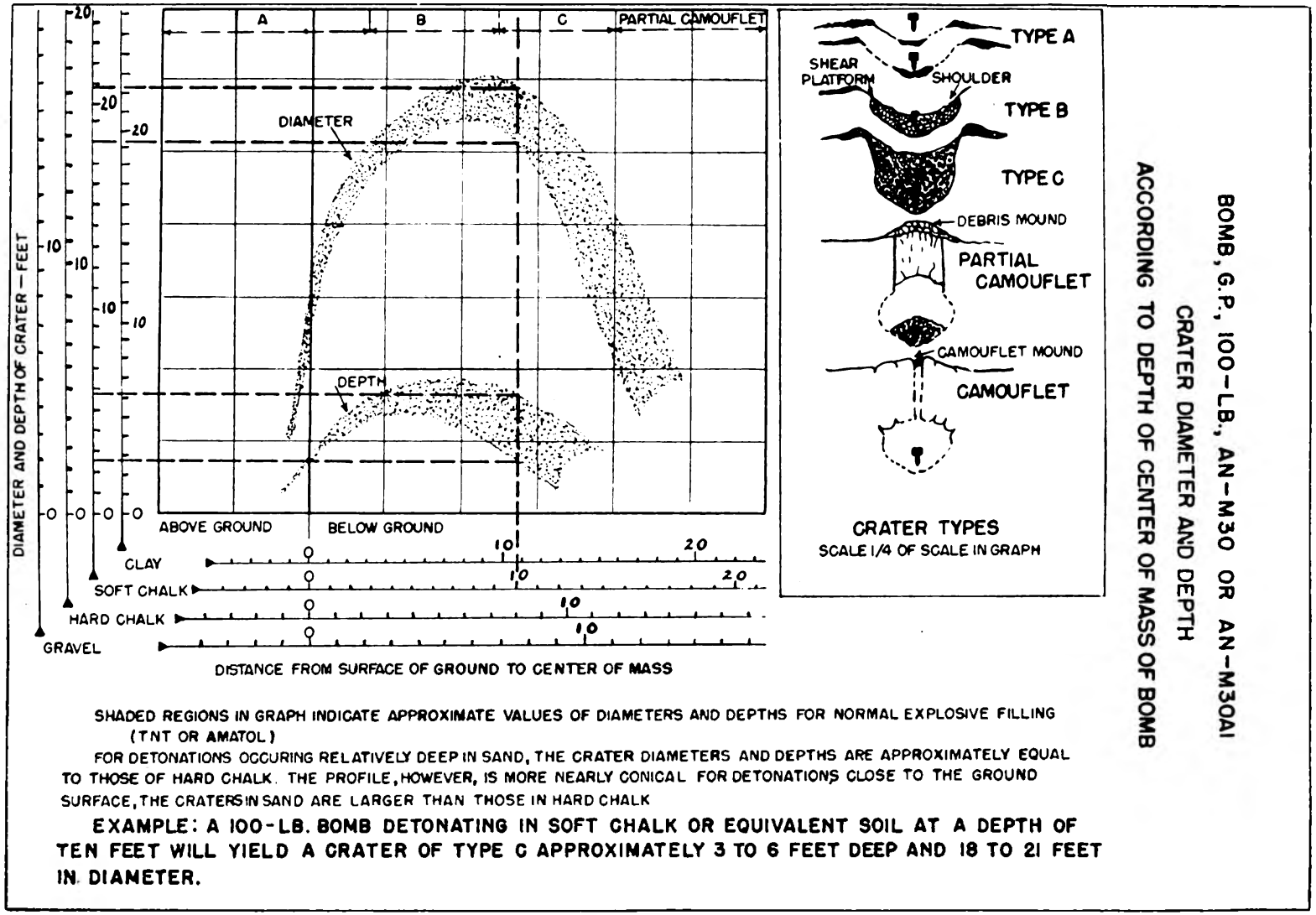

SHADED REGIONS IN GRAPH INDICATE APPROXIMATE VALUES OF DIAMETERS AND DEPTHS FOR NORMAL EXPLOSIVE FILLING (TNT OR AMATOL)

FOR DETONATIONS OCCURING RELATIVELY DEEP IN SAND, THE CRATER DIAMETERS AND DEPTHS ARE APPROXIMATELY EQUAL TO THOSE OF HARD CHALK. THE PROFILE, HOWEVER, IS MORE NEARLY CONICAL FOR DETONATIONS CLOSE TO THE GROUND SURFACE, THE CRATERS IN SAND ARE LARGER THAN THOSE IN HARD CHALK

EXAMPLE: A 100-LB. BOMB DETONATING IN SOFT CHALK OR EQUIVALENT SOIL AT A DEPTH OF TEN FEET WILL YIELD A CRATER OF TYPE C APPROXIMATELY 3 TO 6 FEET DEEP AND 18 TO 21 FEET IN DIAMETER.

Figure 48. Bomb, GP, 100-lb., AN-M30 or AN-M30A1, Etc.

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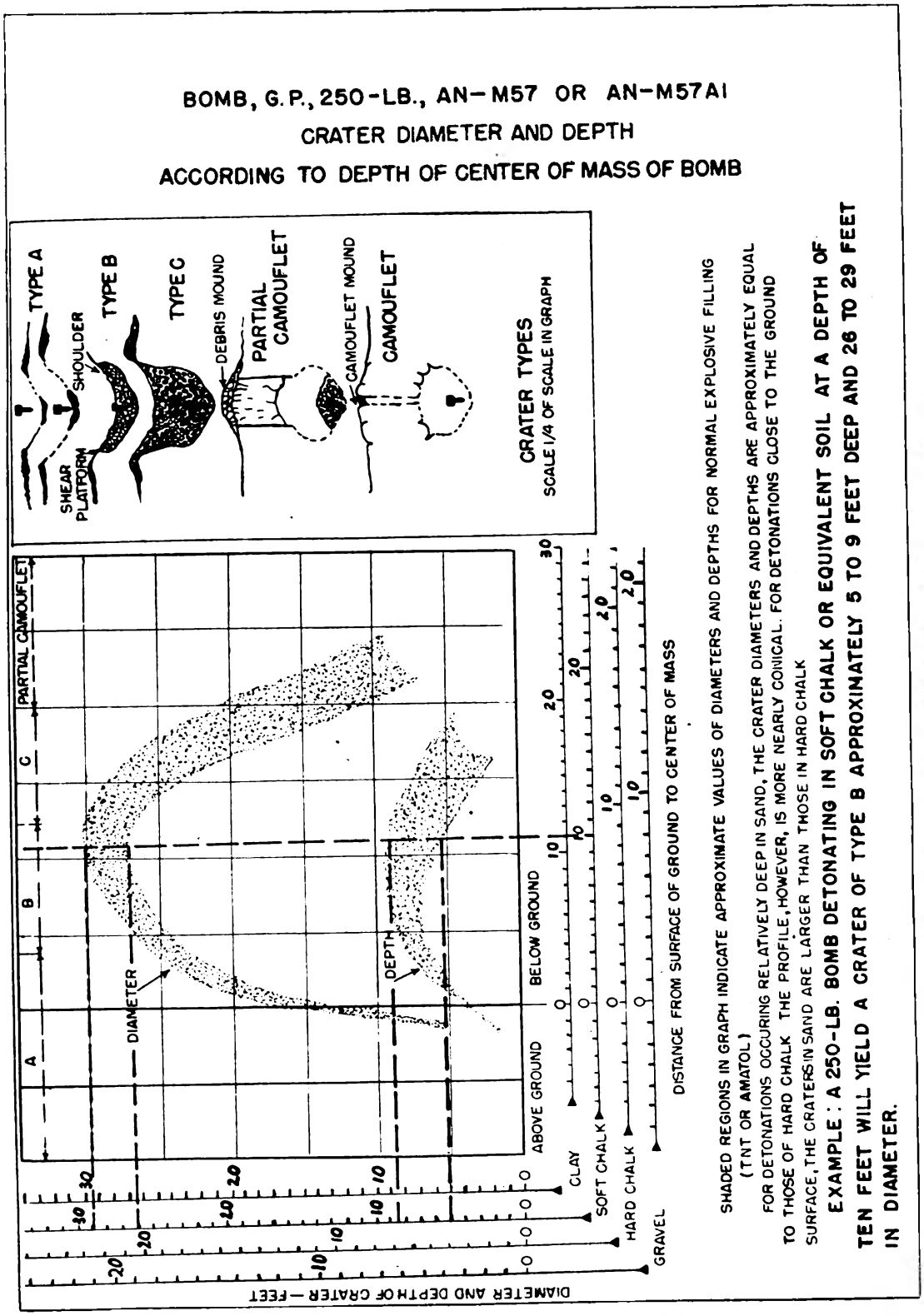

Figure 49. Bomb, GP, 250-lb., AN-M57 or AN-M57A1, Etc.

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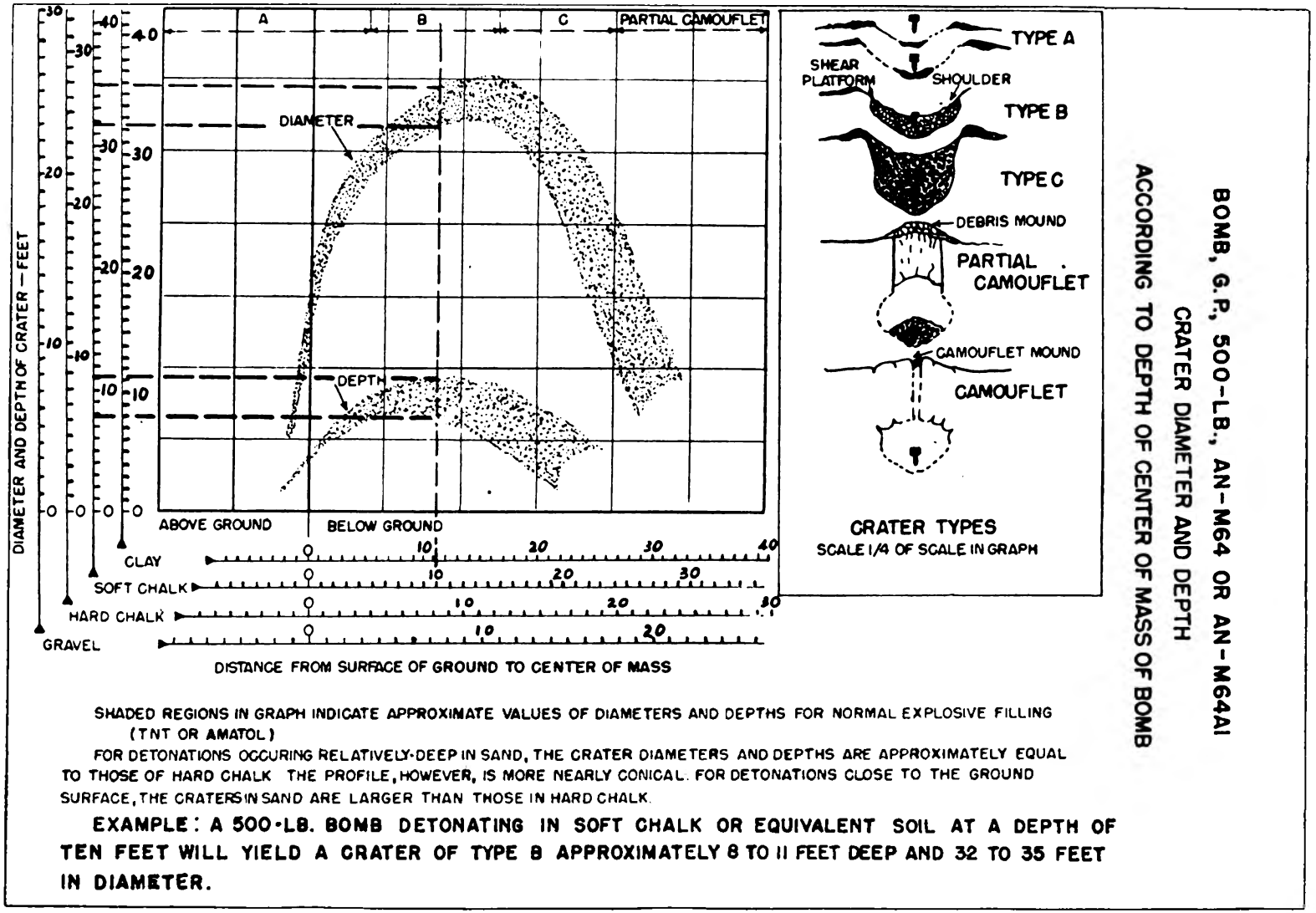

SHADED REGIONS IN GRAPH INDICATE APPROXIMATE VALUES OF DIAMETERS AND DEPTHS FOR NORMAL EXPLOSIVE FILLING (TNT OR AMATOL)

FOR DETONATIONS OCCURING RELATIVELY-DEEP IN SAND, THE CRATER DIAMETERS AND DEPTHS ARE APPROXIMATELY EQUAL TO THOSE OF HARD CHALK THE PROFILE, HOWEVER, IS MORE NEARLY CONICAL. FOR DETONATIONS CLOSE TO THE GROUND SURFACE, THE CRATERS IN SAND ARE LARGER THAN THOSE IN HARD CHALK.

EXAMPLE: A 500-LB. BOMB DETONATING IN SOFT CHALK OR EQUIVALENT SOIL AT A DEPTH OF TEN FEET WILL YIELD A CRATER OF TYPE B APPROXIMATELY 8 TO 11 FEET DEEP AND 32 TO 35 FEET IN DIAMETER.

Figure 50. Bomb, GP, 500-lb., AN-M64 or AN-M64A1, Etc.

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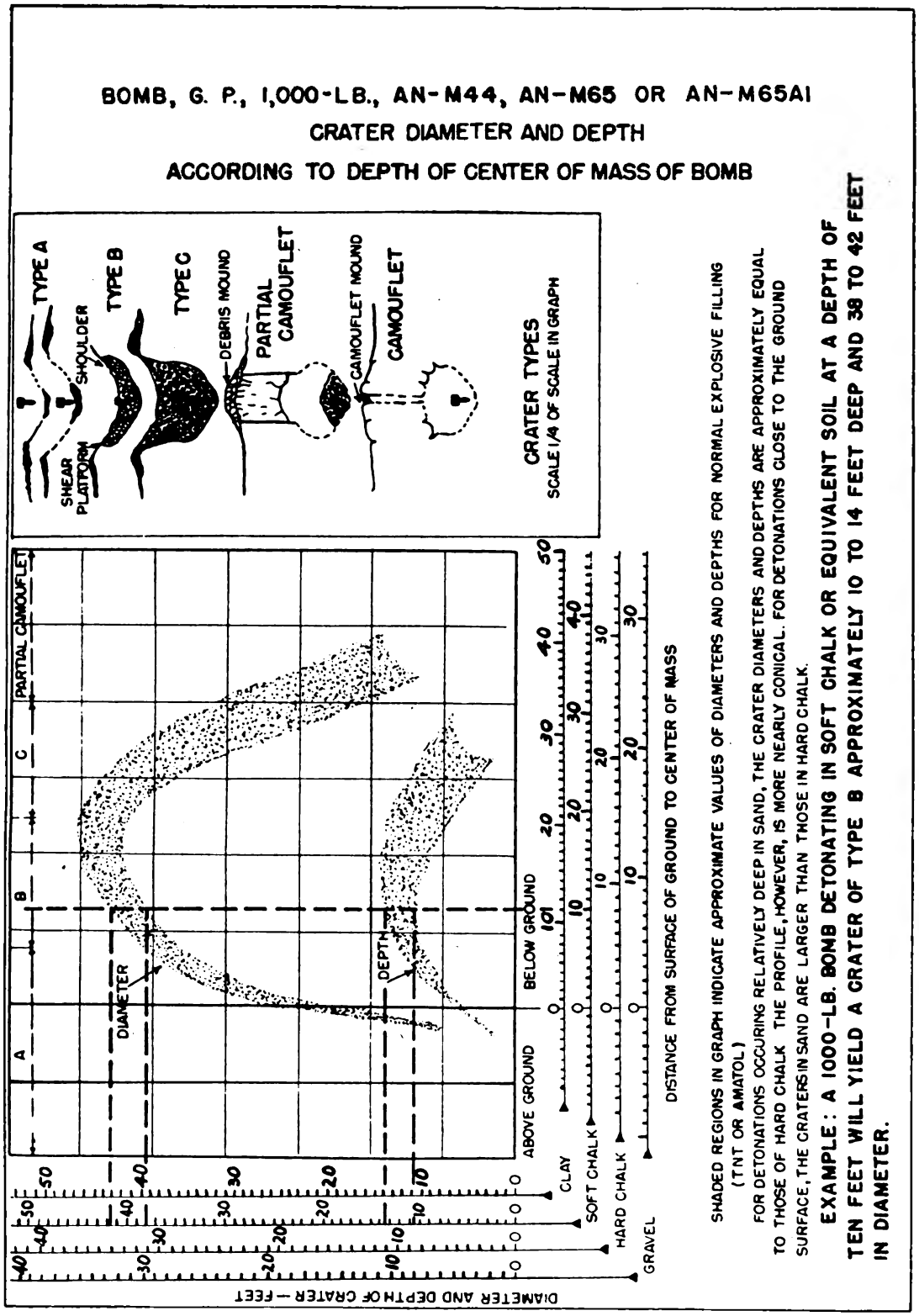

Figure 51. Bomb, GP, 1000-lb., AN-M44, or AN-M65A1, Etc.

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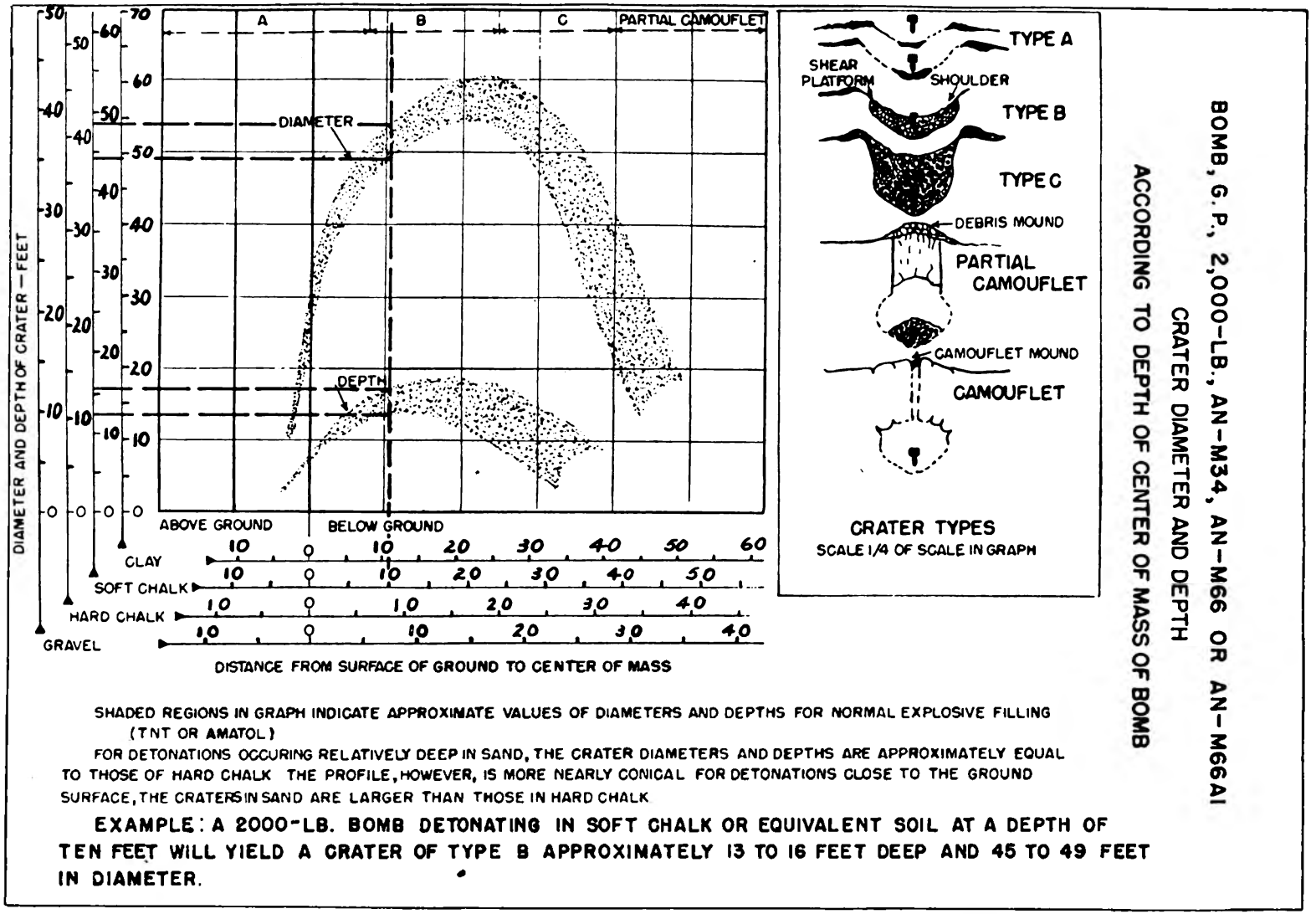

SHADED REGIONS IN GRAPH INDICATE APPROXIMATE VALUES OF DIAMETERS AND DEPTHS FOR NORMAL EXPLOSIVE FILLING (TNT OR AMATOL)

FOR DETONATIONS OCCURING RELATIVELY DEEP IN SAND, THE CRATER DIAMETERS AND DEPTHS ARE APPROXIMATELY EQUAL TO THOSE OF HARD CHALK THE PROFILE, HOWEVER, IS MORE NEARLY CONICAL FOR DETONATIONS CLOSE TO THE GROUND SURFACE, THE CRATERS IN SAND ARE LARGER THAN THOSE IN HARD CHALK

EXAMPLE: A 2000-LB. BOMB DETONATING IN SOFT CHALK OR EQUIVALENT SOIL AT A DEPTH OF TEN FEET WILL YIELD A CRATER OF TYPE B APPROXIMATELY 13 TO 16 FEET DEEP AND 45 TO 49 FEET IN DIAMETER.

Figure 52. Bomb, GP, 2000-lb., AN-M34, AN-M66, or AN-M66A1, Etc.

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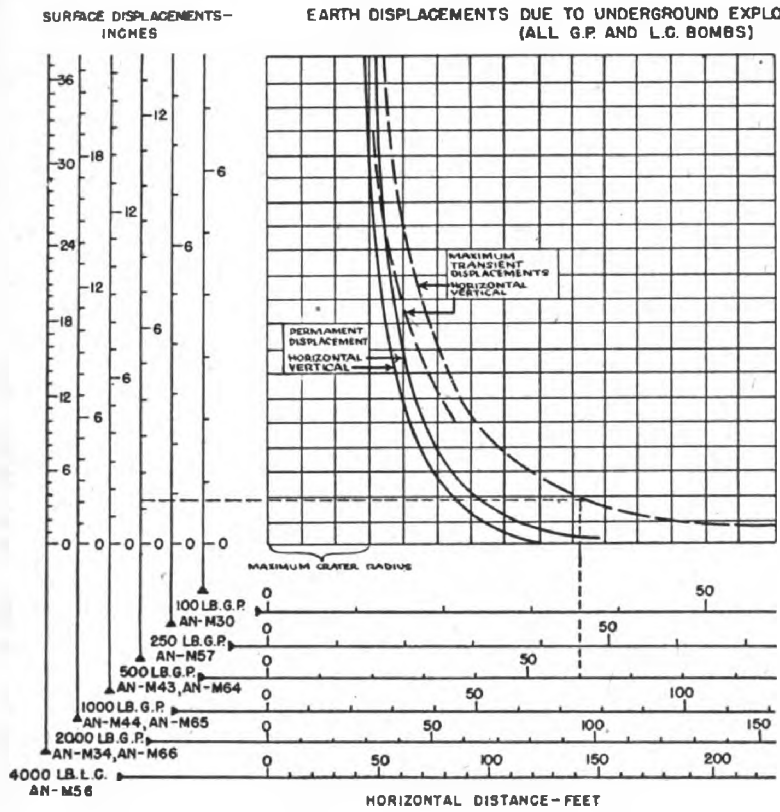

The curves show horizontal and vertical displacements of the surface of the ground measured at various distances from the exploding charge.

Soil effect: Values given are from observations on clay and clay-gravel mixture. Displacements in chalk, not shown on this plot, were found to fall below those in clay.

Type of explosive: The curves are based on experiments using the following types of explosives TNT, 40/60 amatol, baratol, dithalite, minol, black powder and dynamite, with charge weights ranging from 25 to 990 pounds. On the other hand, displacements in clay obtained with torpex and hexanite are greater than for equal weights of any of the above explosives.

Absence of depth effect: The data indicate that for the range of depths tested, the displacements obtained are independent of the depth of burial L provided only that the bomb or charge is completely buried. Depths in these experiments varied from 7 to 22 feet, and the corresponding values of $L/W^{1/3}$ were between 1.1 and 3.6 ft./lb.$^{1/3}$

Accuracy of graph: The curves predict displacements over the entire range with an average deviation of 15%.

EXAMPLE: The maximum horizontal transient displacement at 60 ft. from the point of burst of a 500 lb. G.P. Bomb is 1.3 inches.

Figure 53. Earth Displacements Due to Underground Explosive in Clay Soil (All GP and LC Bombs).

DEFORMATION AND RUPTURE ALTITUDE FOR BOMBS FALLING ON VERY THICK CONCRETE

Bomb	Bombs will begin to deform at altitudes in feet of about		Bombs will rupture at altitudes in feet of about	
	3,400 p.s.i. concrete	5,000 p.s.i. concrete	3,400 p.s.i. concrete	5,000 p.s.i. concrete
G.P. 100-lb., AN-M30 or AN-M30A1	1,500	all	7,000	3,000
250-lb., AN-M57 or AN-M57A1	4,000	800	16,000	7,000
500-lb., AN-M64 or AN-M64A1	3,500	800	14,000	7,000
1,000-lb., AN-M65 or AN-M65A1	3,500	800	14,000	7,000
2,000-lb., AN-M66 or AN-M66A1	5,000	1,500	20,000	10,000
S.A.P. 500-lb., AN-M58, AN-M58A1, or AN-M58A2	15,000	5,000	No rupture	
1,000-lb., AN-M59 or AN-M59A1	23,000	8,000	No rupture	
A.P. (all)	No deformation or rupture			

Chart 10. Deformation and Rupture Altitude for Bombs Falling on Very Thick Concrete.

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APPROXIMATE MAXIMUM THICKNESSES OF CONCRETE PERFORATED BY S.A.P. & A.P. BOMBS

Altitude of plane (ft.) (assumed true air speed, 250 m.p.h.)			5,000	10,000	20,000	30,000
Number of bombs required to hit a 10-yd. x 10-yd. target with probability of[1]		50%	25–250	100–1,000	400–4,000	1,000–10,000
		90%	80–800	350–3,500	1,300–13,000	3,500–35,000
Striking velocity (f/s)	500-lb. S.A.P., AN-M58, AN-M58A1 or AN-M58A2		620	800	1,000	1,080
	1,000-lb. S.A.P., AN-M59 or AN-M59A1		635	820	1,030	1,120
	1,000-lb. A.P., M52A1		640	825	1,050	1,150
	1,600-lb. A.P., AN-Mk.1		660	840	1,080	1,210
Approximate thickness of concrete perforated	Strength of concrete 3,400 p.s.i.	500-lb. S.A.P.	2¼ ft.	3⅓	4¼	4½
		1,000-lb. S.A.P.	3 ft.	4½	6⅓	7
		1,000-lb. A.P.	3¼ ft.	5	7½	8½
		1,600-lb. A.P.	4¼ ft.	6¾	9½	11½
	5,000 p.s.i.	500-lb. S.A.P.	2 ft.	3	3½	3¾
		1,000-lb. S.A.P.	2¾ ft.	4	5	5½
		1,000-lb. A.P.	3 ft.	4½	6¼	7
		1,600-lb. A.P.	4 ft.	5⅔	8	9½

[1]The smaller numbers are based on good accuracy (15 mil); under operational conditions the larger numbers may be more realistic.

Chart 11. Approximate Maximum Thickness of Concrete Perforated by SAP and AP Bombs.

PROBABLE MAXIMUM THICKNESS OF CONCRETE PERFORATED (FT.) BY G.P. BOMBS FROM ALTITUDES ABOVE 5,000 FT.

Strength of Concrete	AN-M30 or AN-M30A1 100-lb.	AN-M57 or AN-M57A1 250-lb.	AN-M64 or AN-M64A1 500-lb.	AN-M65 or AN-M65A1 1,000-lb.	AN-M66 or AN-M66A1 2,000-lb.
3,400 p.s.i. concrete	1	1½	1½	2	4
5,000 p.s.i. concrete	¾	1	1	1½	3

S.A.P. and A.P. bombs which penetrate but fail to perforate a concrete target will remove various volumes of concrete. Table 4 shows the optimum fuze settings, for the different bombs, to remove the greatest volumes.

Chart 12. Probable Maximum Thickness of Concrete Perforated (ft.) by GP Bombs from Altitudes Above 5,000 Feet.

APPROXIMATE VOLUMES[1] OF CONCRETE (5,000 P.S.I.) REMOVED FROM THICK CONCRETE BY BOMBS WHICH PENETRATE BUT FAIL TO PERFORATE

Fuze Setting	500-lb. S.A.P.	1,000-lb. S.A.P.	1,000-lb. A.P.	1,600-lb. A.P.
0.1-sec. delay	10 cu. ft.	30 cu. ft.	100 cu. ft.	350 cu. ft.
0.025-sec. delay	10–30	30–100	150[2]	400[2]
0.01-sec. delay	30[2]	100[2]	100	150
Instantaneous	Several Sq. Ft. 2 to 3" deep, spalled off face			

[1]The shape and depth of the craters vary with the altitude of release but the volume of concrete tends to remain constant.
[2]These volumes correspond to the approximate times at which bomb will detonate at bottom of crater; if fuzed with longer delay, the bomb will rebound prior to detonation.

Chart 13. Approximate Volumes of Concrete (5,000 P.S.I.) Removed from Thick Concrete by Bombs Which Penetrate but Fail to Perforate.

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sufficiently to permit high order detonation within approximately 1 foot of the concrete, the confinement of the dirt greatly increases the blast effect. When this condition occurs a 2,000-lb. GP bomb will probably destroy a wall 7 ft. thick, and a 1,000 lb. GP bomb will seriously damage or destroy a wall 5 ft. thick. A 1,000 S.A.P. bomb will considerably damage a 5-ft wall. This type of bombing requires great precision because the bomb must (1) detonate near enough to a wall of a pillbox, (2) detonate under a sufficient layer of dirt, and (3) except in the case of the stronger S.A.P. bomb, it must have sufficiently low striking velocity to prevent it from breaking up on impact with the concrete wall. Therefore, this method of attack is used to best advantage only when low altitude bombing is employed.

Bombing from Horizontal Flight at Minimum Altitude. Bombs will probably ricochet if they hit flat ground after being dropped from an airplane flying horizontally at low altitude.

(1) A 2,000-lb. GP bomb, necessarily fuzed long-delay, will penetrate almost horizontally up to about 10 ft. if it hits rising ground that has an agle of 25 or more degrees. If it comes to rest close to concrete, or even if it strikes the concrete near the end of its natural path, it will probably detonate after the fuze delay time. Under these conditions the explosive force of the bomb is sufficient to destroy a pillbox up to 7 ft. thick. It it strikes concrete after little penetration into dirt, or after none, the bomb may break up and do no damage.

(2) A 1,000-lb. GP bomb would behave in the same way except for slightly less penetration of dirt and less drastic effect.

(3) A 1,000-lb. S.A.P. bomb would behave similarly, except that it would not break up even upon a direct hit on concrete and that its effect is much less. However, there is no great advantage in a direct hit on concrete (or a hit after slight penetration in earth) from low altitudes, because the striking velocity is low and little demolition will occur in the absence of good confinement.

(4) In conclusion, bombing from horizontal flight at minimum altitude is advantageous only if there is a probability of a bomb striking a sloping cushion of earth over 5 ft. thick in front of the concrete. In this event the 2,000-lb. GP bomb is best, with the 1,000-lb. GP bomb second best.

Bombing From a Glide to Avoid Ricochet. An angle of fall above 25° should prevent ricochet, but for angles below 40° the bomb will tend to remain fairly close to the ground surface instead of penetrating deeply. Short-delay fuzing would be reasonably safe, as ricochet is unlikely, but a delay of less than 0.025 second might result in premature detonation. Since the likelihood of ricochet at various angles is largely dependent upon the nature of the terrain, proper precautions should be observed when ground conformation or composition increases the chance of ricochet.

An angle of fall above 25° is obtained by bombing from a plane at 350 miles per hour or less under the following conditions:

No glide: altitude greater than 1,000 ft.
10° glide: altitude greater than 850 ft.
20° glide: altitude greater than 350 ft.

Bombing under conditions that tend to prevent ricochet makes it possible for a bomb to approach a concrete wall (or a concrete roof) through a comparatively long shallow, underground cushioned path To obtain these advantages the bomb would almost necessarily have to hit 3 to 4 yards in front of the pill box. The 2,000-lb. GP bomb remains the best selection, the 1,000-lb. GP bomb next best.

Bombing From a Glide to Avoid Ricochet and Insure Deep Penetration in the Ground. When the angle of fall is greater than about 40°, the bomb, provided it is not deflected, will probably follow a straight path (at least in the first half of its penetration). This is particularly desirable when a pillbox is deeply encased.

An angle of fall above 40° is obtained by bombing from a plane at 350 m.p.h. or less under the following conditions:

No glide: altitude greater than 2,900 ft.
10° glide: altitude greater than 2,700 ft.
20° glide: altitude greater than 2,100 ft.
30° glide: altitude greater than 1,150 ft.

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The 2,000-lb. GP bomb remains the best selection, the 1,000-lb. GP bomb next best.

Attack of Lighter Pillboxes. Large GP bombs, fuzed 0.025 sec. delay seem to be definitely advantageous against pillboxes encased in dirt when the concrete thickness is 2 ft. or less, since the bombs would probably be effective both by direct hit or by near miss provided they did not ricochet.

Bomb Fragment Damage. Charts 14, 15, and 16 give the number 'B' of effective hits per square foot of target area at a given distance, r, from the burst. They are properly applied only to a considerable number of bursts with random orientation of the bomb axis relative to the target.

LOW ALTITUDE BOMBING

The choice of fragmentation bombs for *low altitude bombing* may be made with the aid of the following table giving the ratio of the number of effective hits for the two sets of bombs listed at the left. The number of bombs compared in each case are those which can be carried in the same station in the bomb bay.

Bombs Compared	Casualties	⅛-in. Perf.	¼-in. Perf.	½-in. Perf.
Six 20-lb. bombs* / One 100-lb. bomb	2.10	2.40	0.94	
Six 20-lb. bombs* / One 260-lb. bomb	1.15	0.95	0.52	
One 100-lb. bomb / One 260-lb. bomb	0.55	0.40	0.55	
Twenty 20-lb. bombs* / Six 90-lb. bombs	1.08	1.11	0.69	
Twenty 20-lb. bombs* / One 500-lb. bomb	2.49	2.75	1.12	
Six 90-lb. bombs / One 500-lb. bomb	2.31	2.48	1.62	0.28
Two 100-lb. bombs / One 500-lb. bomb	0.71	0.69	0.71	
Two 260-lb. bombs / One 500-lb. bomb	1.30	1.74	1.30	0.86

20-lb. AN-M41, TNT Loading.
90-lb. T9 (M82), Comp. B Loading.
100-lb. AN-M30, Amatol Loading.
260-lb. AN-M81 (T10), Comp. B Loading.
500-lb. AN-M64, Amatol Loading.

A fragment with at least 58 ft.-lb. of energy is considered as "causing" a casualty. Other measures of damage are normal perforations of mild steel at various thicknesses.

The above table applies in the strict sense to attacks on unshielded targets with ground bursts and with relatively low altitudes of release.

*Replacing the 20-lb. fragmentation bomb, AN-M41, by the 23-lb. fragmentation bomb, AN-M40, with parachute increases the value of this fragment bomb released at low altitudes approximately three-fold.

Chart 14. Low Altitude Bombing.

Damage Patterns. As distinguished from damage tables, the damage patterns represent typical individual cases and vary with the remaining velocity of the bomb angle of fall and the height of burst. Both damage tables and damage patterns presuppose a graze or air burst with no shielding of the target. The user of the data given here must make due allowance for target shielding and the penetration of the bomb into the ground before burst. The amount of this penetration will depend upon the remaining velocity of the bomb, its angle of fall, the nature of the soil, and the bomb and fuze. In the fragment damage patterns, shadings of different types indicate regions of decreasing density of hits. The regions distinguished are those where there is at least one hit per 1, 4, 10 or 25 sq. ft. of area. These units of area are understood as normal to the fragment trajectories. Unshaded regions entering near the burst do not indicate that there are no effective hits in these regions, but merely that the density of effective hits is less than that belonging to the nearest shaded area.

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The white centers of the fragment patterns are used to indicate the origin of the polar system above which the missile bursts. In general these areas suffer the highest type of fragment damage as well as blast damage.

Types of Damage. The types of damage considered are casualties and normal perforations of mild steel of ⅛-in., ¼-in., and ½-in. thickness. A casualty is assumed to be caused by a hit with at least 58 ft.-lb. of energy. It is incapacitation and not necessarily death. Damage comprising perforation of ⅛-in. mild steel is considered effective against airplanes on the ground. Damage in which there is perforation of ¼-in. or ½-in. mild steel is effective against trucks, light armored vehicles, railway rolling stock, and targets of a similarly resistant nature.

ALTITUDE OF BOMB RELEASE, 10,000 FT.

The choice of fragmentation bombs may be made with the aid of the following table giving the ratio of the number of effective hits for the two sets of bombs listed at the left. The number of bombs compared in each case are those which can be carried in the same station in the bomb bay.

Bombs Compared	Casualties	⅛-in. Perf.	¼-in. Perf.	½-in. Perf.
Six 20-lb. bombs / One 100-lb. bomb	2.18	2.46		
Six 20-lb. bombs / One 260-lb. bomb	1.06	0.87		
One 100-lb. bomb / One 260-lb. bomb	0.49	0.35	0.49	
Twenty 20-lb. bombs / Six 90-lb. bombs	0.88	0.90		
Twenty 20-lb. bombs / One 500-lb. bomb	2.62	2.88		
Six 90-lb. bombs / One 500-lb. bomb	2.98	3.21	2.05	
Two 100-lb. bombs / One 500-lb. bomb	0.72	0.70	0.73	
Two 260-lb. bombs / One 500-lb. bomb	1.48	1.98	1.49	1.03

20-lb. AN-M41, TNT Loading.
90-lb. T9 (M82), Comp. B Loading.
100-lb. AN-M30, Amatol Loading.
260-lb. AN-M81 (T10), Comp. B Loading.
500-lb. AN-M64, Amatol Loading.

A fragment with at least 58 ft.-lb. of energy is considered as "causing" a casualty. Other measures of damage are normal perforations of mild steel at various thicknesses.

The above table applies in the strict sense to attacks on unshielded targets with ground bursts.

Chart 15. Altitude of Bomb Release, 10,000 Feet.

The Choice of Bombs. Charts 14, 15, and 16 will be found useful in making a choice of bombs against unshielded targets according to the type of fragment damage desired. At low or medium altitudes not exceeding 10,000 ft., the 20-lb. Fragmentation Bomb, AN-M41, is to be preferred against personnel or when only light damage is needed. As noted in Table 5, the parachute on the 23-lb Fragmentation Bomb, AN-M40, improves the effect of the nonparachute Bomb, AN-M41, about 300 per cent for low altitude bombing. When released from 20,000 ft., the 20-lb. Fragmentation Bomb, AN-M41, is reduced to less than one-half the power it possesses in low altitude bombing.

For 10,000- and 20,000-ft. altitudes of release, the bombs listed other than the 20-lb. Fragmentation Bomb, AN-M41, are somewhat improved because of the downward change in fragment direction caused by the remaining velocity and the higher angle of fall. The bombs should be used in accordance with the type damage required, consulting Tables 15 and 16. The 90-lb. Fragmentation Bomb, T9(M82), may be used in clusters of six and when so used will be particularly effective, if the required damage is at most equivalent to perforation

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of ¼-in. mild steel. For heavier damage, the 260-lb. Fragmentation Bomb, AN-M81, or the 500-lb. GP Bomb, AN-M64 may be used.

Air Bursts. Against personnel in medium foxholes or on rough terrain, or against other moderately shielded targets, an air burst of the 500-lb. GP Bomb, AN-M64, or the 260-lb. Fragmentation Bomb, AN-M81, is recommended. A height of burst from 20 to 50 ft. would be effective, with the higher burst counteracting the greater shielding of the targets. Released from an altitude of 10,000 ft. or more, the 20-lb. Fragmentation Bomb, AN-M41, is considerably diminished in

ALTITUDE OF BOMB RELEASE, 20,000 FT.

The choice of fragmentation bombs may be made with the aid of the following table giving the ratio of the number of effective hits for the two sets of bombs listed at the left. The number of bombs compared in each case are those which can be carried in the same station in the bomb bay.

Bombs Compared	Casualties	⅛-in. Perf.	¼-in. Perf.	½-in. Perf.
Six 20-lb. bombs / One 100-lb. bomb	0.85	0.99		
Six 20-lb. bombs / One 260-lb. bomb	0.34	0.29		
One 100-lb. bomb / One 260-lb. bomb	0.41	0.30	0.41	
Twenty 20-lb. bombs / Six 90-lb. bombs	0.45	0.48		
Twenty 20-lb. bombs / One 500-lb. bomb	1.08	1.24		
Six 90-lb. bombs / One 500-lb. bomb	2.42	2.59	1.67	
Two 100-lb. bombs / One 500-lb. bomb	0.77	0.75	0.78	
Two 260-lb. bombs / One 500-lb. bomb	1.89	2.52	1.92	1.39

20-lb. AN-M41, TNT Loading.
90-lb. T9 (M82), Comp. B Loading.
100-lb. AN-M30, Amatol Loading.
260-lb. AN-M81 (T10), Comp. B Loading.
500-lb. AN-M64, Amatol Loading.

A fragment with at least 58 ft.-lb. of energy is considered as "causing" a casualty. Other measures of damage are normal perforations of mild steel at various thicknesses.

The above table applies in the strict sense to attacks on unshielded targets with ground bursts.

Chart 16. Altitude of Bomb Release, 20,000 Feet.

fragment damage not only from the effect illustrated in the fragment damage patterns but also because the bomb penetrates the soil to some extent before bursting. Here again an air burst of the 500-lb. GP Bomb, AN-M64, or the 260-lb. Fragmentation Bomb, AN-M81, will be highly effective.

The altitudes of release given for bombs assume a true air speed of 250 m.p.h.

ALTITUDES OF RELEASE FOR AERIAL BOMBS

Purpose and Scope. The decision as to what the altitude for attack should be under any given set of circumstances is a problem that confronts the bombardment-unit commander constantly. The phrase "depending upon the tactical situation" covers all the variables but that language is of no aid in itself to the decision to be made. It is the purpose of this section to establish definitely the minimum altitude for effective bombing from the standpoint of the following factors: sufficient air travel for the fuzes to arm, absolute safety to plane and crew from the action of their own bombs, and the minimum losses that must be risked on occasions when absolute safety is sacrificed for tactical advantage.

Losses from enemy defensive measures are not considered here. It is assumed that the altitude of attack most desirable from the standpoint of avoiding enemy

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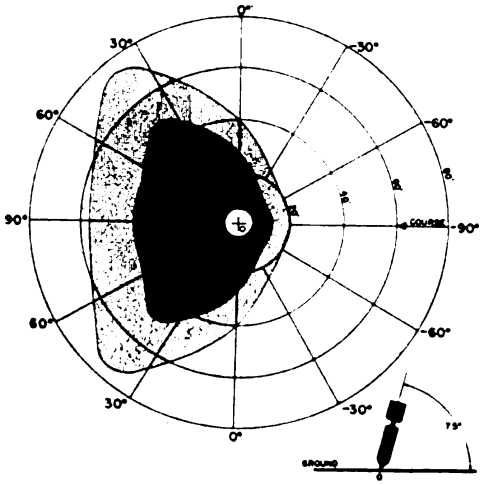
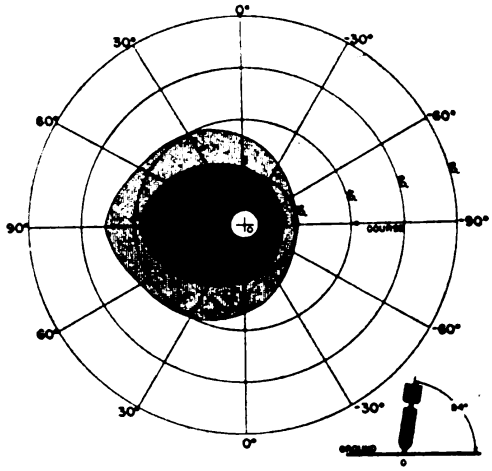
At least 1 hit per 1 sq. ft.
At least 1 hit per 4 sq. ft.
At least 1 hit per 10 sq. ft.
At least 1 hit per 25 sq. ft.

Casualties.

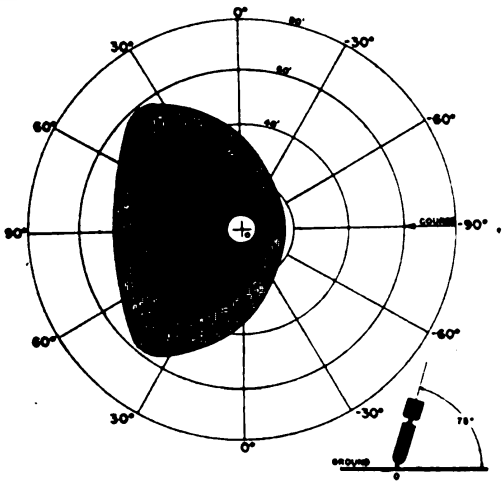


Ground Burst
Remaining Velocity 550 f/s
Altitude of Release 8,500 ft.

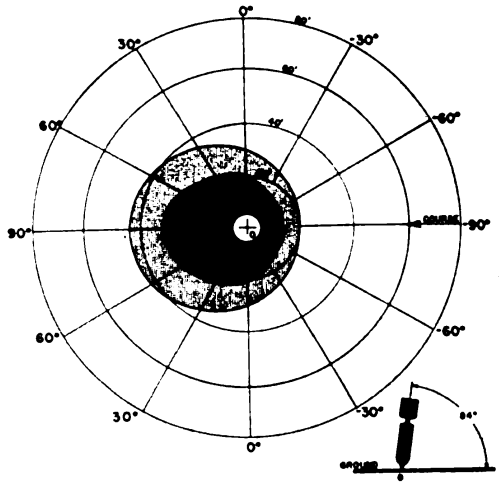


Ground Burst
Remaining Velocity 640 f/s
Altitude of Release 20,000 ft.

Perforation of ⅛-in. Mild Steel.



Ground Burst
Remaining Velocity 550 f/s
Altitude of Release 8,500 ft.



Ground Burst
Remaining Velocity 640 f/s
Altitude of Release 20,000 ft.

Figure 54. 20-lb. Fragmentation Bomb, AN-M41.

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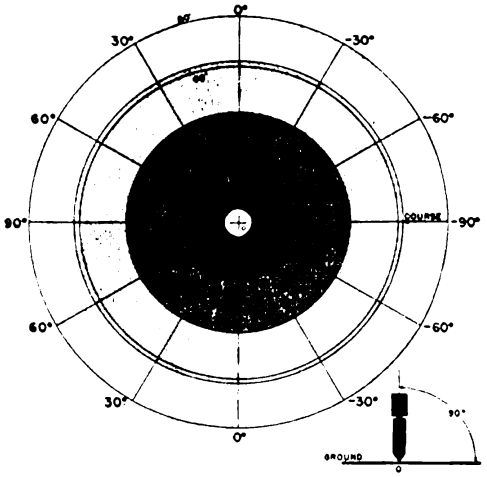
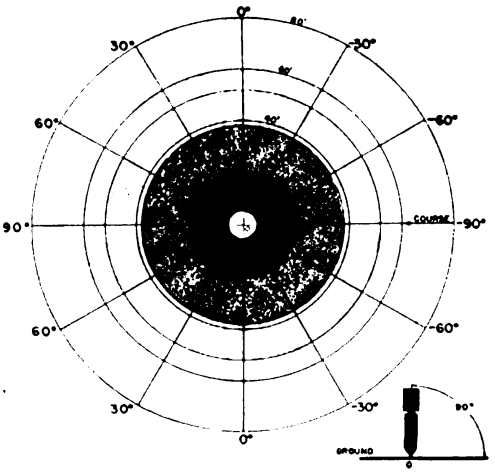
Casualties.



Ground Burst
Bomb Vertical

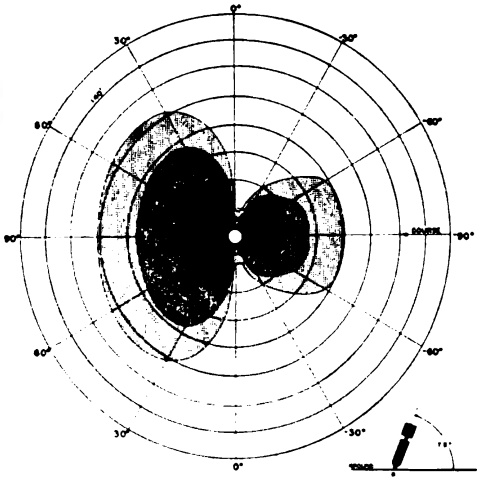
Perforation of ⅛-in. Mild Steel.



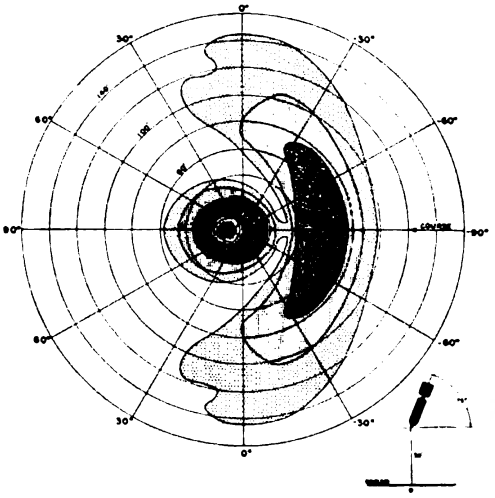
Ground Burst
Bomb Vertical

Figure 55. 23-lb. Fragmentation Bomb, AN-M40.

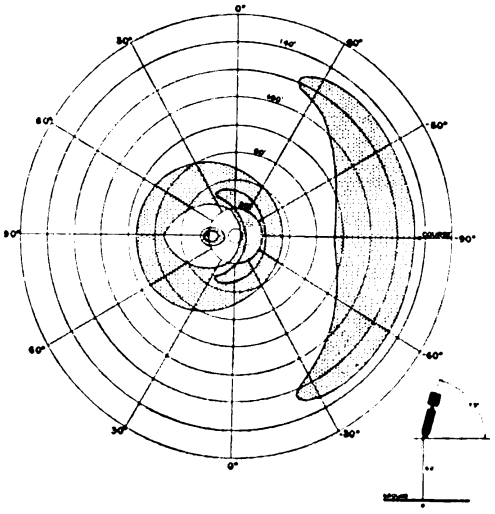
Casualties.



Ground Burst
Remaining Velocity 760 f/s
Altitude of Release 15,000 ft.



Height of Burst 30 ft.
Remaining Velocity 760 f/s
Altitude of Release 15,000 ft.



Height of Burst 60 ft.
Remaining Velocity 760 f/s
Altitude of Release 15,000 ft.

Figure 56. 90-lb. Fragmentation Bomb, M82 (T9). Casualties.

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resistance has been determined beforehand. When an altitude has been selected as best suited to achieve an advantage, such as surprise, the information contained in this report will show whether that altitude is sufficient for the fuzes to function and whether any losses may be expected from the explosion of the bombs. In this way commanders will be able to schedule bombing missions with some degree of certainty as to the proper altitude for the existing circumstances.

Safe Altitude. Safe altitude is the altitude at which fragment dispersion is so thin that the possibility of serious injury to the plane's crew is negligible. This altitude is variable depending on the size and type of bomb, the functioning time of the fuzes, and the nature of the target.

For safety from bomb fragments in dive bombing, the altitude of release must be considerably greater than that required in horizontal bombing. This increase in altitude is required to compensate for the altitude which is lost in the pull-out. For dive bombing, therefore, the altitude must be great enough so that during the pull-out the airplane will not pass below the altitudes given in Chart 17. Information concerning the altitude lost in pull-out is contained in AAF T.O. No. 11-1-19.

Arming the Bomb Fuzes. (Charts 18-30.) The minimum altitude to arm is the vertical difference between the altitude of the plane and the altitude of the bomb at the moment in its flight when the fuze has become completely armed. For a sea-level target it would be the minimum true altitude at which the plane could release the bomb and still allow the fuze sufficient air travel to arm. This altitude may or may not be great enough to preclude damage to the plane from its own bombs. Bombs dropped from lower altitudes, however, will be certain duds. These altitudes depend on the type of fuze used and the characteristics of the air stream around the particular bomb being used.

Air travel required to arm the fuze is the distance the bomb travels through the air, measured along its trajectory, from the point of release from the plane to the point where its fuze is completely armed. Variations will not exceed plus or minus 10% of the value given.

The minimum altitudes and the air travel required to arm bomb fuzes, as given in the Charts 18-30 apply to horizontal flight only. For glides and dives consult AAF T.O. Nos. 11-25-12 and 11-1-19.

Combat Minimum Altitudes of Release. The combat minimum altitude of release is defined as the minimum altitude at which a bomb with a given fuze may be dropped in combat operations. It will be an altitude greater than the minimum altitude required for arming given in Charts 18-30, but will not necessarily be greater than the safe altitudes given in Chart 17. There is no definite line between 'safe' and 'dangerous' when an effort is being made to determine the combat safety distance from an exploding bomb. At altitudes lower than those given in Chart 17, there is a progressive increase of the hazard involved. Whether release of bombs should be made at altitudes wherein danger is involved depends upon the tactical requirement, that is, the purpose of the mission weighed against the cost that may be expected in planes and personnel. Bombing from altitudes within the danger zone can be justified only when great tactical advantage can be gained thereby. Chart XXXI is given as a guide and lists minimum altitudes at which the risk is considered acceptable for normal combat operations. These combat minimum altitudes are computed to give a 1 per cent risk, and are based on proving-ground data of experiments determining fragment characteristics and ricochet characteristics of the various bombs. The altitudes listed are for a single plane against a given target. If additional planes are used, consideration must be given to cover the safety of the planes which follow.

Altitude of 1 per cent risk. A 1 per cent risk is defined as the risk at that altitude of release such that out of a large number of identical missions 1 per cent of the planes will suffer one or more perforations in any vital 25 square feet of horizontal area of the plane. It is generally assumed that for most planes only about 25 square feet of the total area covers portions of such importance (personnel, vital engine parts, controls, etc.) that a perforation will cause significant damage. The perforation is considered to be capable of doing damage only if the fragment were capable of penetrating a 1-inch pine board.

Altitude For Dive Bombing. The altitudes given in Table C are for horizontal

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flight only. Consult AAF Tech Order No. 11-1-19 for information concerning the amount of altitude lost in the pull out of dive bombing operations. Increase the altitudes of release given in Chart 16 by adding the altitude lost in the pull out.

Altitude For Bombs Fuzed With M123, M124, M125, M132, M133, M134 long delay tail fuzes. The combat minimum altitude of release for bombs fuzed with M123, M124, M125, M132, M133, or M134 long delay tail fuzes will be determined by the minimum altitude required to arm these fuzes as given in Chart XVIII through Chart XXXI. The functioning time of these fuzes is ample to allow safe release from any altitude.

CHART XVII
Safe Altitudes of Release (ft.)—Horizontal Bombing

BOMBS	FUZE DELAYS, NOSE OR TAIL FUZING				
Size and Type	Inst. to .1 Sec. (ft.)	4-5 Sec. Water Impact (See Note 1) (ft.)	8-11 or 8-15 Water Impact	8-11 or 8-15 Land Impact	Safe Distance (ft.)
100-lb. GP	1,000	100	No restriction	No restriction	2,000
250-lb. GP	1,500	100	"	"	3,000
300-lb. Demolition					
500-lb. GP or SAP	2,000	150	"	"	3,500
600-lb. Demolition					
1,000-lb. GP	2,500	200	No restriction	No restriction	4,500
1,100-lb. Demolition					
2,000-lb. GP	3,000	200	"	"	5,000
4,000-lb. LC	4,000	----------	----------	----------	6,000
Frag. Bomb	800	----------	----------	----------	2,000
Stabilized 20-lb. Frag. Bomb	100 (See Note 3)	----------	----------	----------	2,000
Parachute, 23-lb.					
M47 Incendiary (Smoke or Chemical)	200	----------	----------	----------	1,000
Practice bomb with spotting charge	50	----------	----------	----------	500
Practice bomb w/o spotting charge	No restriction	----------	----------	----------	----------
Inert loaded bombs, all sizes	No restriction	No restriction	No restriction	No restriction	----------
650-lb. Depth Bomb Incendiary Clusters	750	----------	----------	----------	----------

Note 1—Extensive use of the 4-5 second delay fuze with HE loaded bombs for training purposes is not recommended.

Note 2—Instantaneous fuzing only should be used on the four thousand (4,000) pound LC bomb.

Note 3—Minimum release altitude of the twenty-three (23) pound parachute frag. bomb is determined by fuze arming requirement.

The term "No Restrictions" as used in the table above applies only to restrictions on altitude of release imposed by risk from bomb fragmentation or blast. Altitude restrictions imposed by other considerations, such as target height, fuze arming requirements, and the possibility of damage from ricochets must be determined by the conditions of use.

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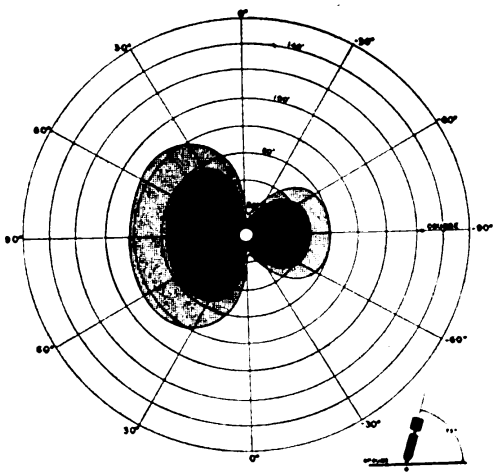
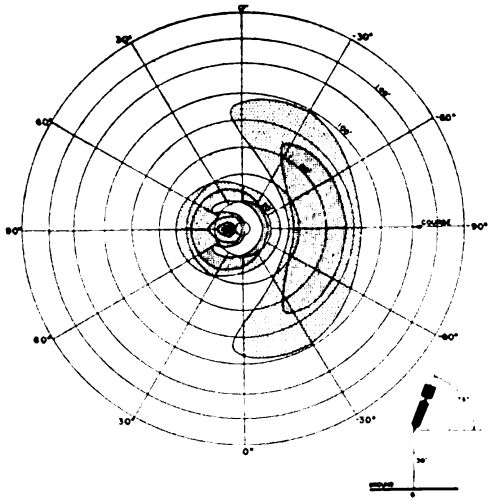
Perforation of ⅛-in. Mild Steel.



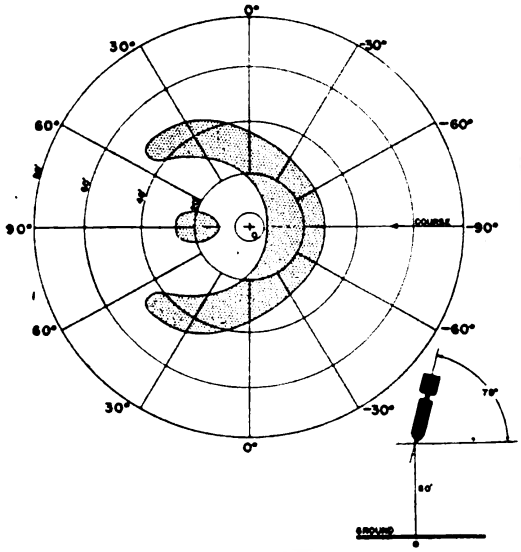
Ground Burst
Remaining Velocity 760 f/s
Altitude of Release 15,000 ft.

Perforation of ⅛-in. Mild Steel.

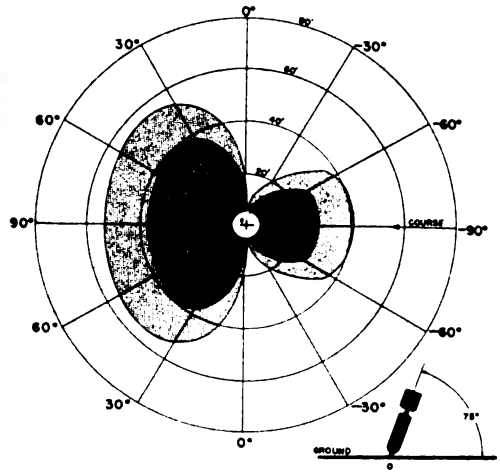


Height of Burst 30 ft.
Remaining Velocity 760 f/s .
Altitude of Release 15,000 ft.

Perforation of ¼-in. Mild Steel.

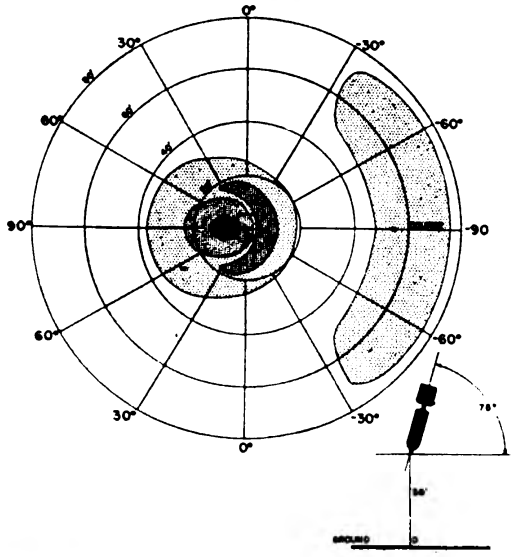


Height of Burst 60 ft.
Remaining Velocity 760 f/s
Altitude of Release 15,000 ft.



Ground Burst
Remaining Velocity 760 f/s
Altitude of Release 15,000 ft.

Perforation of ¼-in. Mild Steel.



Height of Burst 30 ft.
Remaining Velocity 760 f/s
Altitude of Release 15,000 ft.

Figure 57. 90-lb. Fragmentation Bomb, M82 (T9). Perforation of ⅛-inch Mild Steel.

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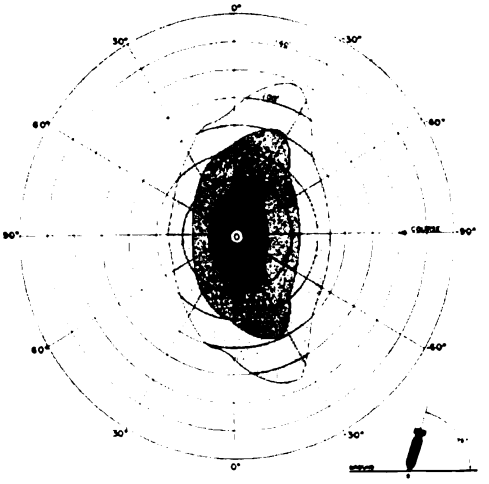
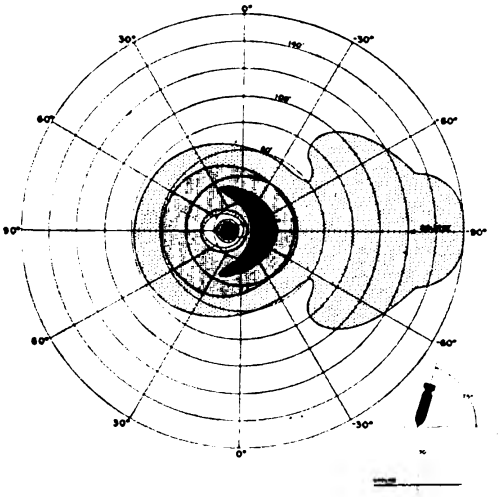
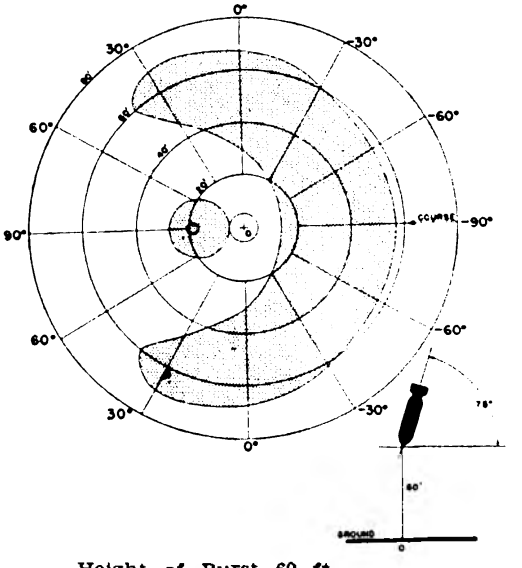
Casualties.



Ground Burst
Remaining Velocity 830 f/s
Altitude of Release 17,000 ft.



Height of Burst 30 ft.
Remaining Velocity 830 f/s
Altitude of Release 17,000 ft.



Height of Burst 60 ft.
Remaining Velocity 830 f/s
Altitude of Release 17,000 ft.

Figure 50. 100-lb. GP Bomb, AN-M30A1 or AN-M30. Casualties.

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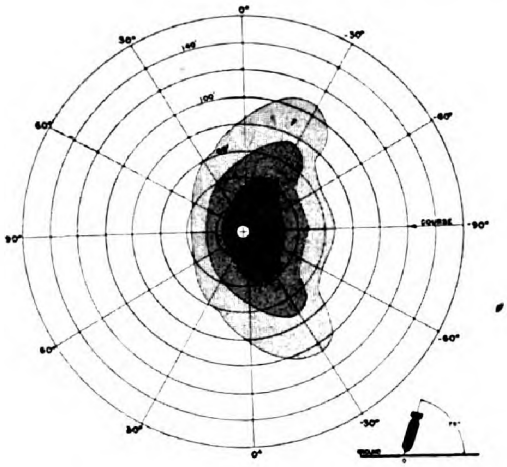
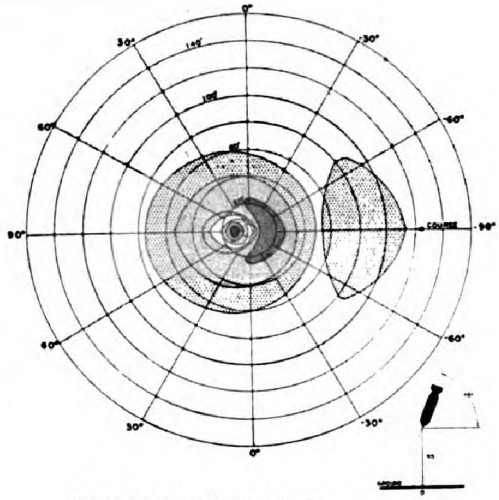
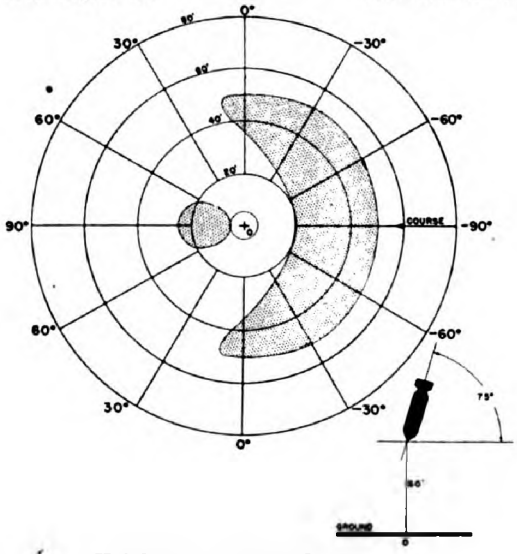
Perforation of ⅛-in. Mild Steel.



Ground Burst
Remaining Velocity 830 f/s
Altitude of Release 17,000 ft.

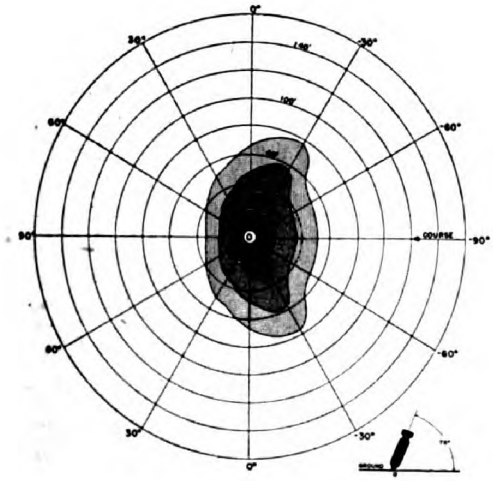


Height of Burst 30 ft.
Remaining Velocity 830 f/s
Altitude of Release 17,000 ft.

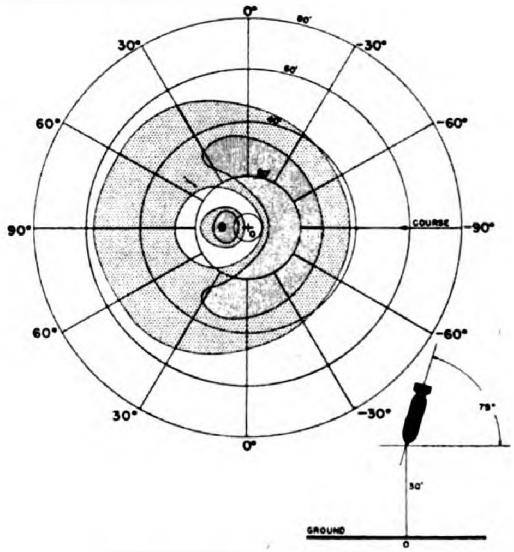


Height of Burst 60 ft.
Remaining Velocity 830 f/s
Altitude of Release 17,000 ft.

Perforation of ¼-in. Mild Steel.



Ground Burst
Remaining Velocity 830 f/s
Altitude of Release 17,000 ft.



Height of Burst 30 ft.
Remaining Velocity 830 f/s
Altitude of Release 17,000 ft.

Figure 59. 100-lb. GP Bomb, AN-M30A1 or AN-M30. Perforation of ⅛-inch Mild Steel.

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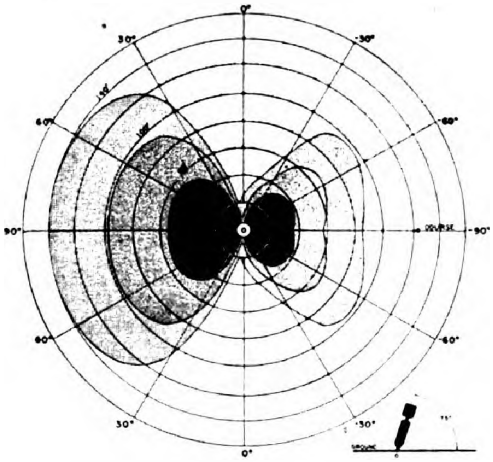
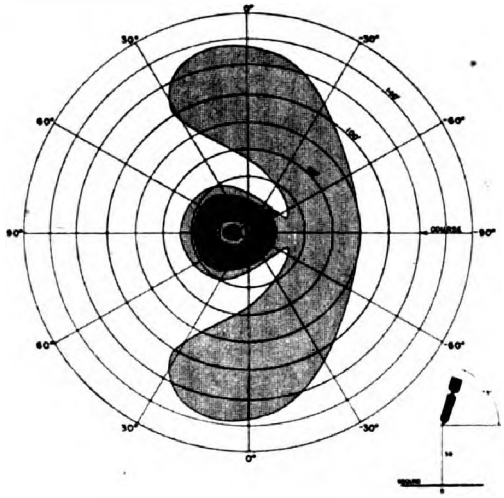
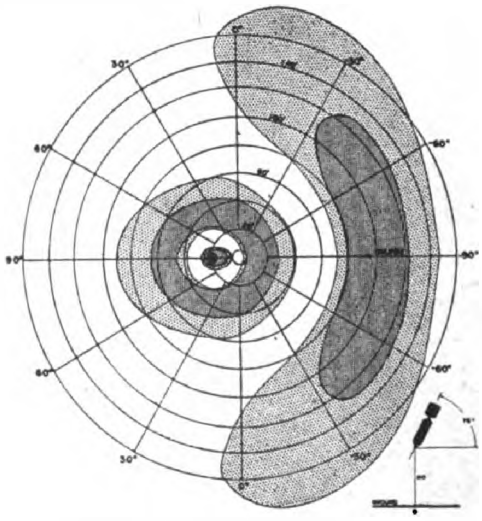
Casualties.



Ground Burst
Remaining Velocity 960 f/s
Altitude of Release 20,000 ft.



Height of Burst 30 ft.
Remaining Velocity 960 f/s
Altitude of Release 20,000 ft.



Height of Burst 60 ft.
Remaining Velocity 960 f/s
Altitude of Release 20,000 ft.

Figure 60. 260-lb. Fragmentation Bomb, AN-M81 (T10). Casualties.

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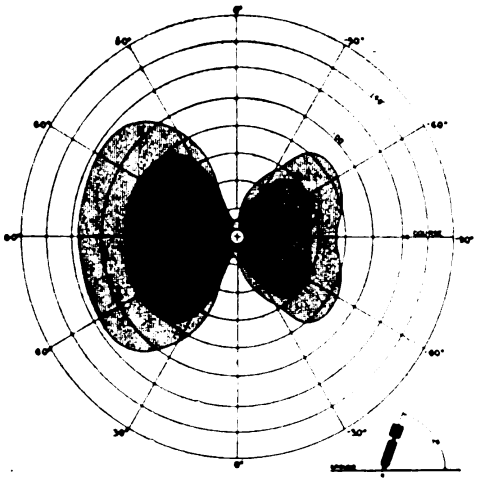
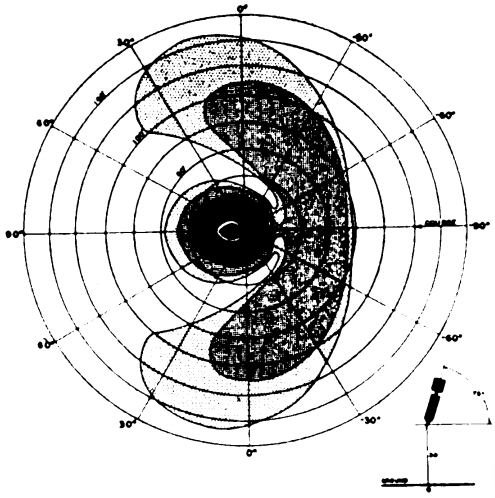
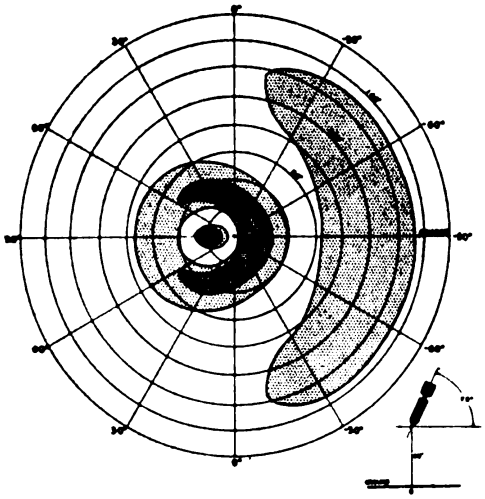
Perforation of ⅛-in. Mild Steel.



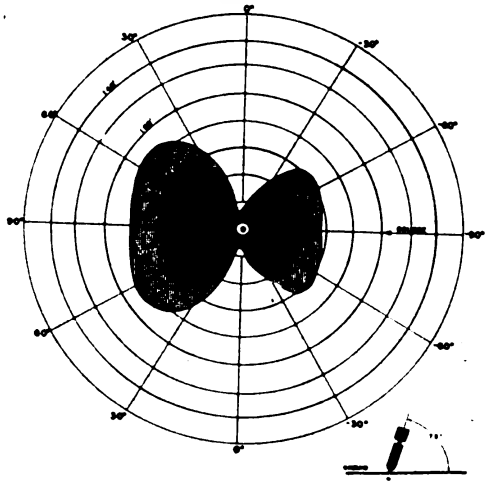
Ground Burst
Remaining Velocity 960 f/s
Altitude of Release 20,000 ft.
Perforation of ⅛-in. Mild Steel.



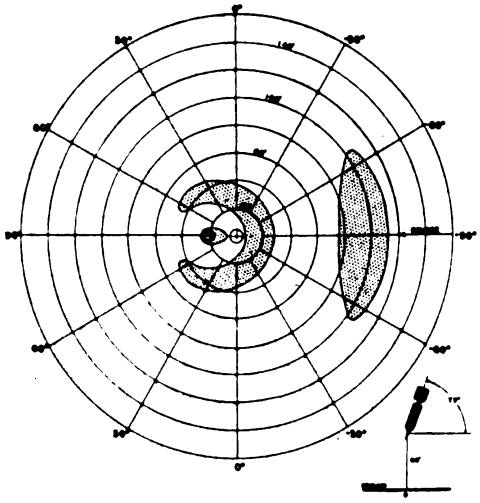
Height of Burst 30 ft.
Remaining Velocity 960 f/s
Altitude of Release 20,000 ft.
Perforation of ¼-in. Mild Steel.



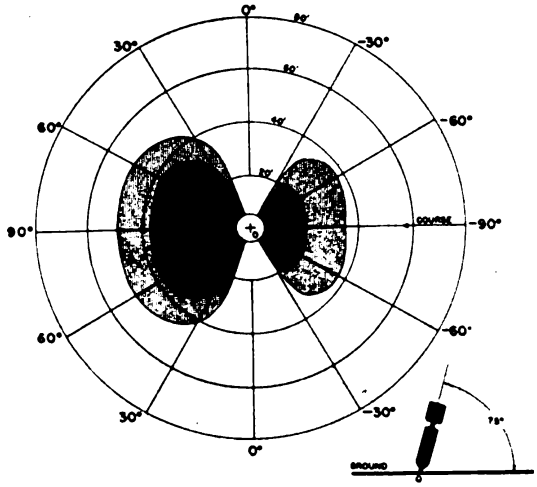
Height of Burst 60 ft.
Remaining Velocity 960 f/s
Altitude of Release 20,000 ft.
Perforation of ¼-in. Mild Steel.



Ground Burst
Remaining Velocity 960 f/s
Altitude of Release 20,000 ft.
Perforation of ½-in. Mild Steel.



Height of Burst 60 ft.
Remaining Velocity 960 f/s
Altitude of Release 20,000 ft.



Ground Burst
Remaining Velocity 960 f/s
Altitude of Release 20,000 ft.

Figure 61. 260-lb. Fragmentation Bomb, AN-M81 (T10). Perforation of ⅛-inch Mild Steel.

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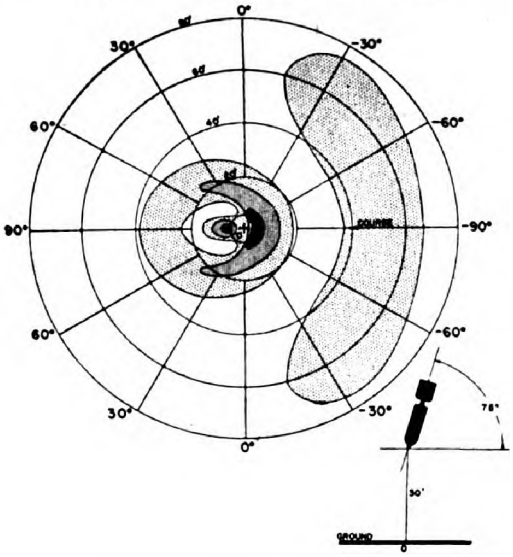
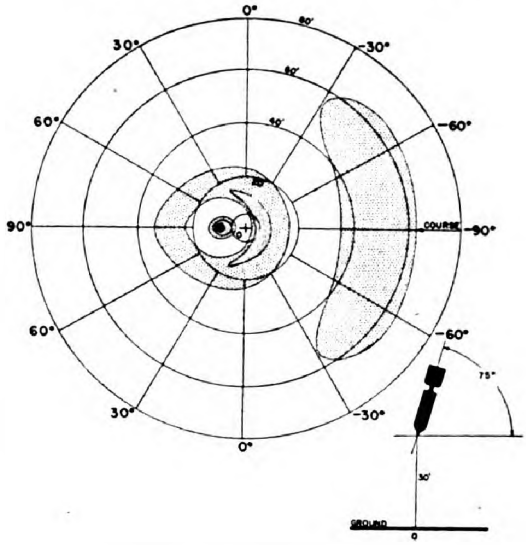
Perforation of ¼-in. Mild Steel.



Height of Burst 30 ft.
Remaining Velocity 960 f/s
Altitude of Release 20,000 ft.

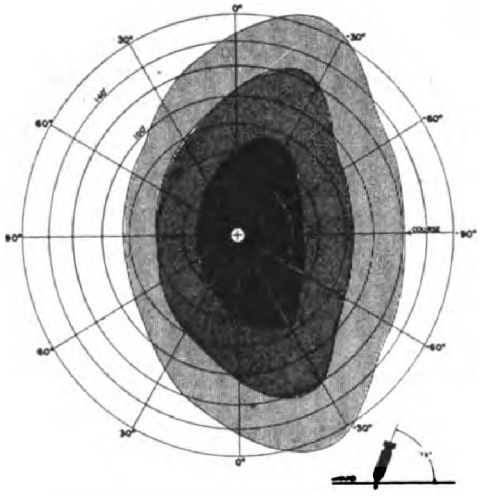
Perforation of ½-in. Mild Steel.



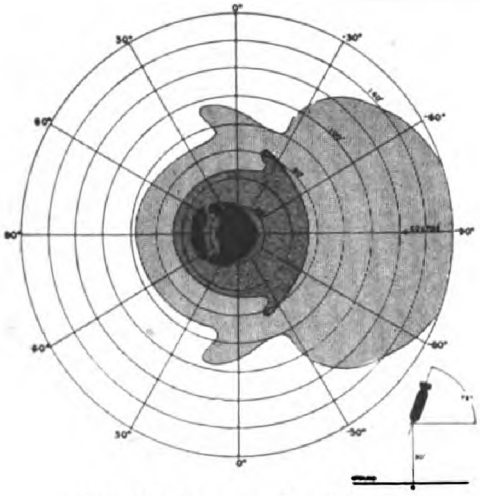
Height of Burst 30 ft.
Remaining Velocity 960 f/s
Altitude of Release 20,000 ft.

Figure 61. 260-lb. Fragmentation Bomb, AN-M81 (T10). Perforation of ½-in. Mild Steel.—(Continued).

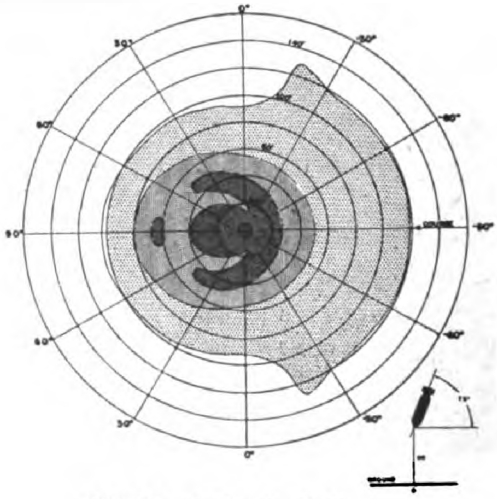
Casualties.



Ground Burst
Remaining Velocity 990 f/s
Altitude of Release 20,000 ft.



Height of Burst 30 ft.
Remaining Velocity 990 f/s
Altitude of Release 20,000 ft.



Height of Burst 60 ft.
Remaining Velocity 960 f/s
Altitude of Release 20,000 ft.

Figure 62. 500-lb. GP Bomb, AN-M64A1 or AN-M64. Casualties.

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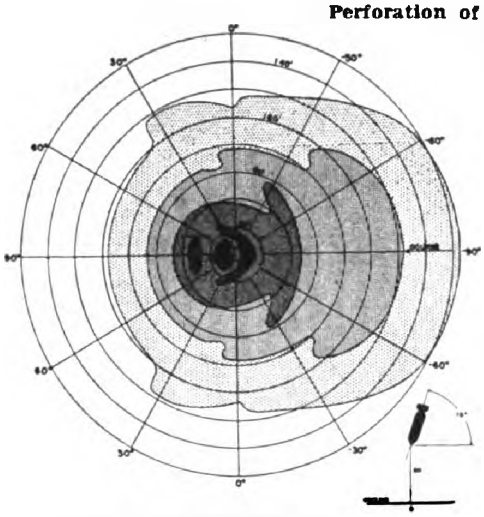
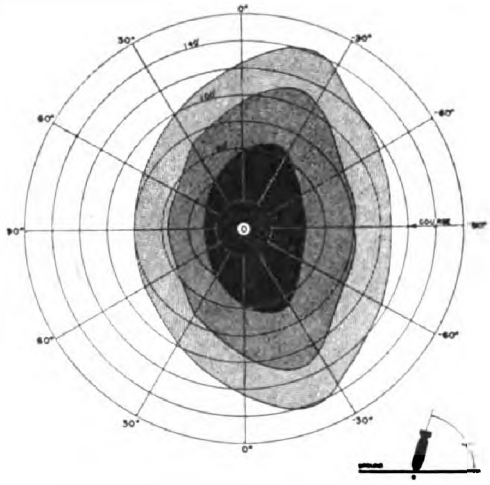
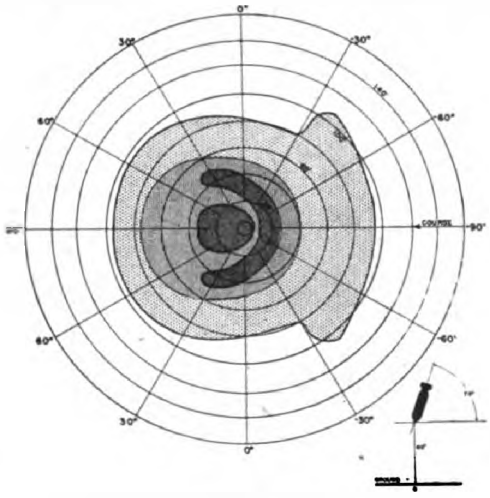
Perforation of ⅛-in. Mild Steel.



Height of Burst 30 ft.
Remaining Velocity 990 f/s
Altitude of Release 20,000 ft.



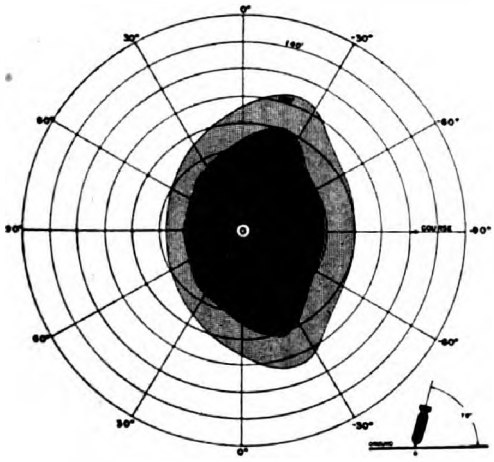
Ground Burst
Remaining Velocity 990 f/s
Altitude of Release 20,000 ft.



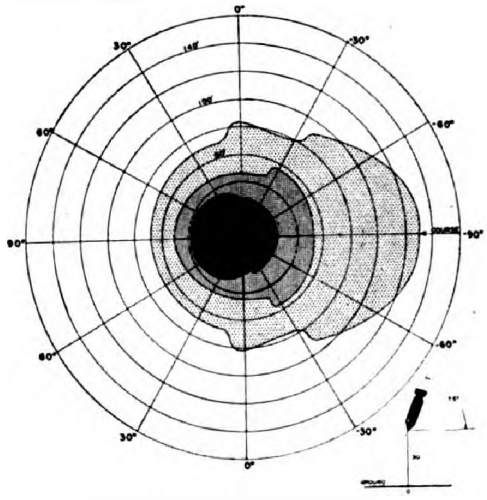
Height of Burst 60 ft.
Remaining Velocity 990 f/s
Altitude of Release 20,000 ft.

Figure 63. 500-lb. GP Bomb, AN-M64A1, or AN-M64. Perforation of ⅛-inch Mild Steel.

Perforation of ¼-in. Mild Steel.



Ground Burst
Remaining Velocity 990 f/s
Altitude of Release 20,000 ft.



Height of Burst 30 ft.
Remaining Velocity 990 f/s
Altitude of Release 20,000 ft.

Figure 64. Perforation of ¼-inch Mild Steel.

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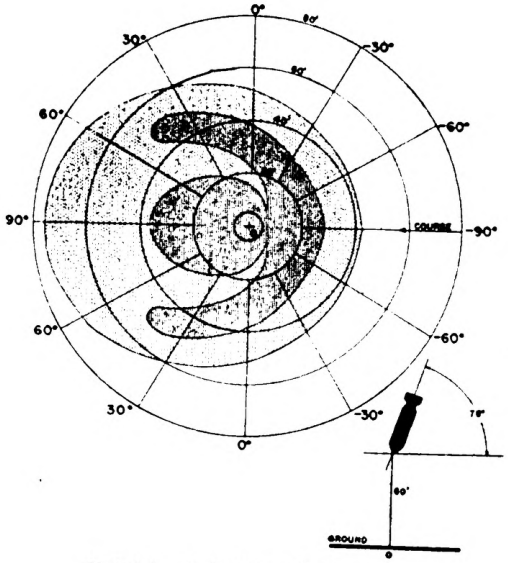
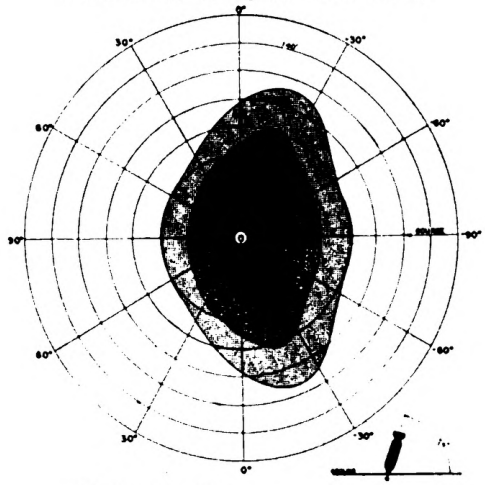
Perforation of ¼-in. Mild Steel.



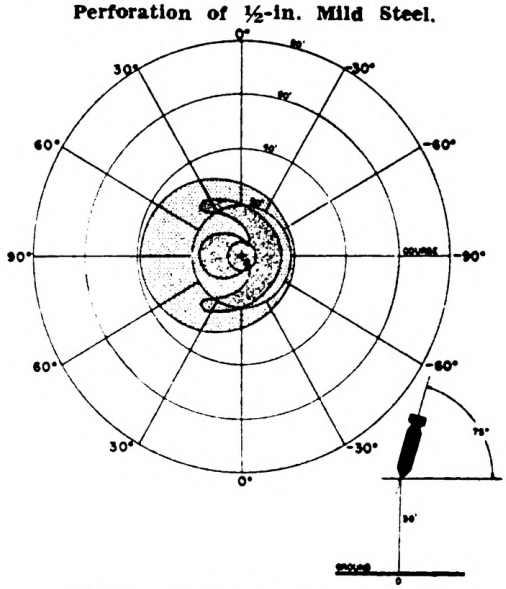
Height of Burst 60 ft.
Remaining Velocity 990 f/s
Altitude of Release 20,000 ft.

Perforation of ½-in. Mild Steel.



Ground Burst
Remaining Velocity 990 f/s
Altitude of Release 20,000 ft.

Perforation of ½-in. Mild Steel.



Height of Burst 30 ft.
Remaining Velocity 990 f/s
Altitude of Release 20,000 ft.

Figure 65. Perforation of ½-inch Mild Steel.

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CHART XVIII
AIR TRAVEL AND MINIMUM ALTITUDE TO ARM FUZES USED WITH BOMBS, GP 100-lb. AN-M30, or AN-M30A1

	FUZE											
	(Nose) M103		(Nose) M103 Partially Armed 250 turns		(Nose) AN-M103		(Tail) AN-M100A1 Partially Armed 350 turns	(Tail) AN-M100A2	(Tail) M112 or M112A1	(Tail) M115	(Tail) M123*	(Tail) M132*
	Delay	Inst.	Delay	Inst.	Delay	Inst.						
AVERAGE AIR TRAVEL IN FEET REQUIRED TO ARM	1,140	1,710	570	1,140	510	765	890	445	75	445	380	250
MINIMUM ALTITUDE IN FEET REQUIRED TO ARM FROM HORIZONTAL FLIGHT												
SPEED OF RELEASE												
100 mph	625	1,115	205	625	170	335	430	130	4	130	100	45
150 mph	375	760	105	375	85	185	240	64	2	64	47	21
200 mph	235	510	61	235	49	110	145	37	1	37	27	12
250 mph	155	345	40	155	32	70	95	24	1	24	17	8
300 mph	110	245	27	110	22	49	65	17	0	17	12	5
350 mph	80	180	20	80	16	36	49	12	0	12	9	4
400 mph	61	140	15	61	12	28	37	9	0	9	7	3
450 mph	48	110	12	48	10	22	29	7	0	7	5	2
500 mph	39	90	10	39	8	18	24	6	0	6	4	2

* Not issued for use with Bomb AN-M30.

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CHART XIX
AIR TRAVEL AND MINIMUM ALTITUDE TO ARM FUZES USED WITH
BOMB, GP 250-lb. AN-M57, AN-M57A1 or BOMB, DEMOLITION M31

	FUZE											
	(Nose) M103		(Nose) M103 Partially Armed 250 turns		(Nose) AN-M103		(Tail) AN-M100A1 Partially Armed 350 turns	(Tail) AN-M100A2	(Tail) M112 or M112A1	(Tail) M115*	(Tail) M123†	(Tail) M132†
	Delay	Inst.	Delay	Inst.	Delay	Inst.						
AVERAGE AIR TRAVEL IN FEET REQUIRED TO ARM	1,410	2,110	705	1,410	630	940	975	485	80	485	410	270
MINIMUM ALTITUDE IN FEET REQUIRED TO ARM FROM HORIZONTAL FLIGHT												
SPEED OF RELEASE												
100 mph	850	1,470	295	850	245	465	495	155	5	155	115	52
150 mph	550	1,060	155	550	125	265	285	75	2	75	55	24
200 mph	355	735	90	355	75	160	175	44	1	44	32	14
250 mph	235	515	59	235	48	105	115	28	1	28	21	9
300 mph	165	370	41	165	33	75	80	19	1	19	14	6
350 mph	125	280	30	125	24	55	58	14	0	14	10	4
400 mph	95	215	23	95	18	42	45	11	0	11	8	3
450 mph	75	170	18	75	15	32	36	9	0	9	6	3
500 mph	61	140	15	61	12	27	29	7	0	7	5	2

* Not issued for use with Bomb, M31.
† Not issued for use with Bombs, M31 and AN-M57.

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CHART XX
AIR TRAVEL AND MINIMUM ALTITUDE TO ARM FUZES USED WITH
BOMBS, GP 500-lb. AN-M64, AN-M64A1, AN-M43 or BOMB, DEMOLITION, 600-lb. M32

	FUZE													
	(Nose) M103		(Nose) M103 Partially Armed 250 turns		(Nose) AN-M103		(Tail) AN-M101A1 Partially Armed 350 turns	(Tail) AN-M101A2	(Tail) M113 or M113A1	(Tail) M116*	(Tail) M124†	(Tail) AN-MK230§		(Tail) M133†
	Delay	Inst.	Delay	Inst.	Delay	Inst.								
AVERAGE AIR TRAVEL IN FEET REQUIRED TO ARM	1,495	2,240	750	1,495	670	1,000	1,115	555	90	555	460	400 to 500		230
MINIMUM ALTITUDE IN FEET REQUIRED TO ARM FROM HORIZONTAL FLIGHT														
SPEED OF RELEASE														
100 mph	920	1,585	325	920	270	510	600	195	6	195	140	110	160	48
150 mph	600	1,150	175	600	145	295	360	100	3	100	70	52	80	22
200 mph	390	805	105	390	85	180	225	57	2	57	39	30	46	13
250 mph	260	560	65	260	53	120	145	37	1	37	25	19	30	8
300 mph	185	410	47	185	37	85	105	26	1	26	18	13	21	6
350 mph	135	305	34	135	27	61	75	19	0	19	13	10	15	4
400 mph	105	235	26	105	21	46	59	14	0	14	10	7	12	3
450 mph	85	190	21	85	16	36	47	11	0	11	8	6	9	2
500 mph	70	155	17	70	13	30	38	9	0	9	6	5	7	2

* Not issued for use with Bomb M32.
† Not issued for use with Bombs M32, AN-M43, AN M64.
§ Not issued for use with Bombs M32, AN M43.

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CHART XXI
AIR TRAVEL AND MINIMUM ALTITUDE TO ARM FUZES USED WITH
BOMBS, GP 1000-lb. AN-M65, AN-M65A1, AN-M44 or BOMB, DEMOLITION, 1,100-lb. M33.

	FUZE													
	(Nose) M103		(Nose) M103 Partially Armed 250 turns		(Nose) AN-M103		(Tail) AN-M102A1 Partially Armed 350 turns	(Tail) AN-M102A2	(Tail) M114 or M114A1	(Tail) M117*	(Tail) M134†	(Tail) M125†	(Tail) AN-MK230§	
	Delay	Inst.	Delay	Inst.	Delay	Inst.								
AVERAGE AIR TRAVEL IN FEET REQUIRED TO ARM	1,535	2,300	770	1,535	685	1,030	940	465	80	465	250	390	400 to 500	
MINIMUM ALTITUDE IN FEET REQUIRED TO ARM FROM HORIZONTAL FLIGHT														
SPEED OF RELEASE														
100 mph	955	1,635	335	950	280	535	465	140	5	140	45	105	110	160
150 mph	625	1,190	185	625	150	315	285	70	2	70	20	50	52	80
200 mph	410	835	110	410	85	190	160	40	1	40	12	28	30	46
250 mph	275	590	70	275	56	125	105	26	1	26	7	18	19	30
300 mph	195	425	49	195	39	90	75	18	1	18	5	13	13	21
350 mph	145	320	36	145	29	65	56	18	0	13	4	9	10	15
400 mph	110	250	28	110	22	50	42	10	0	10	3	7	7	12
450 mph	90	200	22	90	17	39	32	8	0	8	2	6	6	9
500 mph	70	160	18	70	14	32	27	6	0	6	2	5	5	7

* Not issued for use with Bomb M33.
† Not issued for use with Bombs M33, AN-M44, AN-M65.
§ Not issued for use with Bombs M33, AN-M44.

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CHART XXII

AIR TRAVEL AND MINIMUM ALTITUDE TO ARM FUZES USED WITH BOMBS, GP 2000-lb AN-M66, AN-M66A1 or AN-M34

	FUZE													
	(Nose) M103		(Nose) M103 Partially Armed 250 turns		(Nose) AN-M103		(Tail) AN-M102A1 Partially Armed 350 turns	(Tail) AN-M102A2	(Tail) M114 or M114A1	(Tail) M117	(Tail) M125*	(Tail) M134*	(Tail) AN-MK230†	
	Delay	Inst.	Delay	Inst.	Delay	Inst.								
AVERAGE AIR TRAVEL IN FEET REQUIRED TO ARM	2,420	3,625	1,210	2,420	1,080	1,620	1,340	665	110	665	560	380	400 to 500	
MINIMUM ALTITUDE IN FEET REQUIRED TO ARM FROM HORIZONTAL FLIGHT														
SPEED OF RELEASE														
100 mph	1,735	2,875	680	1,735	575	1,025	785	265	9	265	200	100	110	160
150 mph	1,290	2,300	415	1,290	340	685	495	140	4	140	100	47	52	80
200 mph	915	1,775	260	915	210	450	315	80	2	80	59	27	30	46
250 mph	650	1,335	175	650	140	305	210	53	1	53	37	17	19	30
300 mph	470	1,010	125	470	95	215	150	37	1	37	26	12	13	21
350 mph	355	775	90	355	70	160	110	27	1	27	20	9	10	15
400 mph	275	610	70	275	55	125	85	21	1	21	15	7	7	12
450 mph	220	490	55	220	44	100	65	16	0	16	13	5	6	9
500 mph	175	400	45	175	36	80	55	13	0	13	11	4	5	7

* Not issued for use with Bombs AN-M34, AN-M66.
† Not issued for use with Bomb AN-M34.

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CHART XXIII

AIR TRAVEL AND MINIMUM ALTITUDE TO ARM FUZES USED WITH BOMBS, SAP 500-lb. AN-M58A1 or AN-M58A2

	FUZE (Tail)					
	AN-M101A1 Partially Armed 350 turns	AN-M101A2	M113 or M113A1	M116	M124*	M133*
AVERAGE AIR TRAVEL IN FEET REQUIRED TO ARM	965	480	80	480	400	225
MINIMUM ALTITUDE IN FEET REQUIRED TO ARM FROM HORIZONTAL FLIGHT						
SPEED OF RELEASE						
100 mph	475	150	5	150	110	36
150 mph	275	75	2	75	52	17
200 mph	165	46	1	46	30	9
250 mph	110	28	1	28	19	6
300 mph	75	19	1	19	13	4
350 mph	56	14	0	14	10	3
400 mph	42	11	0	11	7	2
450 mph	33	8	0	8	6	2
500 mph	27	7	0	7	5	2

* Not issued for use with Bomb AN-M58A1.

CHART XXIV

AIR TRAVEL AND MINIMUM ALTITUDE TO ARM FUZES USED WITH BOMBS, SAP 1,000-lb. AN-M59 or AN-M59A1

	FUZE (Tail)					
	AN-M102A1 Partially Armed 350 turns	AN-M102A2	M114 or M114A1	M117	M125*	M134*
AVERAGE AIR TRAVEL IN FEET REQUIRED TO ARM	855	445	75	445	370	240
MINIMUM ALTITUDE IN FEET REQUIRED TO ARM FROM HORIZONTAL FLIGHT						
SPEED OF RELEASE						
100 mph	400	130	4	130	95	41
150 mph	225	64	2	64	44	19
200 mph	135	37	1	37	25	11
250 mph	85	23	1	23	16	7
300 mph	61	16	0	16	11	5
350 mph	45	12	0	12	8	4
400 mph	34	9	0	9	6	3
450 mph	27	7	0	7	5	2
500 mph	22	6	0	6	4	2

* Not issued for use with Bomb AN-M59.

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CHART XXV
AIR TRAVEL AND MINIMUM ALTITUDE TO ARM FUZES USED WITH BOMBS, DEMOLITION, LC 4,000-lb. AN-M56 or AN-M56A1

	FUZE							
	(Tail) AN-M102A2 (Non-delay)	(Tail) AN-M102A1 Partially Armed 350 turns	(Nose) AN-M103		(Nose) M103		(Nose) M103 Partially Armed 250 turns	
			Delay	Inst.	Delay	Inst.	Delay	Inst.
AVERAGE AIR TRAVEL IN FEET REQUIRED TO ARM	665	1,340	685	1,030	1,535	2,300	770	1,535
MINIMUM ALTITUDE IN FEET REQUIRED TO ARM FROM HORIZONTAL FLIGHT								
SPEED OF RELEASE								
100 mph	265	785	280	535	955	1,635	340	955
150 mph	140	500	150	315	625	1,195	185	625
200 mph	80	315	85	190	410	840	110	410
250 mph	53	210	56	125	275	595	70	275
300 mph	37	150	39	90	195	430	49	195
350 mph	27	110	29	65	145	320	36	145
400 mph	21	85	22	50	110	250	28	110
450 mph	16	70	17	39	90	200	22	90
500 mph	13	55	14	32	70	160	18	70

CHART XXVI
AIR TRAVEL AND MINIMUM ALTITUDE TO ARM FUZES USED WITH BOMB, CHEMICAL, 500-lb. M78

	FUZE			
	(Tail) AN-M101A2	(Nose) AN-M103	(Nose) M103	(Nose) M103 Partially Armed 250 turns
AVERAGE AIR TRAVEL IN FEET REQUIRED TO ARM	555	1,000	2,240	1,495
MINIMUM ALTITUDE IN FEET REQUIRED TO ARM FROM HORIZONTAL FLIGHT				
SPEED OF RELEASE				
100 mph	196	510	1,858	920
150 mph	100	300	1,155	600
200 mph	57	180	810	390
250 mph	37	120	570	260
300 mph	26	85	415	185
350 mph	19	62	310	135
400 mph	14	47	240	105
450 mph	11	38	190	85
500 mph	9	30	155	70

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CHART XXVII
AIR TRAVEL AND MINIMUM ALTITUDE TO ARM FUZES USED WITH BOMB, CHEMICAL, 1,000-lb. AN-M79

	FUZE				
	(Tail) AN-M102A2	(Tail) AN-M102A1 Partially Armed 350 turns	(Nose) AN-M103	(Nose) M103	(Nose) M103 Partially Armed 250 turns
AVERAGE AIR TRAVEL IN FEET REQUIRED TO ARM	465	940	1,030	2,300	1,535
MINIMUM ALTITUDE IN FEET REQUIRED TO ARM FROM HORIZONTAL FLIGHT					
SPEED OF RELEASE					
100 mph	140	465	535	1,640	955
150 mph	70	265	315	1,200	625
200 mph	40	160	190	845	410
250 mph	26	105	125	595	275
300 mph	18	75	90	430	196
350 mph	13	55	65	325	145
400 mph	10	42	50	250	110
450 mph	8	32	39	200	90
500 mph	6	27	32	160	70

CHART XXVIII
AIR TRAVEL AND MINIMUM ALTITUDE TO ARM FUZES USED WITH BOMB, INCENDIARY, 500-lb. AN-M76

	FUZE				
	(Tail) AN-M101A2 (Non-delay)	(Tail) AN-M101A1 Partially Armed 350 turns	(Nose) AN-M103	(Nose) M103	(Nose) M103 Partially Armed 250 turns
AVERAGE AIR TRAVEL IN FEET REQUIRED TO ARM	555	1,115	1,000	2,240	1,495
MINIMUM ALTITUDE IN FEET REQUIRED TO ARM FROM HORIZONTAL FLIGHT					
SPEED OF RELEASE					
100 mph	195	600	510	1,585	920
150 mph	100	360	295	1,150	600
200 mph	57	225	180	805	390
250 mph	37	145	120	565	260
300 mph	26	105	85	410	185
350 mph	19	75	61	305	135
400 mph	14	59	47	235	105
450 mph	11	47	37	190	85
500 mph	9	38	30	155	70

CHART XXIX
AIR TRAVEL AND MINIMUM ALTITUDE TO ARM FUZES USED WITH BOMB, FRAGMENTATION, 20-lb. AN-M41A1. BOMB, CHEMICAL, 115-lb. M70. BOMB, CHEMICAL, 100-lb. M47A2.

	FUZE (Nose) AN-M110A1	FUZE (Nose) AN-M110A1	FUZE (Nose) AN-M126A1
AVERAGE AIR TRAVEL IN FEET REQUIRED TO ARM	725	1,000	1,000
MINIMUM ALTITUDE IN FEET REQUIRED TO ARM FROM HORIZONTAL FLIGHT			
SPEED OF RELEASE			
100 mph	315	515	515
150 mph	170	300	300
200 mph	100	185	185
250 mph	65	120	120
300 mph	46	85	85
350 mph	35	61	61
400 mph	27	47	47
450 mph	21	38	38
500 mph	16	31	31

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CHART XXX
AIR TRAVEL AND MINIMUM ALTITUDE TO ARM FUZES USED WITH BOMB, FRAGMENTATION, 260-lb. AN-M81

	FUZE				
	(Tail) AN-M100A2 (Non-delay)	(Tail) AN-M100A1 Partially Armed 350 turns	(Nose) AN-M103	(Nose) M103	(Nose) M103 Partially Armed 250 turns
AVERAGE AIR TRAVEL IN FEET REQUIRED TO ARM	445	800	765	1,710	1,140
MINIMUM ALTITUDES IN FEET REQUIRED TO ARM FROM HORIZONTAL FLIGHT					
SPEED OF RELEASE					
100 mph	130	425	335	1,110	625
150 mph	64	240	185	750	375
200 mph	37	145	110	500	235
250 mph	24	95	70	340	155
300 mph	17	65	49	240	110
350 mph	12	49	36	180	80
400 mph	9	37	28	140	61
450 mph	7	29	22	110	48
500 mph	6	24	17	90	39

CHART XXXI
Altitudes of Release Involving 1% Risk (ft.)
Horizontal Bombing

BOMBS	FUZE DELAYS, NOSE OR TAIL FUZING				
Size and Type	Inst. to .1 Sec. (ft.)	4-5 Sec. Land Impact (See Note 1) (ft.)	4-5 Sec. Water Impact	8-11 or 8-15 Sec. Water Impact	8-11 or 8-15 Sec. Land Impact
100-lb. G.P.	500	200	No restriction	No restriction	No restriction
250-lb. G.P.	500	250	"	"	"
300-lb. Demolition					
500-lb. G.P. or S.A.P.	650	250	"	"	"
600-lb. Demolition					
1,000-lb. G.P. or S.A.P.	750	300	"	"	"
1,100-lb. Demolition					
2,000-lb. G.P.	850	300	"	"	"
4,000-lb. L.C. (See Note 2)	1,200	------	------	------	------
Frag. Bomb	500	------	------	------	------
Stabilized 20-lb. Frag. Bomb	100	------	------	------	------
Parachute, 23-lb. M47 Incendiary	100	------	------	------	------
M47 Chemical					
325-lb. Depth Bomb	500	------	See Note 3	See Note 3	------
650-lb. Depth Bomb	750	------	------	------	------
Incendiary Clusters	Any altitude with respect to safety. Altitude required for bomb stabilization and functioning dependent upon release conditions.				

Note 1—The 4-5 second delay fuze is designed primarily for use against water targets and its use on land is not recommended if either 8-11 second or forty-five (45) second delay fuzes are available.
Note 2—Instantaneous fuzing only should be used on the four thousand (4,000) pound L.C. bomb.
Note 3—Hydrostatic fuzes are standard for the depth bomb over water and may be released at any altitude with respect to safety of the bombing airplane.

The term "No Restriction" as used in the table above applies only to restrictions on altitude of release imposed by risk from bomb fragmentation or blast. Altitude restrictions imposed by other considerations, such as target height, fuze arming requirements and the possibility of damage from ricochets must be determined by the conditions of use.

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CHART XXXII
TACTICAL USE OF AERIAL BOMBS

Chart 32 is a guide for determing the most desirable bomb and fuze combination for attack against a specific objective.

CHART XXXII
(Explanatory Notes will be found at end of Chart)
TACTICAL USE OF AERIAL BOMBS

Objective	Altitude of Attack	Point to be Attacked	Bomb	NOSE		TAIL		Alternate Fuzes		Danger of Near Miss Radius	REMARKS
				Fuze	Functioning Time	Fuze	Functioning Time	Nose	Tail		
Land Targets: Air Bases Installations	High (1)	Hanger itself	100-lb. GP	AN-M103	0.1 sec. delay	AN-M100A2	0.025 sec. delay	M103	AN-M100A1	Hanger	When more 100-pound bombs can be carried than 250-pound bombs, it is preferable to use the 100-pound bomb. See notes (4) and (5)
	High	Hanger itself	250-lb. GP	AN-M103	0.1 sec. delay	AN-M100A2	0.025 sec. delay	M103	AN-M100A1	Hanger	
	Minimum (2)	Hanger itself	100-lb. GP	None	None	M112A1	11 sec. delay	None	M123	Hanger	
	or Low (3)		250-lb. GP	None	None	M112A1	11 sec. delay	None	M123	Hanger	
Airplanes in open or uncovered revetments	High	Area occupied by planes	20-lb. Frag.	AN-M110 A1	Instantaneous	None	None	M110	None	25 to 50 ft.	Frag. bomb is recommended, since fragments will have a greater effect than the blast effect of the GP type bomb. Parachute Frag. dropped in clusters of 3 bombs—or dropped separately.
	High	"	100-lb. GP	AN-M103	Instantaneous	AN-M100A2	Non-delay	M103	AN-M100A1	75 to 100 ft.	
	High	"	250-lb. GP	AN-M103	Instantaneous	AN-M100A2	Non-delay	M103	AN-M100A1	100 to 125 ft.	
	Low	"	23-lb. Frag.	AN-M120	Instantaneous	None		AN-M104	None	25 to 50 ft.	
	Minimum	"	100-lb. GP	None	None	M112A1	11 sec. delay	None	M106A1	75 to 100 ft.	
	Minimum	"	250-lb. GP	None	None	M112A1	11 sec. delay	None	M106A1	100 to 125 ft.	
Ammunition Dump	High	Area occupied by dump	100-lb. GP	AN-M103	Instantaneous	AN-M100A2	Non-delay	M103	AN-M100A1	Direct hits	Bombs must hit ammunition directly and function on impact. A delay will not necessarily cause sympathetic detonation.
	High		250-lb. GP	AN-M103	Instantaneous	AN-M100A2	Non-delay	M103	AN-M100A1		
Armored Force Vehicles' Light	High	Vehicles	20-lb. Frag.	AN-M110 A1	Instantaneous	None	None	M110	None	25 ft.	
	High	Vehicles	100-lb. GP	AN-M103	0.1 sec. delay	AN-M100A2	Non-delay	M103	AN-M100A1	75 ft.	
	High	Vehicles	250-lb. GP	AN-M103	0.1 sec. delay	AN-M100A2		M103	AN-M100A1	100 ft.	Use against slow moving convoy or parked vehicles only.
	Low	Vehicles	23-lb. Frag.	AN-M120	Instantaneous	None	None	AN-M104	None	25 ft.	
	Minimum	Vehicles	100-lb. GP	None	None	M112A1	11 sec. delay	None	None	75 ft.	Must be direct hit.
Heavy	High	Vehicles	100-lb. GP	AN-M103	0.1 sec. delay	AN-M100A2	Non-delay	M103	AN-M100A1	Direct	Must be direct hit. Use against slow moving convoy or parked vehicles only.
	High	Vehicles	250-lb. GP	AN-M103	0.1 sec. delay	AN-M100A2	Non-delay	M103	AN-M100A1	Direct	
	Minimum	Vehicles	100-lb. GP	None	None	M112A1	11 sec. delay	None	None	20 ft.	

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Bridges											
Concrete, reinforced and supported wholly by piers	High	Approach and span	1,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	0.01 sec. delay	M103	AN-M102A1	15 ft.	
	High	Approach and span	500-lb. SAP	None	None	AN-M102A2	0.01 sec. delay	None	AN-M101A1	Nil	
	Minimum or Low	Piers and span	1,000-lb. GP	None	None	M114A1	11 sec. delay	None	None	15 ft.	
Concrete, reinforced of massive construction, supported by piers and/or suspended by cables	High	Approach and span	2,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	0.01 sec. delay	M103	AN-M102A1	15 ft.	M106A1—11 sec. delay is possible alternate tail fuze.
	High	Approach and span	1,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	0.01 sec. delay	M103	AN-M102A1	15 ft.	
	Minimum or Low	Approach and span	1,000-lb. SAP	None	None	AN-M102A2	0.01 sec. delay	M103	AN-M102A1		
	High	Piers and span	1,000-lb. GP	None	None	M114A1	11 sec. delay	None	M106A1 M124	15 ft.	
Steel, railway light	Minimum or Low	Approach and span	500-lb. GP	AN-M103	0.1 sec. delay	AN-M101A2	0.01 sec. delay	M103	AN-M101A1	15 ft.	
		Piers and span	500-lb. GP	None	None	M113A1	11 sec. delay		M106A1	15 ft.	
Steeel, railway heavy	High	Approach and span	1,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	0.01 sec. delay	M103	AN-M102A1	15 ft.	
	High	Approach and span	1,000-lb. SAP	None	None	AN-M102A2	0.025 sec. delay	M103	AN-M102A1	------	
	Minimum or Low	Piers and span	1,000-lb. GP	None	None	M114A1	11 sec. delay	------	M106A1		M106A1—11 sec. delay is possible alternate tail fuze.
Buildings											
Bombproof, 1-2 stories	High	Building itself	1,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	0.025 sec. delay	M103	AN-M102A1	Building itself	If building is heavy and extensive, use 0.1 sec. delay.
	High	Bldg. itself	1,000-lb. SAP	None	None	AN-M102A2	0.025 sec. delay	None	AN-M102A1	Building itself	
	High	Bldg. itself	500-lb. SAP	None	None	AN-M101A2	0.025 sec. delay	None	AN-M101A1	Building itself	
	Minimum or Low	Bldg. itself	1,000-lb. GP	None	None	M114A1	11 sec. delay	None	M106A1	Building itself	Also M125.
	"	Bldg. itself	500-lb. SAP	None	None	M113A1	11 sec. delay	None	M106A1		
Bombproof, over 2 stories	High	Bldg. itself	1,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	0.1 sec. delay	M103	AN-M102A1	Building itself	
	High	Bldg. itself	1,000-lb. SAP	None	None	AN-M102A2	0.1 sec. delay	None	AN-M102A1	Building itself	
	High	Bldg. itself	500-lb. SAP	None	None	AN-M101A2	0.1 sec. delay	None	AN-M101A1	Building itself	
	Minimum or Low	Bldg. itself	1,000-lb. GP	None	None	M114A1	11 sec. delay	None	M106A1	Building itself	
	"	Bldg. itself	500-lb. SAP	None	None		11 sec. delay	None	M106A1	Building itself	
Light, industrial, factories, warehouses, etc.	High	Bldg. itself	250-lb. GP	AN-M103	0.1 sec. delay	AN-M100A2	0.025 sec. delay	M103	AN-M100A1		Use size or combination of sizes, giving greatest over-all load. Mix with incendiaries.
	High	Bldg. itself	500-lb. GP	AN-M103	0.1 sec. delay	AN-M101A2	0.025 sec. delay	M103	AN-M101A1		
	Minimum or Low	Bldg. itself	250-lb. GP	None	None	M112A1	11 sec. delay	None	M106A1, M123		
	"	Bldg. itself	500-lb. GP	None	None	M113A1	11 sec. delay	None	M106A1, M124		

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CHART XXXII—Continued

Objective	Altitude of Attack	Point to be Attacked	Bomb	NOSE		TAIL		Alternate Fuzes		Danger of Near Miss Radius	REMARKS
				Fuze	Functioning Time	Fuze	Functioning Time	Nose	Tail		
Heavy, industrial, steel works	High	Bldg. itself	500-lb. GP	AN-M103	0.1 sec. delay	AN-M101A2	0.025 sec. delay	M103	AN-M101A1		Use size or combination of sizes giving greatest over-all load.
	High	Bldg. itself	1,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	0.025 sec. delay	M103	AN-M102A1		
	High	Bldg. itself	500-lb. SAP	None	None	AN-M101A2	0.01 sec. delay	M103	AN-M101A1		
Build-up, and residential areas, morale	High	Bldg. itself	250-lb. GP	AN-M103	1/10 sec. delay	AN-M100A2	0.025 sec. delay	M103	AN-M100A1		Use size or combination of sizes, giving greatest over-all load (with Incendiaries.)
			500-lb. GP	AN-M103	1/12 sec. delay	AN-M101A2	0.025 sec. delay	M103	AN-M101A1		
	High	Bldg. itself	1,000-lb. GP	AN-M103	Instantaneous	AN-M102A2	Non-delay	M103	AN-M102A1		
	High	Bldg. itself	2,000-lb. GP	AN-M103	Instantaneous	AN-M102A2	Non-delay	M103	AN-M102A1		
	High	Bldg. itself	4,000-lb. LC	AN-M103	Instantaneous	AN-M102A2	Non-delay	M103	AN-M102A1		
	Low	Bldg. itself	500-lb. GP	None	None	M124	1 to 144 hrs.				
Dams Heavy masonry and earth	High	Powerhouse close to dam on water side	2,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	0.025 sec. delay	M103	AN-M102A1	15 ft.	
	Low	Water-50 to 100 ft. from side of dam	2,000-lb. GP	None	None	AN-Mk 230	25 ft.	------	------		AN-M66
	Low	"	1,000-lb. GP	None	None	AN-Mk 230	25 ft.	------	------		AN-M65
	Low	"	650-lb. DB	None	None	AN-Mk 230	25 ft.	------	------		Depth bomb AN-Mk 224, 234 (Traverse hydrostatic fuze).
Light masonry	High	Powerhouse or close to dam on water side	2,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	0.025 sec. delay	M103	AN-M102A1	15 ft.	
	Low	Water -50-100 ft. from side of dam	650-lb. DB	None	None	AN-Mk 230	25 ft.	None	None		
	Minimum	Dam-Water side	1,000-lb. GP	None	None	M113A1	11 sec.	None	M106A1	25 ft.	
Motor Vehicles Convoy	High	Vehicles	20-lb. Frag.	AN-M110A1	Instantaneous	None	None	M110	None	25 ft.	
	High	Vehicles	100-lb. GP	AN-M103	Instantaneous	AN-M100A2	Non-delay	M103	AN-M100A1	75 ft.	
	Low	Vehicles	23-lb. Frag.	AN-M120	Instantaneous	None	None	AN-M104	None	25 ft.	
	Minimum	Area	100-lb. GP	None	None	M113A1	11 sec. delay	None	M106A1	25 to 50 ft.	
Motor Park	High	Oil field area	500-lb. GP	AN-M103	Instantaneous	AN-M101A2	Non-delay	M103	AN-M101A1		
Oil Fields	Minimum	Oil field area	500-lb. GP	None	None	M113A1	11 sec. delay	None	M106A1, M124		
Oil Tanks	High	Area occupied by tanks	100-lb. GP	AN-M103	0.1 sec. delay	AN-M100A2	Non-delay	M103	AN-M100A1	25 to 50 ft.	
	High	Area occupied by tanks	250-lb. GP	AN-M103	0.1 sec. delay	AN-M100A2	Non-delay	M103	AN-M100A1	25 to 50 ft.	If tanks are buried, use same bombs with 0.1 sec. delay.
	Minimum	Area occupied by tanks	100-lb. GP	None	None	M112A1	11 sec. delay	None	M106A1, M123	25 to 50 ft.	
	Minimum	Area occupied by tanks	250-lb. GP	None	None	M112A1	11 sec. delay	None	C106A1, M123	25 to 50 ft.	

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Power Plants											
Power stations and transformers	High	Station itself	500-lb. GP	AN-M103	0.1 sec. delay	AN-M101A2	0.025 sec. delay	M103	AN-M101A1	Station itself	
Railways											
Yard, junction, cars, etc.	High	Yard	100-lb. GP	AN-M103	0.1 sec. delay	AN-M100A2	Non-delay	M103	AN-M100A1	7 ft.	
			250-lb. GP	AN-M103	0.1 sec. delay	AN-M100A2	Non-delay	M103	AN-M100A1	9 ft.	
	Minimum	Yard	100-lb. GP	None	None	M112A1	11 sec. delay	None	M123	7 ft.	
	Minimum	Yard	250-lb. GP	None	None	M112A1	11 sec. delay	None	M123	9 ft.	
Embankments	Minimum	Roundhouse	500-lb. GP	None	None	M113A1	11 sec. delay	None	M124		
	Minimum	Embankment	500-lb. GP	None	None	M113A1	11 sec. delay	None	M106A1	Embankment	
			1,000-lb. GP	None	None	M114A1	11 sec. delay	None	M106A1	Embankment	
Water Targets											
unarmored vessels	High	Vessel	1,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	0.025 or 0.01 sec. delay	M103	AN-M102A1		The .025 sec. delay will give deep damage. The .01 sec. delay is recommended against heavier built vessels to prevent deflagration.
	High	Vessel	500-lb. GP	AN-M103	0.1 sec. delay	AN-M101A2	0.025 or 0.01 sec. delay	M103	AN-M101A1		
	High	Vessel	250-lb. GP	AN-M103	0.1 sec. delay	AN-M100A2	0.01 or 0.025 sec. delay	M103	AN-M100A1		
Large	Minimum	Side of vessel (to penetrate)	500-lb. GP	None	None	M113A1	4-5 sec. delay	------	------		
	Minimum	"	250-lb. GP	None	None	M112A1	4-5 sec. delay	------	------		
Small	High	Vessel	1,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	Non-delay	M103	AN-M102A1		Non-delay is recommended so bombs will detonate before penetration through the bottom of the vessel.
	High	Vessel	500-lb. GP	AN-M103	0.1 sec. delay	AN-M101A2	Non-delay	M103	AN-M101A1		
	High	Vessel	250-lb. GP	AN-M103	0.1 sec. delay	AN-M100A2	Non-delay	M103	AN-M100A1		
	Minimum	Side of vessel (to penetrate)	500-lb. GP	M118 (6)	4-5 sec. delay	M113A1	4-5 sec. delay	------	------		
	Minimum	"	250-lb. GP	M118	4-5 sec. delay	M112A1	4-5 sec. delay	------	------		
Small highly maneuverable vessels (Destoyer type)	High	Vessel	1,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	Non-delay	M103	AN-M102A1	35 ft.	A non-delay is recommended as the tail fuze will probably not initiate functioning until it hits a second deck.
	High	Vessel	500-lb. GP	AN-M103	0.1 sec. delay	AN-M101A2		M103	AN-M101A1		
	Minimum	Side of vessel (to penetrate)	500-lb. GP	M118	4-5 sec. delay	M113A1	4-5 sec. delay	------			
Aircraft carriers anad light and heavy cruisers	High	Vessel	1,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	.025 sec. delay	M103	AN1M102A1	35 ft.	These vessels have light weather decks and moderately armored lower decks. The tail fuze should control. The .01 could be used so that the bomb would detonate before it strikes the armored lower deck. Bomb must not hit target but should detonate alongside or underneath vessel.
	High	Vessel	2,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	.025 sec. delay	M103	AN1M102A1	35 ft.	
	Minimum	10 to 100 ft. short of target	1,000-lb. GP	M118	4-5 sec. delay	M114A1	4-5 sec. delay	------	------	35 ft.	
	Minimum	Side of vessel (to penetrate)	500-lb. GP	M118	4-5 sec. delay	M113A1	4-5 sec. delay	------	------	15 ft.	
Battleship and battle cruisers	High	Vessel	2,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	.025 sec. delay	M103	AN-M102A1	35 ft.	
	High	Vessel	1,000-lb. GP	AN-M103	0.1 sec. delay	AN-M102A2	.025 sec. delay	M103	AN-M102A1	35 ft.	
	High	Vessel	1,000-lb. SAP	None	None	AN-M102A2	0.1 sec. delay	None	AN-M102A1	Nil	
	High	Vessel	1,600-lb. AP	None	None	AN-Mk 228	0.08 sec. delay	------	------	Nil	
	Minimum	10 to 100 ft. short of target	2,000-lb. GP	M118	4-5 sec. delay	M114A1	4-5 sec. delay	------	------	35 ft.	
	Minimum		1,000-lb. GP	M118	4-5 sec. delay	M114A1	4-5 sec. delay	------	------	35 ft.	

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CHART XXXII—Continued

Objective	Altitude of Attack	Point to be Attacked	Bomb	NOSE (8)		TAIL		Transverse Hydrostatic		Alternate Fuzes	Danger of Certain Fatal Damage	REMARKS
				Fuze	Functioning Time	Fuze	Functioning Depth	Fuze	Depth			
Submarines	(7)	Vessel itself	350-lb. AN-Mk 47	Mk 219	Instantaneous	None	None	AN-Mk 234	25 ft.	Mk 221, AN-Mk 224 (11)	22 ft.	(flat nose, other filler)
		Vessel itself	700-lb. AN-Mk 49	Mk 219	Instantaneous	AN-Mk 229 (9)	50 ft.	AN-Mk 234	25 ft.	Mk 221, AN-Mk 224	32 ft.	(flat nose, other filler)
		Vessel itself	650-lb. AN-Mk 38	Mk 219	Instantaneous	AN-Mk 229	50 ft.	AN-Mk 234	25 ft.	Mk 22, AN-Mk 224	25 ft.	(flat nose, TNT filled)
		Vessel itself	650-lb. AN-Mk 37	AN-M103	Instantaneous	AN-Mk 229	50 ft.	AN-Mk 234	25 ft.	Mk 219, 221, AN-Mk 224	25 ft.	(round nose, TNT filled)
		Vessel itself	650-lb. AN-Mk 29	AN-M103	Instantaneous	AN-Mk 229	50 ft.	AN-Mk 234	25 ft.	Mk 219, 221, AN-Mk 224	25 ft.	(round nose, TNT filled)
		Vessel itself	350-lb. AN-Mk 44	AN-M103	Instantaneous	None	None	AN-Mk 234	25 ft.	Mk 219, 221, AN-Mk 224	22 ft.	(round nose, other filler)
		Vessel itself	325 lb. AN-Mk 41	Mk 219	Instantaneous	None	None	AN-Mk 234	25 ft.		18 ft.	(flat nose, TNT filled)
		Vessel itself	325 lb. AN-Mk 17	AN-M103	Instantaneous	None	None	AN-Mk 234	25 ft.	Mk 219, 221, AN-Mk 224	18 ft.	(round nose, TNT filled)
		Vessel itself	500 lb. AN-M64	None	None	AN-Mk 230	25 ft.					
		Vessel itself	1,000 lb. AN-M65	None	None	AN-Mk 230 (9)	25 ft.				18 ft.	
		Vessel itself	1,000 lb. AN-M65	None	None	AN-Mk 230	25 ft.				26 ft.	(filled with Comp. B)

EXPLANATORY NOTES

(1) High—is any altitude above which the airplane is safe from its bomb fragments. This is the altitude from which all level flight precision bombing and dive bombing using instantaneous or short delay (less than one second) fuzes is conducted.
(2) Minimum—is that altitude necessary for the plane to clear the target. This is the altitude from which all masthead bombing is conducted using long delay (greater than one second) fuzes.
(3) Low—is that intermediate altitude between minimum and high. This is the altitude from which fragmentation bombs are dropped, and from which either level or dive bombing may be conducted, using long delay fuzes.
(4) The M123, M124, and M125 tail fuzes have delays of one (1) hour, 2, 6, 12, 24, 36, 72, or 144 hours.
(5) The 4-5 second delay tail fuze has been designed for minimum altitude bombing against water targets, whereas the 11 second fuze has been designed for use against land targets. It is considered unsafe to use a 4-5 second delay fuze against a land target, since it is entirely likely that air bursts dangerous to the plane could result from ricochet.
(6) When the M118 nose fuze (4-5 second delay) is unavailable, bombs will be dropped without nose fuzes in minimum altitude attacks against water targets.
(7) The altitude of attack depends upon whether or not the submarine is submerged or on the surface. If surfaced and the nose fuze is used to detonate the bomb, the arming time of that fuze and the danger to the plane of surface blast will be the limiting factors. If submerged, only the hydrostatic fuze will be permitted to arm. The AN-Mk 224 and the AN-Mk 234 arm instantaneously from any altitude. The minimum altitude of release of the 650-pound and the 700-pound depth bomb with the instantaneous nose fuze is 1200 feet.
(8) Nose fuzes are used on depth bombs only when selective arming is possible so that the nose fuze can be armed and used against surfaced submarines. Against submerged submarines, the nose fuze will have to be released UNARMED by releasing the bomb with the arming wire intact. No damage will result from a near miss when armed instantaneously for attack against surfaced craft.
(9) In a definite submarine attack, both the tail and transverse hydrostatic fuze are recommended. The TAIL hydrostatic fuze should be set at a greater depth for functioning than the transverse hydrostatic fuze. If selective arming is not possible, the arming wire for the AN-M229 and AN-M230 tail fuze must be attached to the plane or rack so that these fuzes will always arm upon release.
(10) For General purpose antisubmarine warfare the 25-foot setting is desired. However additional bombs may be carried fuzed for greater depth.
(11) The AN-M103 nose fuze must not be used with 'flat nose' depth bombs as the fuze will not arm properly. The Mk 219 nose fuze should be used.
(12) The M106 tail fuze has been restricted from use.

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AIRCRAFT PYROTECHNICS

Pyrotechnics today are ordnance, not fireworks. They produce brilliant light for illumination, or colored lights or smokes for signaling.

Pyrotechnic Flame Compositions. Pyrotechnic flame compositions are mixtures of chemical elements and compounds which, upon combustion, produce light and color. The light is due to small particles of solid matter heated to incandescence. Color is due to the wave length of the light given off by certain compounds (such as the refractory oxides of barium and strontium) during combustion.

Classification. *According to Use.*

Aircraft types—for use from aircraft.

Ground types—for use on the ground.

According to purpose.

Flares which provide illumination for an appreciable time.

Signals which produce lights (or smokes) of various colors and arrangements for the conveyance of messages.

Photoflash bombs for night photography.

Drift signals for aiding navigation over water.

THE FIRE TRAIN

Because a pyrotechnic must be safely handled, shipped, and stored, its illuminant charge is composed of materials that are not too readily ignited. Consequently, to obtain proper ignition of the illuminant charge at the right time and under the circumstances desired, it is necessary to use a 'fire train,' similar in purpose to the 'explosive train' of a bomb fuze. The term 'fire train' means the continuous series of combustibles that translate the initial firing action into the proper burning of the illuminant charge. It starts with a small amount of material that is quite easily ignited and terminates with a large amount of material that is not.

Classification. In general, the fire trains of U. S. Army pyrotechnics may be classified in two categories:

The fire train of the parachute aircraft flares (such as the M8A1, M24, and M26), consisting of a friction igniter, delay fuze, quickmatch, priming charge, first fire, and illuminant charge.

The combination explosive-fire train of the projected types of flares and signals, consisting of a percussion primer, propelling charge, delay fuze, expelling charge, priming charge, first fire, and illuminant charge.

Components. The following are the components of the fire train. *Friction igniters.* A friction igniter consists of a primer cup containing a friction composition of potassium chlorate, charcoal, and dextrine binder. Through this cup projects a loop of braided picture wire, coated with red phosphorous in shellac; the other end of the wire may be attached to the parachute suspension assembly. Upon operation of the flare the friction wire is jerked from the primer cup, and the resulting action, which is analagous to the striking of a match, ignites the contents of the primer cup. This initial fire is then picked up either by a delay fuze or a quickmatch.

Delay Fuze. A column of compressed black powder which introduces a delay into the fire train by its slow rate of burning.

Quickmatch. Twisted strands of cotton which are impregnated with mealed black powder, resembling the fuze on ordinary firecrackers.

Priming Charge. A dried paste of black powder in intimate contact with the first fire. It serves to pick up the flame, from either a delay fuze or quickmatch, and transfer it to the first fire.

First Fire. A mechanical mixture of 75% illuminant charge and 25% black powder loaded under pressure in the base of the candle. It is ignited by the priming charge, and serves to initiate the burning of the illuminant charge.

Illuminant Charge. That part of the pyrotechnic whose burning produces the desired visual effect. Its composition varies, depending on the intended use. It constitutes the main body of the candle, and is usually loaded into the candle case in small increments under considerable pressure.

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METHODS OF PROJECTION

Pyrotechnics may be projected from aircraft by several means, depending on the size and type:

Vertical or horizontal flare racks
Internal or external bomb racks
Pyrotechnic pistols
Manually

Flare Racks. *Types.* Two general types of flare racks are used, the horizontal and the vertical, so designated from the position in which the flare is suspended.

Horizontal
  A-2 Flare Rack
Vertical
  A-3 Flare Rack
  A-4 Flare Rack

Horizontal Flare Racks. The A-2 horizontal rack is installed within the wing of an airplane. The opening in the lower surface of the wing is closed by a spring-retained door. The door is opened by the flare release cable 20° ahead of the release of the flare to insure positive egress of the flare. The A-2 rack consists of two carrying hooks pivoted in the frame, linked together and released simultaneously by a releasing latch at the forward end of the flares. The suspension bands will be installed on the flare body 14 inches apart to support the flare on the rack. The arming wire swivel loop is attached to a snap hook fastened to the front end of the flare rack.

Vertical Flare Racks. The A-3 rack consists of a cylindrical guide chute, closed at the bottom by a carrying and releasing door on which the flare rests when installed. The top of the chute is covered by a hinged lid to which the hangwire swivel loop of the flare is held by the loop-retained plunger. The lid is fastened by a spring latch and covers the chute to prevent the entrance of water, etc. The A-3 rack may be loaded from either top or bottom, depending upon the overhead and ground clearance available.

The A-4 rack consists of a corrugated metal guide chute open at the bottom. The flare, when installed, is retained in the chute by a carrying hook which projects into the chute and covers a portion of the bottom of the flare. A camming lever to which the release cable is attached locks the carrying hook in place after each release. Entrance of water through the top is prevented by a hinged cover which is retained in place by a spring latch. The hangwire swivel loop of the flare is held by a loop-retained plunger located in this cover. Entrance of dirt and water into the bottom of the chute is prevented by a spring-retained door in the fuselage of the airplane. The rack is mounted so that there is a minimum of 3 inches between the bottom of the flare and the closest point of this door, which is opened by the impact of the falling flare. The A-4 flare rack may be loaded from the top or bottom, depending upon clearance.

Bomb Racks. The larger pyrotechnics can be dropped from internal or external bomb racks, using the standard B-7 shackle. When the B-7 shackle is used, the hangwire swivel loop will be attached to a structural member of the airplane which supports the rack. A wire or clamp of sufficient strength to withstand the load of the falling flare will be used for this purpose.

Pyrotechnic Pistols. *Pistol, Pyrotechnic M2.* The M2 Pyrotechnic pistol is used for firing signals and small flares from aircraft. It is now limited standard.

Description. This pistol is of the self-cocking type and uses signals with detachable barrels. It was developed so that the pilot could load, fire, and extract the empty barrel with one hand. It has replaced the Very pistol as a projector of flares from aircraft. It has a safety grip similar to the .45 cal pistol. To accomplish this the signal or flare is assembled in a light, expendable, detachable barrel. The barrel of the pistol serves only as a seat or socket into which the detachable barrel can be inserted. The base of the detachable barrel is provided with an annular groove which accommodates the locking lug of the projector. The signals are held in the plane by detachable clip bands.

Operation. The barrel of the pistol is placed over the base of the signal or flare, which is automatically locked in place. A continuous pull on the trigger cocks and fires the projector. The detachable barrel is unlocked by depressing

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the thumb release on the left side at the breech of projection. It is then free to fall from the pistol by gravity. In case of a misfire or hangfire the signal can be disposed of in the same way without endangering the aircraft by bringing the loaded projector into the cockpit.

Safety Rules for Flares and Signals Fired from M2 Pyrotechnic Pistol. (a) Care should be exercised not to damage or break the waterproof seal in the end of the case.

Care should be taken to avoid denting or deforming the aluminum case.

Allow no object to rest or strike or press upon the primer.

Signal cases which have serious dents or which are so damaged that they will not fit properly into the projector will not be used.

Do not allow the signal case to come in contact with oil or grease.

All foreign matter, such as dirt, sand, mud, or grease will be carefully removed before use.

Pistol, Pyrotechnic AN-M8 and Mount M1. *Description.* The Pyrotechnic Pistol AN-M8 has a barrel of seamless steel tubing. The barrel is hinged to the frame by the barrel pivot stud and screw and is locked by the breech lock when in position for firing. Assembled on the top of the barrel is the breech lock and the mount latch. The breech lock housing receives both the mount latch and the breech lock. The grips are of plastic. The back plate and the cover plate, fitted on the aluminum frame, are locked to the frame by screws. Within the frame, between the cover and the back plate, is housed the firing mechanism of the pistol. The Pyrotechnic Pistol Mount M1 is of the spring-recoil type and is fastened to the aircraft by machine bolts. The mount receives the muzzle end of the pistol. The pistol is locked to the mount by the lugs on the recoil sleeve of the mount, being held behind the recoil lugs on the pistol barrel. Both the pistol and the mount are painted a glossy black.

Operation. Before loading, test action of trigger and firing pin. When loading the cartridge type of signal, insertion must be made through the breech end of the barrel. However, rimless type signals can be loaded either through the muzzle or breech end. To load through the muzzle end, it is necessary to remove the pistol from the mount for loading. To remove pistol from the mount, retract the mount latch with the forefinger and turn the pistol one-quarter turn until the recoil lugs of the barrel are aligned with the slots of the recoil sleeve of the mount. Then withdraw the pistol from the mount. When firing from the mount, insert all signals through the breech end.

To load the cartridge-type signal, place the thumb of the right hand on the knurled portion of the breech lock and force upward. Breech will then drop open. Glance into the barrel chamber to detect any obstructions. Place the signal into the barrel chamber. Swing breech upward until it is positioned and locked by the breech lock.

The rimless-type signal can be inserted in the same way as the cartridge type. It may also be inserted by first removing the pistol from the mount, and then inserting the signal through the muzzle end until the ejector engages in the cannelure in the barrel of the signal. This method of inserting the rimless type is recommended only when the pistol is to be hand fired and the signal length is smaller than the barrel length; otherwise insertion should be made through the breech end. The pistol can be hand-fired with either type of signal.

The pistol is fired by a continuous squeeze on the trigger. Precaution should be taken to point the pistol to the rear flank and in such a manner that the pyrotechnic will not strike the aircraft whenever the pistol is hand-fired.

Manually. Certain smaller pyrotechnics, such as drift signals, are projected from aircraft by merely being tossed overboard.

FLARES

Flares for aircraft use are designed to provide illumination for reconnaissance, observation, bombardment, and landing. Details of design vary with the purpose of the flare, but all flares have certain characteristics in common.

All flares produce a white or yellowish light of high intensity for an appreciable length of time ranging from 60,000 candlepower for 1 minute, to 1,000,000 candlepower for 3.5 minutes or longer.

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All flares are parachute-supported to retard their dropping speed and make additional time available for illuminating purposes.

All flares have some form of delayed ignition to insure their clearing the plane before starting to burn. The method usually employed is the use of the cut-off action of a short cord—attached to parachute cable or shock absorber—to pull ignition wires through a block of flame composition. The flame is then carried by quickmatch to the primer, first fire, and illuminant composition of the candle.

Flares designed for use below the plane, such as those intended for bombardment, are provided with shades to shield the glare from the bombardier.

Flares designed for release from launching tubes or racks are equipped with a hang wire assembly which is attached to the arming pawl of the tube or rack. When the flare is released armed, the hangwire remains attached to the plane and pulls out the parachute or stabilizing sleeve. A section of soft metal tear wire enables the flare to break free.

Flares designed for release from racks or launching tubes may be released armed or unarmed. If released unarmed, they will not function in the air, but may ignite on impact. This possibility must be kept in mind in releasing flares unarmed over friendly territory.

Flares equipped with hangwire are shipped with the hangwire in a hangwire container in the base of the flare case. The case is closed with a shipping cover, which is sealed by means of a strip of tape or a soft metal tear strip. The tape or tear strip is torn off and the shipping cover removed when the flare is installed in the plane. If the flare is removed from the plane and returned to storage, the shipping cover will be replaced and sealed with tape.

Pyrotechnic compositions are subject to deterioration with time. Although some mixtures become more sensitive, most pyrotechnics become more difficult to ignite and hence less dependable. Such pyrotechnics are marked with an expiration date of serviceable life at which time they are withdrawn from service and assigned to another use, such as training. These flares are identified by a 2-inch blue band painted around the flare case. Further information will be found in OFSB 3-9.

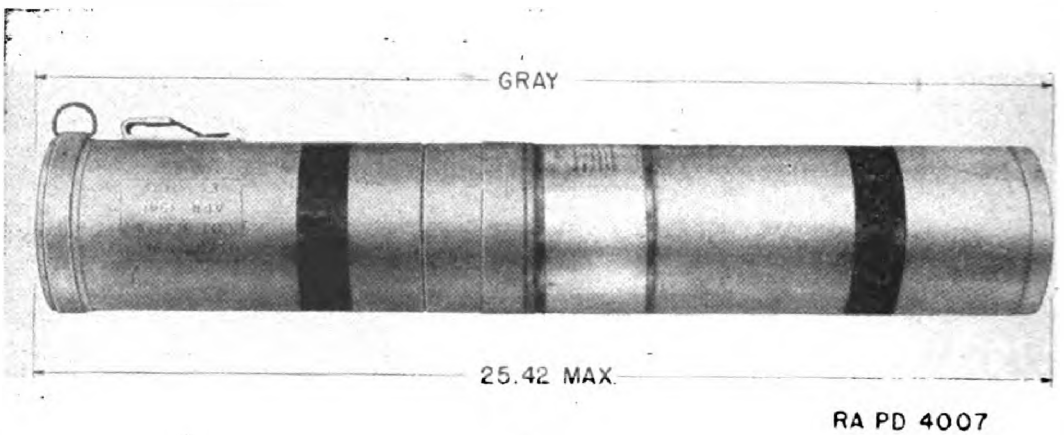

Figure 66. Flare, Aircraft, Parachute M8A1.

Flare, Aircraft, Parachute M8A1. The flare, M8A1, is used primarily for emergency night landings by airplanes in distress or for landing on fields which have insufficient ground illumination. The candle is unshaded and burns for about 3 minutes with an average candlepower of 350,000. The use of sodium oxalate in the illuminant composition gives the flame a soft yellow color. This type of light reduces the contrast between highlight and shadow, and does not tend to blind the pilot. The flare may be released from vertical or horizontal flare racks, or from internal or external bomb racks. When installed in horizontal racks, the suspension bands, which are shipped separately, must be first attached. The M8A1 reaches full ignition 3 to 5 seconds after release from the plane. Its

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average dropping rate while burning is about 8 feet per second. It may be released from planes flying at speeds not in excess of 200 m.p.h.

Description. The flare, aircraft, parachute, M8A1, is 25.4 inches long by 4.25 inches in diameter. It weighs about 18 pounds. It is packed without suspension bands in individual fiber containers, one per wire-boundbox.

Serviceable Life. The serviceable life of flares for flights where emergency night landings might be involved (OFSB 3-9) is as follows:

Six years from the date of manufacture for flares which are stored in hermetically sealed containers, or one year from the date the seal is broken; the maximum or combined period—six years.

Three years from the date of manufacture for flares which are not packed in hermetically sealed containers when manufactured, or one year from the date they are first used on an airplane; the maximum or combined period—three years.

When the serviceable life as defined above has expired, flares which are otherwise serviceable will be assigned to training. This applies to all flares even though they have not been used on airplanes. Flares so assigned will have a blue band approximately 2 inches wide painted around the body immediately below the label. This will be done at the points where the flares are located. Pending incorporation of date explaining the significance of the blue band in suitable technical or training regulations the flares may be stenciled "for training use only."

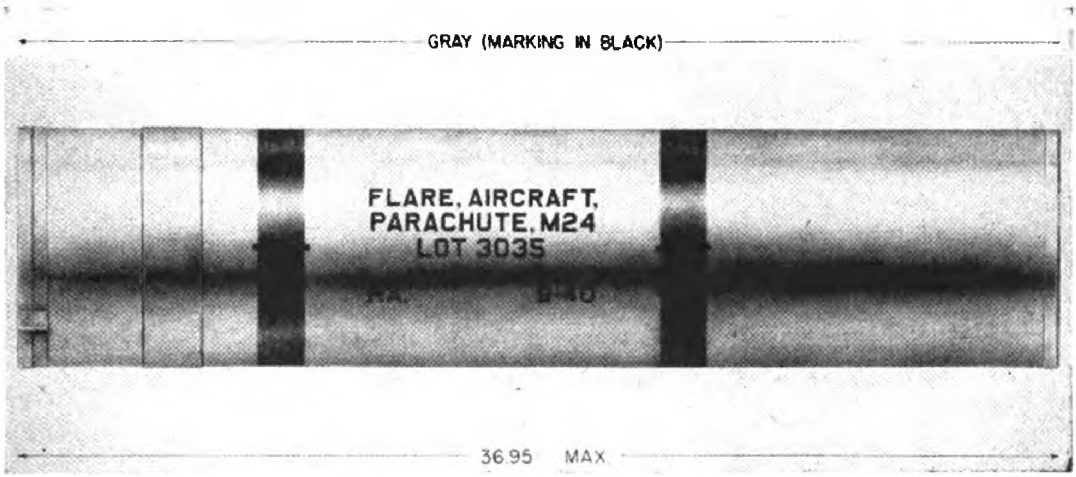

Figure 67. Flare, Aircraft, Parachute M24.

Flare, Aircraft, Parachute M24. The M24 flare is substitute standard for night bombardment and observation. It is similar to the M8A1, except that the candle is shaded and is designed to burn with a minimum of 800,000 candlepower for 3 to 3½ minutes. This increase in illumination is obtained by incorporating more magnesium and less aluminum into a candle 50% longer, the increased burning rate consuming the flare in about the same time as the M8A1. This flare is hung from horizontal racks and is designed for release from planes flying at an altitude of 2500 to 3000 feet at speeds not greater than 200 m.p.h. The M24 reaches full ignition about 5 seconds after release from the plane. Its average dropping rate while burning is about 11½ feet per second.

Description The flare, aircraft, parachute, M24, is 37 inches long by 8 inches in diameter. It weighs 47 pounds. Most of this increase in size and weight is caused by the shade assembly. The M24 flare is packed one to a carton, one such carton to a box.

Flare, Aircraft, Parachute AN-M26 (With Fuze, Nose, Mechanical Time, M111-A2). This flare is designed for high altitude night bombardment. It incorporates the M111A2 variable time fuze which permits the flare to function 2,000 to 3,000 feet above ground when released from altitudes of 6,000 to 25,000 feet. The

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parachute-supported, shaded candle is identical with the M24; however, a substitute composition which gives a light of only 600,000 C.P. may be used, as indicated on the data card. Like the M24, the M26 flare may be released only from horizontal racks, and from planes flying not more than 200 m.p.h. Its dropping rate while burning is 11½ feet per second.

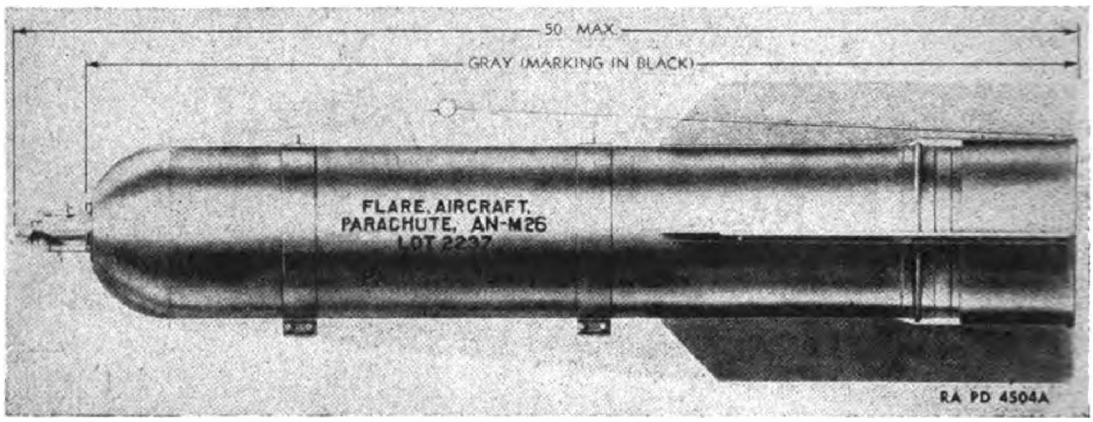

Figure 68. Flare, Aircraft, Parachute AN-M26. With Fuze, Nose, Mech. Time, M111A2.

Description. The sheet-steel flare case is cylindrical, with the nose rounded and adapted for the M111A2 fuze, and the tail is finned. It is 50 inches long (fuzed) and 8 inches in diameter. It weighs 53 pounds (fuzed), and is equipped with two suspension lugs, the rear lug being located above the center of gravity of the flare. A shipping cover with handle closes the tail end of the body and is sealed by a strip of tape.

Special Precautions in Handling. Fuzes will be handled with care at all times. They will be assembled to, and disassembled from, the flare as directed, with particular attention to keeping the seal wire and safety pin in place until after the arming wire is inserted. The seal wire and safety pin will be replaced before removing the arming wire if the fuze is disassembled from the flare.

In assembling the arming wire hangwire and in installing the flare in the plane, care will be taken not to pull so strongly on the hangwire as to loosen or remove the hangwire container.

If the fuze is disassembled from the flare, care will be taken to replace the fuze hole plug, to replace and reseal the shipping cover on the flare, and to repack and reseal the flare and the fuze in the original containers.

Packing and Marking. The parachute aircraft flare M26, is packed, one to a sealed metal-lined wooden box, with or without a fuze, in a fuze can. The mechanical time nose fuze M111A2, when shipped separately, is packed one in a metal container, 50 such containers to the wooden box.

Fuze, Flare, Mechanical, Time, M111A2 (Nose). *Description.* This fuze is classified in regard to function as time and impact and, in regard to arming, as a combined arming vane-arming pin type. It is designed to function a predetermined number of seconds (from 5 to 92 seconds) after release or, if not previously operated by the time mechanism, to function on impact. When the arming wire is withdrawn as the fuze is released armed, the arming pin is ejected, allowing the time mechanism to start. At the same time the vane assembly is released to be turned by the air stream. The vane acts through a reduction gear to release a C-shaped safety block from its position between the striker head and the fuze body. This occurs approximately 3 seconds after release, that is, after approximately 750 feet of air travel. Once the safety block is ejected, the firing pin is restrained only by a detent which is released, at the expiration of the time set, by the clockwork mechanism. If impact should occur before the time elapses, the detent is sheared and the firing pin is driven into the primer.

Data. The fuze is about 4.5 inches in length. The body is cylindrical and 1.74 inches in diameter. The vane assembly is 3 inches in diameter and the vanes are set to rotate counterclockwise. The time is graduated in half-second inter-

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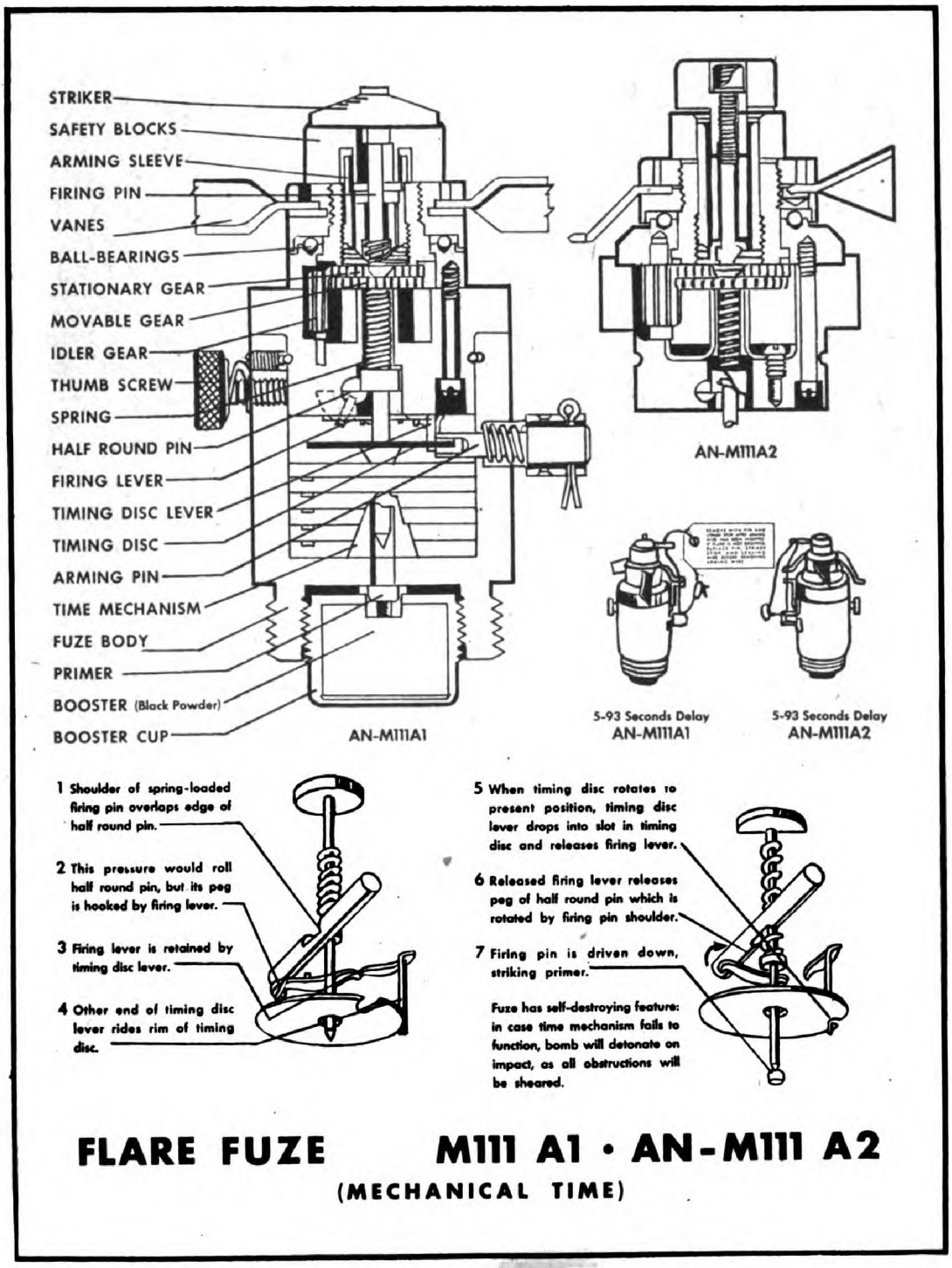

Figure 69. Fuze, Flare, Mechanical Time, M111A2 (Nose).

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vals from 5 to 92 seconds. In order to set the fuze for the desired time, it is necessary to perform the following steps. Loosen the time set screw, turn the head of the fuze until the number of the seconds desired is opposite the index mark near the set screw, and retighten the set screw.

Earlier Models. Earlier models of this fuze differ as follows:

Fuze, flare, mechanical, time, M111A1: The safety block is made up of three segments instead of being a single C-shaped piece.

Fuze, flare, mechanical, time, M111: The time setting range is from 15 seconds minimum (instead of 5 seconds) to 90 seconds.

Packing. This fuze is packed one per metal container, 50 such containers per box. As shipped, there is a safety cotter pin in the arming pin and a forked striker stop between the striker head and the safety block. A sealing wire is threaded through the vane lock, the arming wire guide, the safety cotter pin, and the striker stop, and sealed in place.

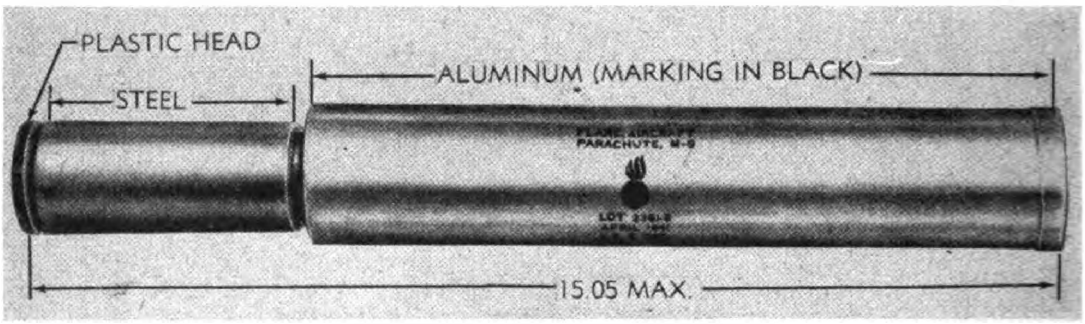

Figure 70. Flare, Aircraft, Parachute M9A1.

Flare, Aircraft, Parachute M9A1. *Description.* The flare, aircraft, parachute, M9 was developed to satisfy the requirement for a small parachute flare for reconnaissance. The complete round is supplied in cartridge form for projection from the pistol, pyrotechnic, M2, similarly to aircraft signals.

Operation. When the flare is discharged, the fuze burns for 2.5 seconds before igniting the expelling charge, which ignites the flare and expels the flare and parachute from the case. The flare burns with a white light of 60,000 candlepower for 1 minute while dropping at an average rate of 7 feet per second. The M9 flare is 13.8 inches long by approximately 2 inches in diameter, and weighs about 1.9 pounds. The M9A1 is 15.05 inches long and weighs 2.1 pounds. Although the pistol is designed for operation by one hand, the use of both hands is recommended because of the powerful recoil. The signals designed for use with this pistol may be discharged from a grounded plane but the flare, aircraft, parachute, M9 or M9A1, should not be so used. The M9A1 flares are packed in individual fiber (metal containers for M9 flares) containers, 25 such containers per box.

Flare, Tow Target M50. *General.* Flare, tow target M50 provides a target for both night and day practice firing of antiaircraft guns. The flare is towed by a plane at the end of a steel cable. When one flare burns out, another may be released from the plane to take its place. The flare is not so bright that it will obscure the navigation lights of the plane, or that it will require the use of filters in fire control instruments.

Description. The flare candle is contained in a cylindrical case of laminated paper with sheet metal caps on both ends. The closing cap on the head end is sealed with a strip of adhesive tape. Under this cap the case is closed by a wooden plug fastened in place with four wire nails. A flexible steel suspension cable passes through the center of the plug and is attached to the base block of the flare. The slack of the suspension cable is coiled in the cavity between the base block and the closing plug. Two ball fittings are clamped to the cable just inside the closing plug and serve for the attachment of the ignition wire. They also prevent the coiled suspension cable from being pulled through the plug, thus pulling the ignition wire. When the flare functions, the holding nails shear and

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the plug is pulled from the case. The ignition wires pass through a cup of primer mixture in the base block. Two strands of quickmatch connect the ignition cup with the primer and first fire composition on the outer end of the flare by passing through a paper tube in the axis of the flare candle.

Data. The flare burns with a yellowish light of 60,000 candlepower for approximately 6 minutes. The assembled flare is 23 inches in length by 2.5 inches in diameter, and weighs 7.13 pounds. It may be used effectively on a 6,000-foot towline at any combination of altitude or slant range up to 20,000 yards. The flare should not be released from a plane flying in excess of 120 miles per hour nor should it be released while the towing plane and the cable are completing a turn. Once the flare has become properly engaged on the exchange release trigger, the speed of the towing plane may be increased to any practical speed desired.

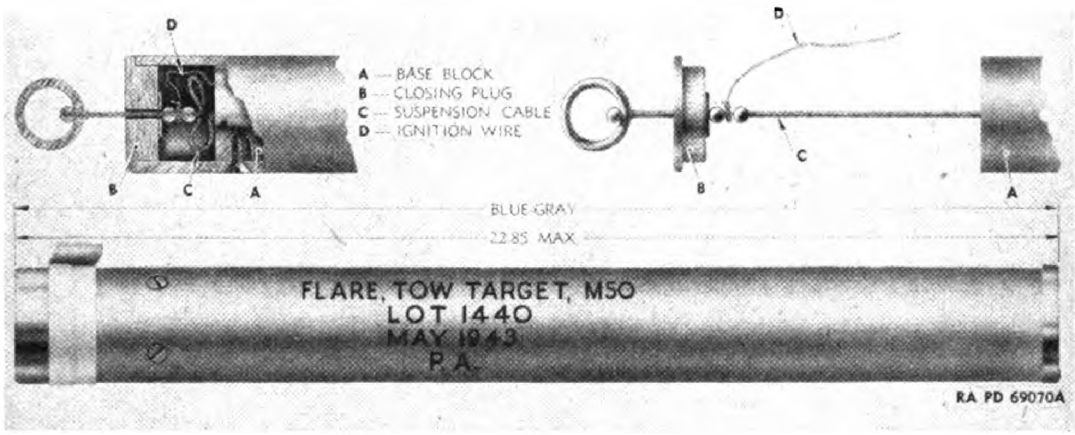

Figure 71. Flare, Tow Target M50.

Operation. For operation of the towline mechanism, see TM 1-500. To prepare the flare for launching, the sealing tape and closing cap are removed. The ring at the end of the suspension cable is tied to the lead rope. When the flare is launched, it travels down the towline until the ring of the lead rope strikes the exchange release trigger. The sudden stop jerks the suspension cable taut, pulling out the closing plug and pulling the ignition wire through the primer. The primer ignites the quickmatch, which flashes through the central tube, blowing off the base cap and igniting the flare.

Care and Precautions in Handling. In opening flare, tow target, M50, and attaching it to the lead rope, care will be exercised not to pull on the suspension cable so as to loosen or pull out the closing plug. If a flare should be found with a loose plug, the flare will not be used. In such a case, the suspension cable should not be pulled; the closing cap will be replaced and resealed and the flare marked and set aside for disposal.

Marking. The flare is painted blue gray and is marked on the side with type and model, lot number, date loaded, and manufacturer's initials.

Packing. Flare, tow target, M50, is packed one per fiber container, 16 such containers per wooden box.

SIGNALS

General. *Description.* Aircraft signals are designed to be fired from pistol, pyrotechnic M2 or M8. With the exception of the single and double star signals they are all of the same size and shape: cylindrical 7.7 inches in length and 1.56 inches in diameter. Each can be identified by markings in black on the side, and by an embossed and colored identification top.

Components. Each signal, except the single and double star types, consists of an illuminant assembly with or without a parachute, depending on the type, housed in an aluminum signal case. This signal case contains a delay fuze and

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an expelling charge in its base, and is assembled in a detachable aluminum barrel (for the pyrotechnic pistol) containing a primer and propelling charge.

Loading the Pyrotechnic Pistol. The receiver of the pistol is pushed down over the primer end of the signal until the locking lug engages the groove in the barrel.

The signal is withdrawn from the rack and aimed outside the plane—45° to the rear and 45° upward.

The pistol is cocked and fired by one continuous pull on the trigger.

The pistol is pointed downward and the releasing tab depressed, allowing the empty barrel to drop clear.

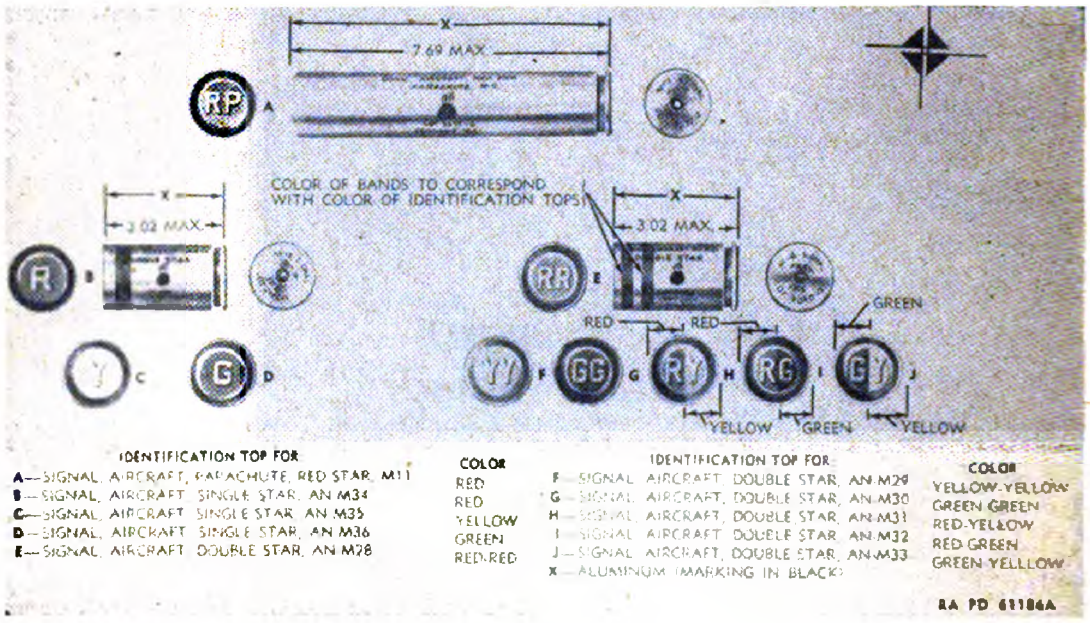

Figure 72. Aircraft Signals.

Operation of the Signal. Firing the pistol initiates the operation of the signal, as follows:

The primer ignites the propelling charge which ignites the delay fuze and propels the signal case outward.

The fuze burns for about 2 or 3 seconds and then ignites the expelling charge, at which time the signal has tumbled 150 to 200 feet through the air.

The expelling charge ignites the candle and expels the signal assembly from the case.

The signal burns, producing the effect of its type.

In the case of the single and double star signals, the illuminant assembly is projected directly from the barrel and ignited without delay. The effect is quite similar to the older Very signal lights.

Safety precautions. In addition to the general safety precautions for all pyrotechnics the following will be observed:

Signal cartridges will be guarded against a blow on the primer, as such a blow may discharge the propellant and ignite the signal.

Aircraft signals and M9 parachute aircraft flares will be examined on installation in planes. Those with dented, deformed, or cracked barrels, or with loose identification tops, will not be used.

Packing and Marking. Aircraft signals are identified by markings on the packages and on the signals themselves. In addition to the usual marking as to type, color, lot number, etc., the identification top or closing cap is painted the color of the signal and embossed—for identification in the dark—as given in the following table:

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Embossed letters	*Color of top*	*Signal*
WP	white	M10
RP	red	M11
RS	red	M14
WB	white	M15
GB	green	M16
RR	red	AN-M28, 37
YY	yellow	AN-M29, 38
GG	green	AN-M30, 39
RY	½ red, ½ yellow	AN-M31, 40
RG	½ red, ½ green	AN-M32, 41
GY	½ green, ½ yellow	AN-M33, 42
R	red	AN-M34, 43
Y	yellow	AN-M35, 44
G	green	AN-M36, 45

The single and double star signals are packed 6 to a carton, 12 cartons per box, while the larger signals are packed 12 to a carton, 5 such cartons per wooden box.

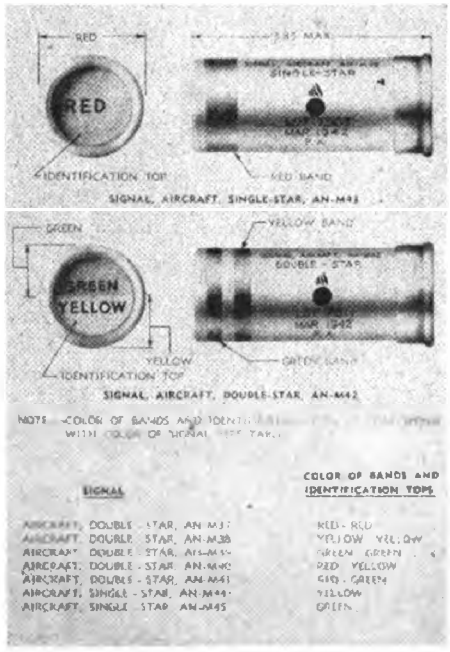

Figure 73. Aircraft Signals—Cartridge Type.

Signal, Aircraft, White Star, Parachute M10. This signal is limited standard. It is parachute supported, dropping at an average rate of 6 feet per second. It produces a white light of approximately 20,000 candlepower for about 30 seconds.

Signal, Aircraft, Red Star, Parachute M11. This standard signal is parachute supported, dropping at an average rate of 6 feet per second. It produces a red light of about 20,000 candlepower for about 30 seconds. This signal is the only aircraft signal which is authorized to be fired from the ground, and when so projected will mean DISTRESS. All life rafts carried in aircraft are equipped with M11 flares.

Signal, Aircraft, Red Star, Cluster M14. This signal is limited standard. It contains five freely falling stars which burn simultaneously, from 8 to 11 seconds, each producing a red light of about 4,000 candlepower.

Signal, Aircraft, White Star, Blinker M15. This signal is limited standard. It is parachute supported, dropping at a rate of about 6 feet per second. The candle

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burns for about 45 seconds, producing alternately a white light of 10,000 candlepower for 5 to 6 seconds, and a so-called dark light (which is almost invisible) for 4 to 5 seconds, until five periods of light occur.

Signal, Aircraft, Green Star, Blinker M16. This signal is limited standard. It operates in the same manner as the M15 white star blinker, except that the intervals of green light produce a candlepower of 1,500 and burn for about 7 seconds.

Signals, Aircraft Double Star. There are two series of double star signals, the so-called interim type, having an aluminum base and barrel, and the final type, having a brass base and cardboard barrel. The interim type is limited standard. The final type is standard. These signals produce two simultaneously burning stars upon projection from the pyrotechnic pistol or discharger. They come in six color combinations of red, yellow, and green.

Types. The following table lists the double star signals.

Interim type: Aluminum Barrel:

	Color		*Candlepower*		*Burning*	
Nomenclature	*1st Star*	*2nd Star*	*1st Star*	*2nd Star*	*Time*	*Projector*
AN-M28	Red	Red	9,000	9,000	7-sec.	M2
AN-M29	Yellow	Yellow	2,000	2,000	7-sec.	or
AN-M30	Green	Green	6,000	6,000	7-sec.	M8
AN-M31	Red	Yellow	9,000	2,000	7-sec.	Pyro.
AN-M32	Red	Green	9,000	6,000	7-sec.	Pistol
AN-M33	Green	Yellow	6,000	2,000	7-sec.	

Final Type: Brass base, cardboard barrel.

	Color		*Candlepower*		*Burning*	
Nomenclature	*1st Star*	*2nd Star*	*1st Star*	*2nd Star*	*Time*	*Projector*
AN-M37	Red	Red	25,000	25,000	7-sec.	M8
AN-M38	Yellow	Yellow	12,000	12,000	7-sec.	or
AN-M39	Green	Green	20,000	20,000	7-sec.	M5
AN-M40	Red	Yellow	25,000	12,000	7-sec.	Pyro.
AN-M41	Red	Green	25,000	20,000	7-sec.	Dis-
AN-M42	Green	Yellow	20,000	12,000	7-sec.	charger

Signals, Aircraft, Single Star. These signals are similar to the double star type except that only one red, yellow, or green star is projected. They come in two types. The interim type, now limited standard, and the final type which is standard for issue and manufacture.

Types. The following table lists the single star signals:

Interim type: Aluminum Barrel:

Nomenclature	*Color*	*Candlepower*	*Burning Time*	*Projector*
AN-M34	Red	9,000	7 seconds	M2 or M8
AN-M35	Yellow	2,000	7 seconds	Pyro. Pistol
AN-M36	Green	6,000	7 seconds	
Final Type.				
AN-M43	Red	25,000	7-13 sec.	M8 Pistol or
AN-M44	Yellow	15,000	7-13 sec.	M5 Pyro. Discharger
AN-M45	Green	30,000	7-13 sec.	

Drift Signals. A drift signal is an aid to navigation of aircraft flying over water. It provides a stationary reference point on the surface of the water for determining the sidewise drift of the airplane. It is a small, bomb shaped device, usually dropped overboard by hand. The drift signals now used include the following:

(1) The AN-Mk I
(2) The AN-Mk IV
(3) The M25
(4) The AN-Mk V

Signal, Drift, AN-Mk. I. *Description.* The signal consists of a stream-lined, moulded paper shell containing 2 pounds of fine bronze powder of the composition: Copper, 82%, Zinc, 17%, Oil 1%. The total weight of the signal is approximately 3 pounds. The shell is rigid, waterproof paper 1/16 inch thick. The

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nose is of hemispherical shape, 3½ inches in diameter, while the body is 10 inches long and tapers to a blunt point. The cone of the tail has 4 paper fins formed as an integal part of it, which tend to stabilize the signal in flight. Because the paper shell is fragile, these signals should be handled with care to prevent their destruction by breakage.

Operation. The signal is dropped by hand. Upon impact with water, the thin paper shell body breaks, scattering the metallic powder, which forms a bronze slick upon the water. The minimum altitude for dropping to insure breakage of paper shell is 100 ft. This drift signal is effective only in daylight.

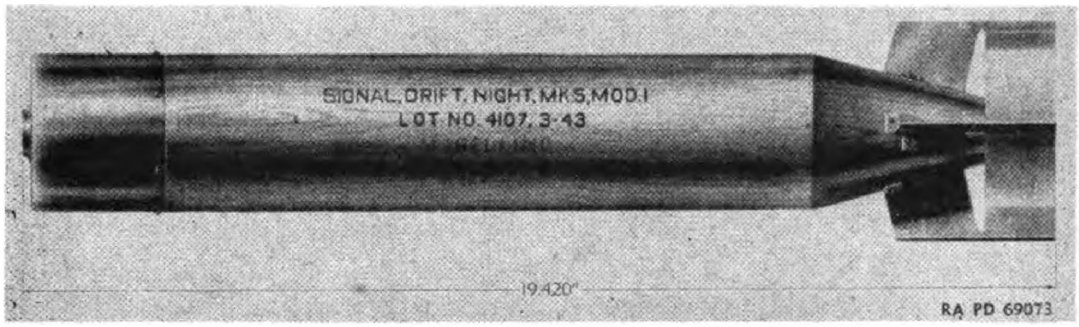

Figure 74. Signal, Drift Night, AN-Mk. 5 Mod. 1.

Signal, Drift, AN-Mk. IV. This small torpedo-shaped signal is 13.3 inches long and 2.9 inches in diameter. It has a rounded metal nose and an aluminum alloy tail fin assembly. Inside its hollow-wooded body is an ignition composition which is functioned by impact with water, producing both flame and smoke. The signal burns for about 3 minutes, floating in a vertical position, nose down.

Signal, Drift, AN-Mk. V. This signal is similar to the signal, drift, AN-Mk. IV in its use and operation, but differs in construction in the following features:

Its overall length is 18.82 inches compared to the 13.3 inches of the Mk IV.

It containss 3 ignition pellets of the type contained in the Mk IV instead of one.

The ignition pellets are contained in a bakelite tube instead of a lead tube as in the Mk IV.

These changes increase the volume of smoke and flame emitted at any given time by a considerable amount, as well as lengthening the burning time. The AN-Mk V is the latest type of drift signal, and will eventually replace both the M-25 and the Mk IV.

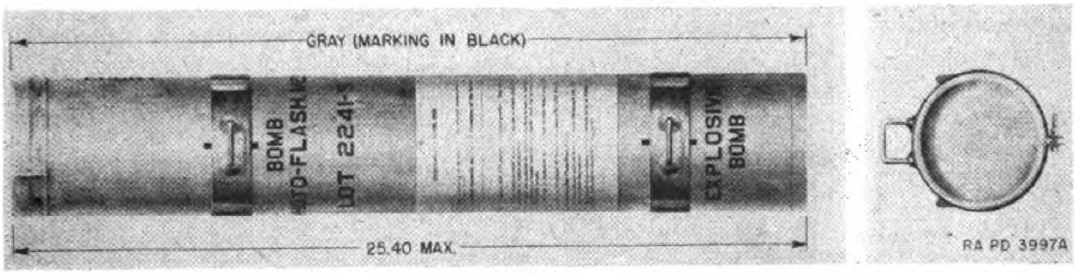

Figure 75. Bomb, Photoflash M23A1.

Bomb, Photoflash M23A1. Photoflash bombs are designed to provide a light of high intensity and short duration for night photography. In function they are strictly pyrotechnic but are designated bombs because of their explosive effect. They consist of a charge of flashlight powder and a means of ignition. The M23A1 replaced the larger and more costly M12A1 as photographic technique improved.

Description. Bomb, photoflash, M23A1, is in the shape of a cylinder 25.4 inches long and 4.25 inches in diameter. Its weight is 10.5 pounds, of which 7.75 is flashlight powder charge. The front end (*Front* is marked on the case for the information of persons attaching suspension bands and installing bomb in rack) con-

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tains the hangwire assembly and hangwire container. It is closed by a shipping cover sealed with adhesive tape. When functioned, the charge produces a light reaching a peak of 100 to 300 million candlepower during an interval of 0.17 second.

Care and Precautions in Handling. In addition to the precautions given on the label of the bomb itself, the following precautions will be observed:

A photoflash bomb, which is dropped safe or whose fuze fails to function, may detonate on impact. Any that do not will be sought out and destroyed in place by authorized and experienced personnel.

Because of the brilliance of the flash, it is detrimental to vision to watch the explosion of photoflash bombs, even at distances prescribed as safe from bomb fragments.

Packing and Marking. Bomb, photoflash, M23A1, is packed in individual fiber containers, one such container per wire-bound box.

The bomb is marked to indicate the position of suspension bands, to indicate the front, and with regulation information as to type, model, and lot. The label also carries instructions as to storage and handling.

Bomb, Photoflash M23. The M23 is an earlier model with which it is necessary to use an adapter with certain lots as a means of allowing the bomb to clear the plane by 90 to 100 feet before functioning.

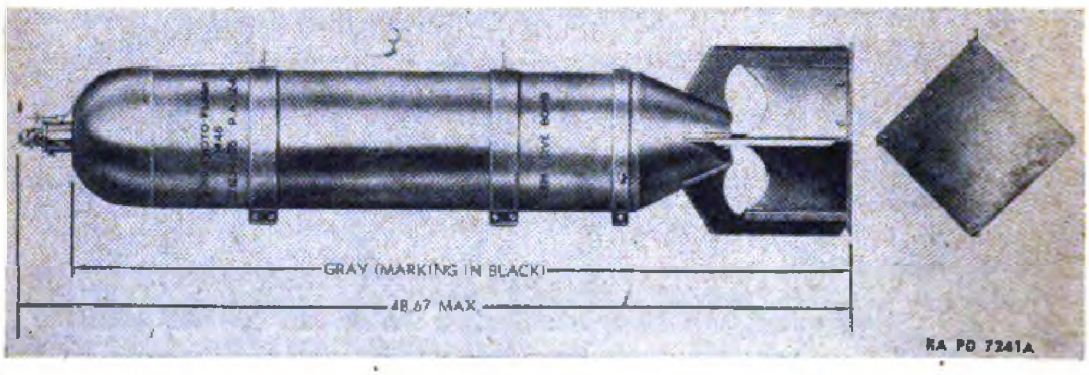

Figure 76. Bomb, Photoflash, M46.

Bomb, Photoflash M46. The bomb, photoflash M46, has been recently developed by the Ordnance Department to satisfy the requirements of the Air Force for a source of illumination which might be dropped from high flying reconnaissance planes for the purpose of night photography. The older M23A1 bomb gives sufficient illumination for night photography at altitudes up to 5000-6000 feet, but at higher altitudes is not satisfactory because it functions too soon and with too little illumination. The M46 overcomes these difficulties by the use of a larger amount of photoflash powder, 25 pounds, set off by the same M111, mechanical time delay fuze that is used on the M26 aircraft, parachute flare for high altitude night bombardment.

Description. In appearance bomb, photoflash, M46 resembles the 100-lb. M47 chemical bomb. It consists of a thin-sheet steel cylindrical body to which a rounded nose and box fin tail assembly are attached. The overall length of the bomb is 45¼ inches, and the body diameter is 8 inches. The nose is adapted to take the M111 nose fuze, which can be set to function from 15 to 93 seconds after the bomb is released. Thus, when dropped from altitudes of 6,000 to 25,000 feet, the bomb can be set to function at 2,000 to 3,000 feet. Bomb, photoflash, M46 will illuminate for photographic purposes an area of about five square miles, developing a maximum candlepower approaching one billion. At the peak of its intensity the camera shutter is functioned by a photo-electric cell, and the resultant photograph taken from altitudes up to 20,000 feet is comparable to one taken in daylight.

Special Precautions. Should the mechanical clockwork fail to function the M111 fuze at the predetermined time, impact with the ground will. Consequently, use of the M46 is hazardous over friendly terrain.

In storage and handling, photographic flashlight powder is considered as hazardous as an equal amount of black powder. Should any duds or unserviceable

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bombs be encountered, they should be destroyed in accordance with the provisions found in TM 9-1900. One ½-lb. TNT block should suffice for such destruction.

AERIAL MINES

NAVAL GROUND MINES (AIRCRAFT)

The ground mine is so called because it rests on the sea bottom. Its unfamiliar cylinder shape is almost entirely a development of World War II. Laid by aircraft, ship, or submarine, the ground mine is limited in its usefulness only by the fact that it cannot be laid effectively in very deep waters. The weight of the mine prevents it from rising to the surface or rolling about.

Firing of a Mine by Acoustic Influence. The newest type of firing mechanism does not require actual contact between mine and ship, but only the presence of a vessel near the mine. For this reason, mines so detonated are known as 'influence,' as opposed to 'contact,' mines.

Two means through which a ship's presence are translated into firing influence are: (1) the sound created by the ship's screw or engines, and (2) reaction to the magnetic field of the vessel.

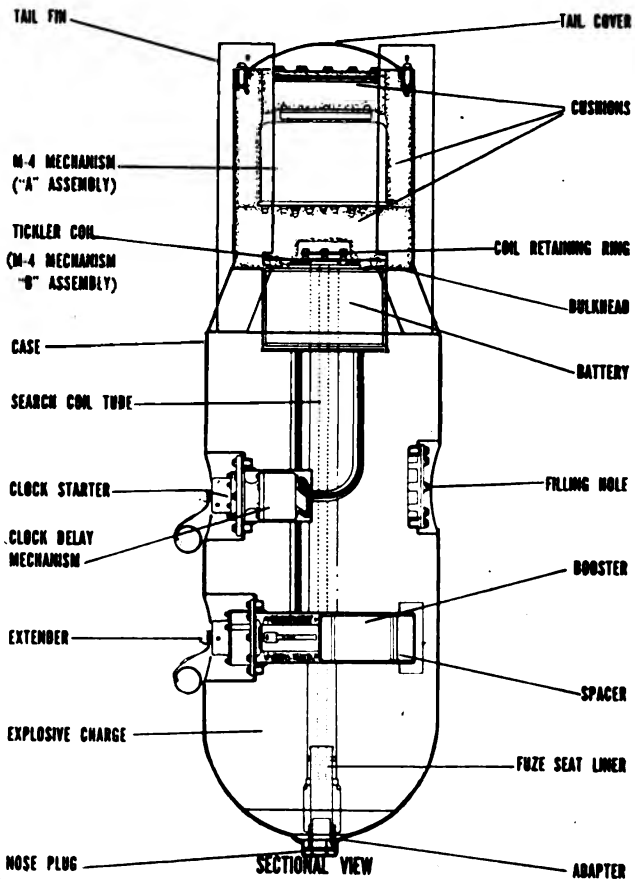

Figure 77. Mine, Mk. 13 (Navy).

The pounding of a ship's engines, the churning of the screws, and the disturbances of the water along her hull create a considerable underwater din. This noise travels great distances through the water. In the acoustic mines, a mechanical ear installed in the mine case will react to these waves; and when a ship approaches close enough for the sound to be of sufficient intensity, the ear closes a contact and fires the mine. The diaphragm in a telephone is an example of this principle. No means has yet been found to neutralize the sound of a vessel's passage through the water.

Firing of a Mine by Magnetic Influence. The magnetic mine was one of Hit-

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ler's first secret weapons. Although the American and British services had experimented with it, the Germans were the first to put the device to use.

The principal components of a Mk. 13 magnetic mine are:

Case Mk. 13.
Extender—Mk. 12 Mod. 2, or Mk. 12 Mod. 4.
Firing mechanism—M-4, M-4 Mod. 1, or M-4 Mod. 2.
Battery—B-6 (two).
Cushion—Mk. 2.
Clock delay mechanism—CD-1 Mod. 1, or CD-6 with CA-2 cable.
Clock starter—Mk. 1 Mod. 2, or Mk. 1 Mod. 4.
Electric detonator—Mk. 1 Mod. 1.
Booster—Mk. 6 Mod. 1, Mk. 6 Mod. 2, or Mk. 6 Mod. 3.
Explosive charge—Cast TNT, 640 pounds or Torpex, 700 pounds.
Thermostat—T-1 (optional).
Bomb fuze AN-Mk. 219 (optional).
Auxiliary booster (two).

CHART XXXIIIA
AERIAL MINES

Mine Type	Case	Diameter	Length	Material and Shape	Method of Laying	Firing Mech.	Extender	Booster	Detonator
MK12 Ground Mod 1 Influence	MK12-1	20.812	130.0 inches	Aluminum cylindrical	Aircraft	M-3 M-3-1 Needle	MK12-1 MK12-4	MK6 MK6-1	MK1-1
MK12 Ground Mod 4 Magnetic	MK12-1	20.812	94.0 inches	Aluminum cylindrical	Aircraft	M-3	MK12 MK12-5	MK6 MK6-1	MK1-1
MK13 Ground Influence	MK13	19.875	69.0 inches	Steel case; shaped like a bomb	Aircraft	M-4 M-4-1 Ind.	MK12-2 MK12-4	MK6-1 MK6-2 MK6-3	MK1-1
MK13 Ground Mod 4 Influence	MK13	19.875	69.0 inches	Steel Case; shaped like a bomb	Aircraft	M-4 M-4-1 Ind.	MK12-2 MK12-4	MK6 MK6-1	MK1 MK1-1
AN-MK26 Mod 1 Ground Influence	MK26	18.625	64¾ inches	Steel	Aircraft	M-9-1	MK12-4 MK14-2	MK6 Mod 1, 2 or 3	MK1-1

The iron ship is magnetized by the same magnetic field of the Earth that controls the compass needle. The Earth's field acts upon the vessel and makes it a huge magnet, which in turn puts out a highly concentrated field, shown schematically by concentric circles. The mine contains a magnetic needle which is very similar to that in a compass. The enormous magnetism of the ship is sufficient to turn the mine needle on its pivot. It is an easy matter to have this turning needle close an electrical circuit and fire the mine. In order to protect the minelaying aircraft in flight, a gap in the electrical circuit is kept open until closed by water pressure acting upon a hydrostatic plunger. The magnetic mechanism may be installed in either the ground mine or the moored mine cases.

Laying Mines by Aircraft. Minelaying by aircraft is a new development of World War II. Germany attempted early in the war to block off the British Isles by aircraft laid mines, but failed due to the British ingenuity in developing counter measures. Planes loaded with mines may penetrate far into enemy areas, planting fields in inland waters, landlocked harbors, or across well-guarded shipping lanes. Almost any aircraft capable of carrying bombs or torpedoes is adaptable for minelaying. The number of mines carried will vary with the aircraft type, but is roughly the same as for standard army-navy bombs or torpedoes.

Aircraft-laid mines are usually of the ground influence type, dropped with or without parachutes. Mines with parachutes or drogues are capable of being laid from high altitudes, as the chute will slow up descent and protect the mines' inner mechanism. However, the use of parachutes results in a slight loss of accuracy in planting. Chuteless mines must be laid from lower altitudes. Laying of such mines is less apt to be observed by minewatchers on shore.

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Aircraft-laid Offensive Field. Waters inaccessible to surface layers are readily mined by aircraft. Potential areas include anchorages upstream from a river mouth, landlocked bays, inland waterways, or closely protected coastal shipping lanes. These waters may be effectively blocked by aircraft-laid mines. An aircraft may replenish a minefield without danger to itself from mines previously laid—a danger always present with surface layers.

Degaussing Magnetic Mines. Ships may be protected against some magnetic mines by a process known as 'degaussing.' A magnetic mine is actuated by the magnetic field of a ship, but if this field can be sufficiently neutralized, the vessel may pass over the mine without actuating it. Degaussing protection is effected by application of one of the basic laws of physics. If an electrical current is passed through a wire, a magnetic field is set up around the wire. British engineers, faced with the problem of the German magnetic mine, soon decided upon the use of this principle as a means of protecting ships. They wrapped horizontal coils of wire completely around the ship at about main deck level. Strong electrical currents passing through this wire loop set up a magnetic field which is in an

CHART XXXIIIB
AERIAL MINES

Depth Control	Clock Starter	Clock	Total Weight	Buoyancy	Charge	Other Fillings	Remarks
Grnd.	CSI-1 1-4	CD-1	1,660-lb.	480-lb.	1,125-lb.	MK1 parachute MK6 chute release TD1, S.E.1, & SD-5	28-shrowd chute, 500-ft. for submarines.
Grnd.	CS-1 1-5	CD-1 CD1-4	1,500-lb.	------	1,100-lb.	Parachute	Designed like MK12-3 with parachute.
Grnd.	CSI-2 CSI-4	CD1-1 CD6	1,029-lb.	------	680-lb.	Bomb nose fuze TD-1, SD-4, T-1 thermostat	Max drop 500-ft. at 200 mph. 500-ft. deep for submarines.
Grnd.	CSI-2 CSI-4	CD1-1	1,029-lb.	------	680-lb.	Bomb nose fuze	MK13 adapted for shallow plant. CS and extender are altered.
Grnd.	CSI-4	CD10	1,000-lb.	------	525-lb.	Bomb nose fuze MK-2 parachute MK7, chute release SD-4, SC-15	Release higher 200-ft., slower 200-ft. mph 500-ft. for submarines, 3 hr. arming delay.

opposite direction to the ship's field. The total magnetic influence of the ship is thereby reduced. The wire loops are given the name of 'degaussing coils.' Degaussing coils may be clearly seen on Japanese warships, girdling the hulls at about main deck level. But more modern installations are designed with the coils placed inside the hull of the ship where they are protected against damage due to ship contact or sea action. The redesign has also made it possible to place the coils at approximately water level where they are more effective.

Minesweeping by Aircraft. An aircraft adapted for magnetic minesweeping has the obvious advantage of being able to cover large distances with great speed. The aircraft sweep is equipped with a generator for providing electric current to pass through the huge coil carried by the plane. This current sets up an extensive magnetic field which sweeps mines of this type that come within its influence. The field is strongest directly under the coil where the magnetic lines of force are concentrated. The width of the swept path of such an aircraft is rather limited, but the speed with which rivers and canals may be cleared renders aircraft sweeps admirably suited to this type of work. Certain mines, however, may not be swept or may fire at such a position as to damage the sweeping plane.

AIRCRAFT TORPEDOES

Torpedo, Aircraft, Navy Mark 13 Mod. 1 and 2. A complete torpedo is an assembly of units or sections comprising either a war or exercise head, an air flask, an afterbody, a tail, and a gyroscope.

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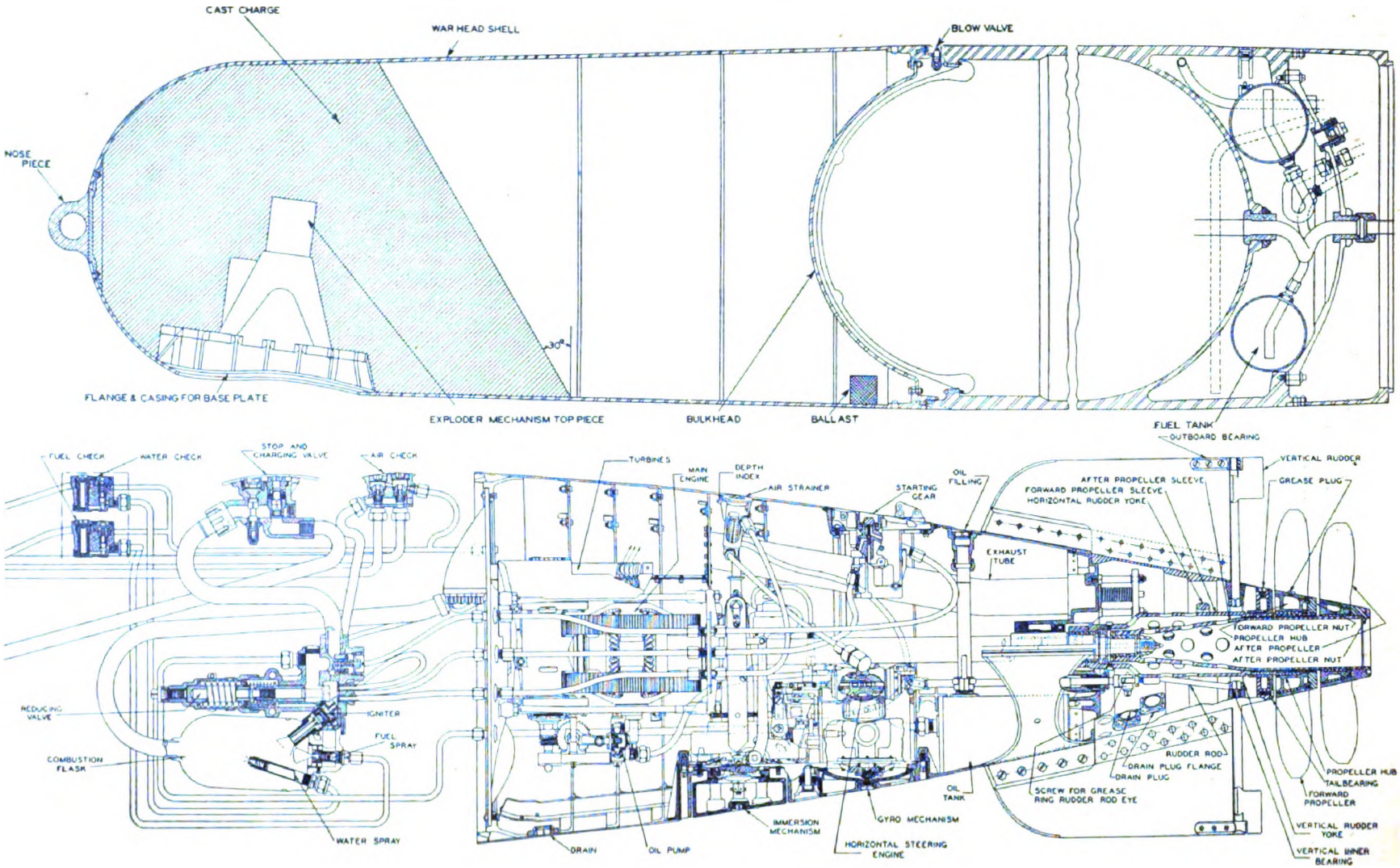

Figure 78. Torpedo, Mark 13-1 (Navy).

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The Exercise Head. Obviously, a torpedo mounting a war head cannot be given test runs or used in target exercises, and so the exercise head has been developed to replace the war head for test and practice runs. This head consists primarily of a shell of the same thickness of metal and the same outward appearance and dimensions as the war head. It is strengthened internally by means of metal rings, and at the nose by a lattice work of steel resembling a basket. In the newest exercise head the metal nose or dome section is materially thickened to resist crushing or denting.

The exercise head shell is fitted with transverse bulkheads to form two compartments. The forward compartment may be filled with sea water, the weight of which brings the total weight of the exercise head to that of a war head carrying its full charge of TNT and standard exploder. A torpedo mounting and exercise head may thus be sent through an exercise run weighted and balanced to simulate exactly a torpedo ready for war.

However, if the exercise head retained its water ballast at the end of a run, the torpedo would sink and be lost; therefore, the exercise head is equipped with devices which automatically drive out the water ballast at the end of a run, replacing it with air, which supplies the buoyancy necessary to keep the torpedo afloat until recovered.

War Head. The war head is the torpedo's reason for existence, that is, it is the vehicle for the transporting of and the means of exploding the TNT, which, if the torpedo finds its mark, may sink an enemy battleship. The war head itself is of comparatively simple design and construction. It consists of a steel shell which is identical in material and dimensions with the exercise head shell, and which is fitted with a towing eye, strengthening rings, lead ballast block, and a single bulkhead aft.

On the underside well forward is carried a flange into which may be fitted an exploder which works on the inertia principle, much as does the searchlight for the exercise head. Normally the war head, fitted with a protecting ring at the joint line, is stowed separately from the exploder. In time of war, when torpedoes may be kept in a 'fully-ready' condition for weeks on end, a servicing routine must be rigidly followed. A war head may be used only once and therefore must be kept in perfect operating condition.

Air Flask. The air flask, with which is combined the water compartment and midship section, is the main body of the torpedo. It carries the compressed air, the fuel, and the water which release the energy necessary to drive the mechanisms that propel and guide the torpedo. The forward and by far the greater portion of the air flask is for all practical purposes a storage tank for air at 2,800 pounds pressure. Air alone, however, cannot propel the torpedo for any useful distance at a substantial speed. But, by combining the air with a highly volatile fuel and with water in predetermined proportions, a gas is produced, which may be likened to steam and which provides sufficient energy to propel the torpedo at a consistent speed of $33.5 \pm .2$ knots per hour.

Afterbody. The various mechanisms and devices mounted on and within the afterbody start the torpedo, generate and apply the power necessary to drive it from a launching point to the target, determine the torpedo's vertical and horizontal courses, and maintain it on these two courses, so that it will hold true to the mark over ranges of two thousand yards and more.

The Tail. There are relatively few parts in the tail assembly; and fitting them into their proper places should present no great problem to anyone with any mechanical turn of mind at all, provided it is always remembered that the forward propeller sleeve fits into place from the forward end of the tail cone and that all other units in the assembly fit into or against the after end.

Gyro Mechanism. The gyroscope which steers the Mk 13-1 torpedo on its vertical course resembles the gyroscope tops which were once popular toys. It obeys the same natural law. The immersion mechanism which maintains the torpedo on its horizontal course at a 'set depth' resembles the pendulum of a clock.

Theoretically, a torpedo should exactly follow a straight line between its launching point and the target. Actually, however, it is prevented from so doing by such interfering agencies as cross currents which deflect it from its exact course, either to port or starboard. The gyro's function is to correct all such deviations from the

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desired course. As noted below, the manner in which the gyro performs its function results in the torpedo's actual course being a series of surges across its theoretical course.

Again theoretically, a torpedo should follow exactly a horizontal straight line at set depth between its launching point and the target. But actually, a torpedo launched from an airplane or from a deck tube first dives well below the set depth. Upon being steered towards the set depth by the immersion mechanism, it will overshoot that set depth somewhat. When steered downwards toward the set depth it will again undershoot it, and so on. In practice, therefore, the immersion mechanism merely holds the torpedo to a close approximation of its horizontal course.

References: O.P. (Navy) No. 950 U. S. Navy
Torpedoes Mark 13-1 and 2

PREPARATIONS FOR A WAR SHOT

Preliminary Adjustments. *Charge Air Flask.* Install propeller locks, remove water and fuel compartment filling plugs, remove charging valve plug, seat starting piston by rotating starting index spindle, open stop valve, install charging line and wing nut securing the wing nut with the safety strap, admit air to charging line and charge air flasks to 1,000 lbs./sq. in. Remove wing nut and strap after closing stop valve.

Drain Air Flask. Rotate torpedo 180 degrees, remove air lead from blow valve to exercise head, open blow valve. All condensed water should be forced out through the blow valve. For a war shot do not replace air lead.

Oil and Grease. Fill oil tank, stir gently after filling to remove all air bubbles. Remove after propeller sleeve and bushings, clean thoroughly and grease with tail bearing compound. Remove grease packing plug from after propeller shaft and grease with gun. Replace grease packing plug and after propeller sleeve, bushings, hub, and propeller. Secure with lock nut. Fill tail bearing with tail bearing compound and also forward propeller hub. Drain afterbody and tail from drain plugs.

Clean and Oil Valves and Strainers. Remove fuel and water air checks, clean, blow dry with air, oil with gyro oil, replace. Remove fuel and water delivery checks, clean, blow dry with air, oil with gyro oil, replace. Remove fuel and water strainers, wash with gasoline, or cleaning fluid, blow well with air and inspect for cleanliness, replace.

Check Speed Ring. Remove speed ring and check thickness with figure in record book. If satisfactory, replace and tighten.

Check and Adjust Depth Control Mechanism. Remove air strainer and install adapter. Test atmospheric chamber for leaks—it should hold, with test fixture and gauge installed, 15 lbs./sq. in. air pressure for 5 minutes. If not renew diaphram and repeat. Remove test fixtures. With stop valve closed, install test gauge and reducer and connect to adapter. After checking alignment of rudders by hand with scribe marks on tail cone and with transportation pin still installed, open stop valve (air is reduced to 400-450 lbs./sq. in. by reducer in gauge) and note position of valve in relation to valve stop. The mid-graduation should be in line with scribe mark on valve stop. If not, adjust. Check neutral position of depth rudders by tail cone scribe marks (should be 1½ scale divisions down). If out, adjust. Set depth index at 10 ft. Hoist torpedo clear of truck, and remove access plug. Using screw hook, secure 16-lb. weight. Remove transportation pin and using spirit level, level torpedo. Then with weight on, mid-graduation on depth engine valve connecting rod should be in line with reference mark on valve stop. Adjust until this is so by changing depth setting. If depth setting does not read 10 feet when marks are aligned, disengage side gear spindle and reset index. Check by moving pendulum several times. Reference marks should always realign themselves. Remove weight and screw hook and replace access plug. Set depth index on 0 and give torpedo a tilting test. Pendulum should begin to move at no more than ½ degree up or down and reach full travel at 2½ degrees tilt. Check full throws of rudders by moving pendulum by hand. Replace transportation pin.

Check Vertical Rudder Adjustment. Move propellers by hand until cam pawl

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is in its furthest position from the cam. Move steering engine valve by hand, recording rudder throws on vernier scale (both upper and lower rudder should be checked). Check vernier readings with record book. Lower torpedo on truck, close stop valve, remove test fixtures, wash and replace air strainer.

Test Gyro Mechanism. With torpedo upside down, remove gyro clamp plate and bottom head. Clean and inspect pot, oil top and bottom bearings, move cam pawls to aft position and install gyro. Replace bottom bearing. Rotate torpedo right side up and test locking and unlocking of gyro to see that it is free. Rotate torpedo 180 degrees and install gyro clamp plate and again turn torpedo right side up, after locking gyro. Center vertical engine valve by hand and then rotate propellers by hand. Vertical engine valve should not move unless top plate is incorrectly centered.

Test Depth Engine, Spinning and Unlocking Mechanism and Steering Engine With Air. Install dummy igniter, connect igniter lead, install propeller locks, remove transportation pin and install replacement pin. Install firing toggle, and hoist torpedo clear of truck. Trip starting spindle arm. Open stop valve smartly, spinning gyro, and close immediately. Remove propeller locks, and reopen stop valve starting main engines for operation of pallet mechanism. Swing torpedo in azimuth and vertically, noting operation of rudders. If satisfactory, rotate starting gear index spindle, close stop valve, and replace propeller locks. Replace transportation pin and permit gyro to run down by itself. When gyro has run down, remove, replace fuel filling plug after removing water filling plug and then replace water filling plug. Remove tension on speed ring and replace hand hole cover plates.

Final Adjustments. Any of the steps in final adjustments are repetitions of those in preliminary adjustments since quite often there is considerable lapse of time between the preliminary and final adjustments.

Oil and Grease. Remove grease packing plug and grease bearings with grease gun. Fill tail bearing with tail bearing compound. Fill forward propeller grease cavity with tail packing compound. Fill oil tank with hot running torpedo oil. *Wire propellers for flight* and install standard propeller locks. Oil Reducing valve. Check speed ring.

Check Starting Mechanism. Rotate starting gear index spindle, click should be heard. Install safety strap on starting gear spindle arm.

Charge Air Flask. Remove fuel and water filling plugs, remove charging valve plug, install charging line and wing nut. Secure wing nut safety strap. Open stop valve and begin to charge. Charge to 2,800 lbs. sq. in. Rotate torpedo 180 degrees and open blow valve to drain air flask. Check pressure and charge to 2,800 lbs. sq. in. Attach war head.

Inspect Check Valves. Remove, clean, blow dry, inspect, and oil lightly with gyro oil, the fuel and water air checks and the fuel and water delivery checks. See that action is not sluggish. Clean fuel and water strainers.

Check Afterbody Fittings. Check all joint screws, check lock nut on after propeller sleeve, check all drain plugs, replace hand hole cover plates.

Open Stop Valve.

Fill Fuel and Water Compartments. Fill fuel compartment, replace fuel filling plug. Fill water compartment, replace water filling plug. Rotate torpedo 180 degrees to port and drain combustion pot through igniter hole, keeping igniter lead clear.

Install Gyro. Remove gyro clamp plate cover and bottom head. Oil top and bottom bearings with gyro oil. With cam pawls in after position, install gyro. Replace bottom head. Check gyro for freedom of movement and clearance. Lock gyro being sure it is fully locked. Finger trip flush against pot wall will indicate this. Replace gyro clamp plate after inspecting gasket.

Prepare Depth Mechanism. Set depth index to required depth. Remove transportation pin and install replacement pin.

Install Exploder Mechanism After Testing. Assemble exploder mechanism after checking all serial numbers for match. With idler gear removed, arm mechanism and fire by push balance against firing ring, which should fire at between 3½ to 5½ lbs. pressure. Clearance between anticountermining push rod and bell crank should be .003 inch to .009 inch. Cock and unarm exploder mechanism,

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Clean exploder cavity thoroughly and install booster. Install gasket and exploder mechanism and secure. After once more testing impeller, turning pressure secure arming wire. With test fixture, check exploder mechanism with 5 lbs./sq. in. air pressure put in through test plug. There should be no leaks. Replace impeller guard.

Install Stabilizer. Rotate stabilizer 45 degrees and slip over tail vanes. Rotate back and slip onto tail vanes. Should fit securely against outboard bearing shoes.

The torpedo is now ready for loading.

Loading Procedure. *Make Final Inspection.* Replacement pin installed, propeller locks on, propellers wired for flight, starting spindle arm safety strap secured, and stop valve open.

Hoist Torpedo To Plane. Secure hoisting band to center of gravity line on torpedo. Secure hoisting cables to hoisting band and hoist torpedo into place. Install centering pin, and hoist torpedo snugly against chocks or sway braces. Secure torpedo with supporting cables. Tighten turnbuckles on supporting cables to remove any possible chance for shifting of torpedo. Check alignment of axis of torpedo with axis of plane by measuring from wing tip to center of nose ring. Distance should be the same from each wing tip. (This is only necessary where torpedo is aligned by adjustable sway braces.) Remove hoisting cables and bands. Secure detracting cables to supporting cables.

Secure Arming Wire. From loop in arming wire just above nose ring, secure the arming wire to some stationary, permanent fitting on the plane. (This may be done with any strong wire or cord.)

Install Firing Toggle. Remove one of the pins in the firing toggle brackets and slip firing toggle into place. Be careful not to trip starting spindle arm. Replace pin. Secure firing toggle to lanyard or fixture to which it is attached.

Install Igniter. Remove dummy igniter, if still installed, and install live igniter. Attach igniter air lead securely.

Remove Standard Propeller Locks.

Remove Starting Spindle Arm Safety Strap.

Maintaining Torpedo in Ready Status. With the torpedo in a fully ready condition, whether on a plane or not, if it is held in this stage for any length of time, certain routine procedures must be followed. These are set for daily, weekly, and monthly periods and are as follows:

Daily

Gauge air charge. Boost if necessary.

Check oil level in oil tank. Fill if necessary.

Weekly

Turn propellers 50 turns, then refill oil tanks.

Repack propeller sleeves with grease.

Operate depth spindle from 0 feet to 50 feet. Reset at required depth.

Monthly

Remove igniter, inspect for any signs of deterioration.

Remove drain plugs and drain.

Rotate torpedo 180 degrees, drain combustion flask enroute.

Remove exploder mechanism and booster. Turn torpedo right side up.

Remove check valve plugs, oil, and operate check valves. Clean fuel and water strainers. Clean air strainer. Reassemble.

Check action of starting gear by removing safety strap, tripping, and reseating. Replace safety strap.

Operate depth setting mechanism from 0 feet to 50 feet and resent at required depth.

Remove one hand hole cover plate and operate pendulum by hand.

Work both vertical and horizontal rudders by hand, checking freedom of movement.

Remove propeller lock and rotate propellers 50 turns. Check pallet and slide, that pallet does not engage pallet pawls while gyro is locked. Move vertical steering engine control valve by hand and note that while propellers are being turned, pallet blade does not strike pallet pawls. Listen for any unusual noises. Replace propeller lock.

Lubricate torpedo. Fill oil tank and grease all fittings.

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Open stop valve gradually, rotate torpedo and drain combustion pot.

Inspect gyro and gyro mechanism. Remove gyro, unlocking before removing bottom plate. Inspect gyro, noting that the balance nut is tight; then apply two drops of gyro oil with syringe to each bearing. Lock and unlock spinning mechanism by hand and by spinning. Replace and lock gyro. Replace hand hole cover plate and drain plugs.

Install booster, detonator, and exploder mechanism. Turn torpedo upright.

Gauge and boost air flask.

Check level of fuel, oil, and water.

Load on plane if required.

These procedures should be followed meticulously if the torpedo is to be kept available in the fully ready state at all times.

Storage. Finally we are faced with the problem of storage of ready torpedoes and war heads. Storage of war heads is a fairly simple matter. They are generally stored with bombs and other ammunition in the magazine area. The afterbodies should have inside storage where that is at all possible. At best they should be protected from the elements. However, it will depend upon the situation, and the best that can be done should be done.

It cannot be emphasized too much that extreme care must be taken with all adjustments and work done on the torpedo. Careful investigation has proved that 80% of torpedo failures are due to carelessness. If sufficient care is taken, our torpedoes will all run "Hot, Straight, and Normal."

DEPTH BOMBS AND FUZES

Depth bombs are light case bombs designed primarily for use against submerged submarines; but dependent upon the fuzing, they may be used for their demolition effect on surface craft.

The depth bomb is a short, cylindrical, light case type bomb. The fin is mounted on a cone, which, upon assembly, is bolted to the body. These bombs are adapted for use with either a transverse hydrostatic fuze which is secured to the bomb by means of machine bolts or with an impact nose fuze which is secured by threads. The bombs are shipped unfuzed with suitable plugs and plates protecting the fuze cavities. These cavities are swabbed with gun-slushing or rust preventive compound, and must be cleansed of this and other foreign matter before the fuzes are assembled.

The bomb body is provided with three suspension lugs. Two lugs are located on one side of the bomb body and are used for double hook racks and shackles. The third lug is located diametrically opposite from these two lugs, in the center of the bomb body, and is used for single hook suspension. The hoisting lug, located between the double suspension lugs, may interfere with installation on the Army B-7 shackle, but the hoisting lug may be bent aside by prying or sawing to avoid interference. *Do Not Hammer the Lugs.*

The arming wire assembly for use with the fuze, bomb, hydrostatic AN-Mk 224, AN-Mk 234, consists of a swivel loop to which are attached two lengths of wire each approximately 20 inches long. For use with the fuze, bomb AN-Mk 219, AN-M 103, AN-Mk 229, the arming wire assembly consists of a swivel loop or arming plate and a single wire approximately 22 inches long.

Assembly of a Complete Round. *Inspection.* Prior to assembly of complete rounds, examine all mating parts such as fuze cavities and fuzes for burrs and defects in threading.

Threads must be clear and all surfaces free of foreign matter.

Examine fuzes for evidence of deterioration such as rust or corrosion. Use only serviceable fuzes.

Examine fin assemblies for straightness and alignment of the fins.

Gage suspension lugs, and examine them for damage which may have weakened them.

Assembly: Remove the fin assembly from its crate and inspect and bolt it to the bomb body with one blade of the fin aligned with the suspension lugs.

Remove the fuze hole covers and thoroughly clean the fuze cavity.

Remove the pistol and its gasket from the container. Insert the pistol in either end of the transverse tube with gasket in place between the pistol flange and

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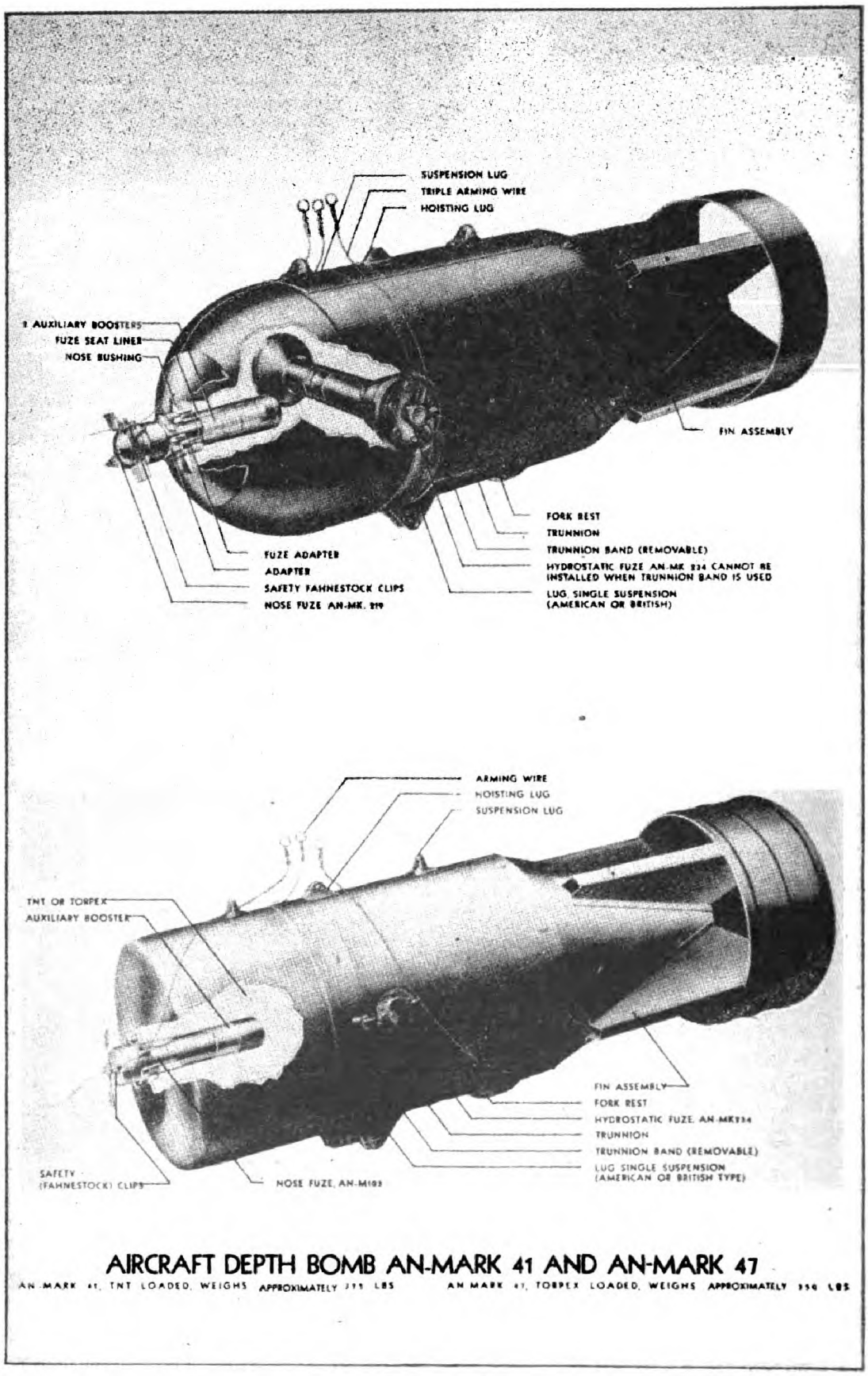

Figure 79. C. S.

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the head of the tube, taking care that the assembly enters freely and locates itself properly upon the locating dowel pin. Insert the holding screws and draw them up evenly. Be careful to tighten the screws uniformly. They should be checked two or three times, in rotation, after the initial tightening.

Remove the booster extender and the booster from the packing. Attach the booster to the extender by means of the slip joint provided. Insert the assembly, with the gasket in place, into the end of the tube opposite the pistol.

Install the arming wire (type B) into the eyelets of the jump-out pins.

Installation in the bomb stations.

Attach the shackle to the bomb.

Attach the swivel loop to the arming pawl.

Hoist the bomb into place on the rack by the means of a bomb sling and mechanical winch.

Shackle the bomb into the bomb station.

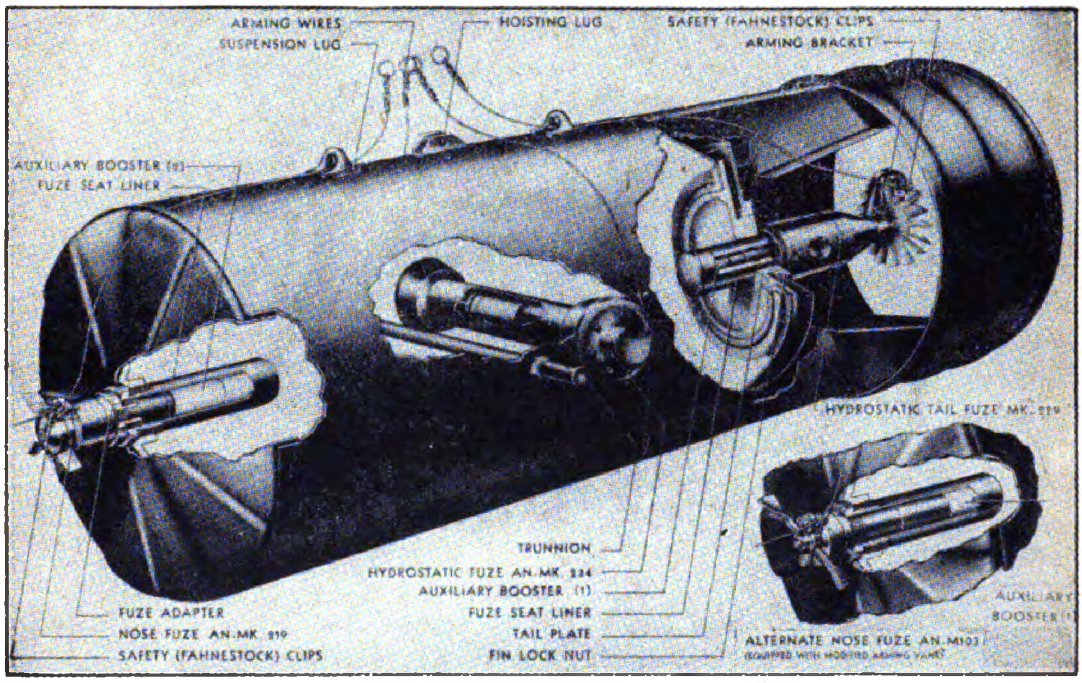

Figure 80. C. S.

Cut off surplus length of wire so that no more than 6 or 7 inches extend beyond the Fahnestock clip. Fahnestock clips are used on each end of the arming wire to keep it from vibrating out of the eyelet in the jump-out pin of the fuze.

Remove all kinks and burrs from the arming wire.

Altitude and Speed of Release. Tests show that this bomb will function if released from an altitude below 5,000 feet. However, when dropped from high altitudes, the hydrostatic fuze will function at a greater depth than that for which it is set.

If speed and altitude at release of the round nose bombs is such as to produce an angle of impact flatter than 20 degrees from the horizontal, a ricochet is probable; and if flatter than 15 degrees, a ricochet can be expected.

The minimum altitude to provide safety from blast in horizontal bombing is 100 feet with the hydrostatic fuzes armed only, and 2,000 feet with nose fuze armed.

Painting and Markings. The bomb and the fin are painted a dull olive drab

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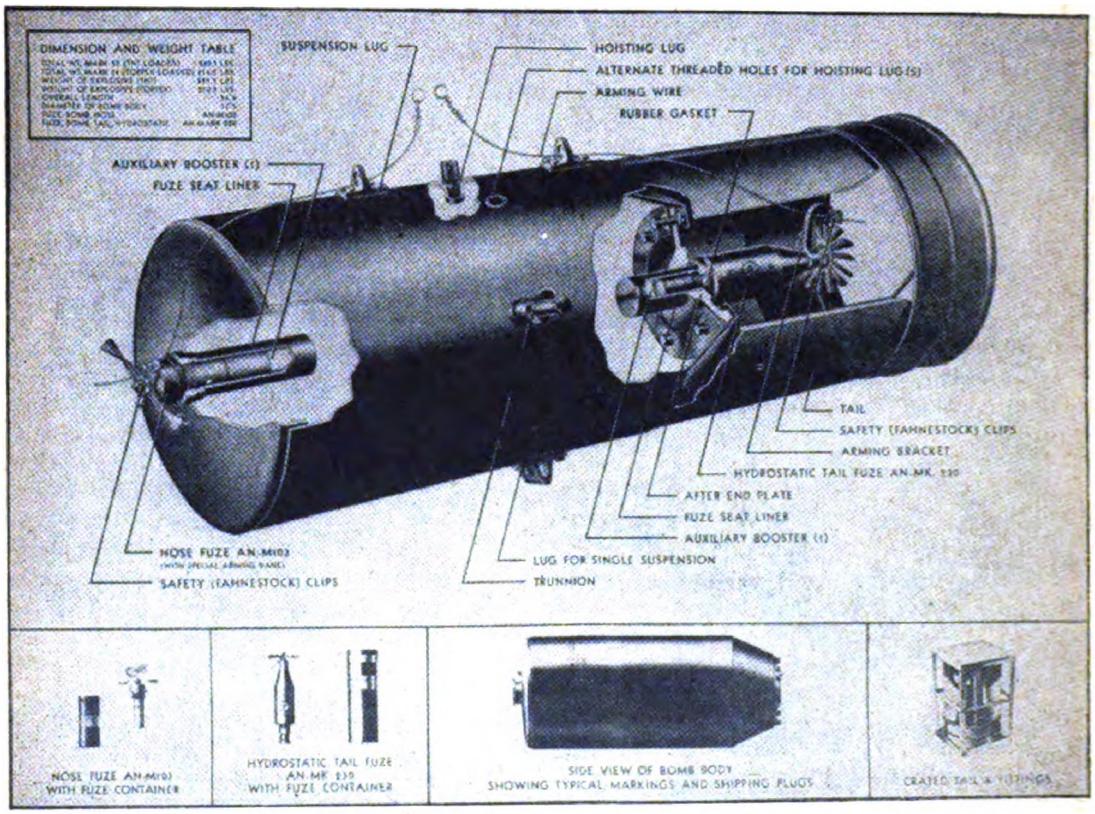

Figure 81. Depth Bomb Mark 53 and Mark 54.

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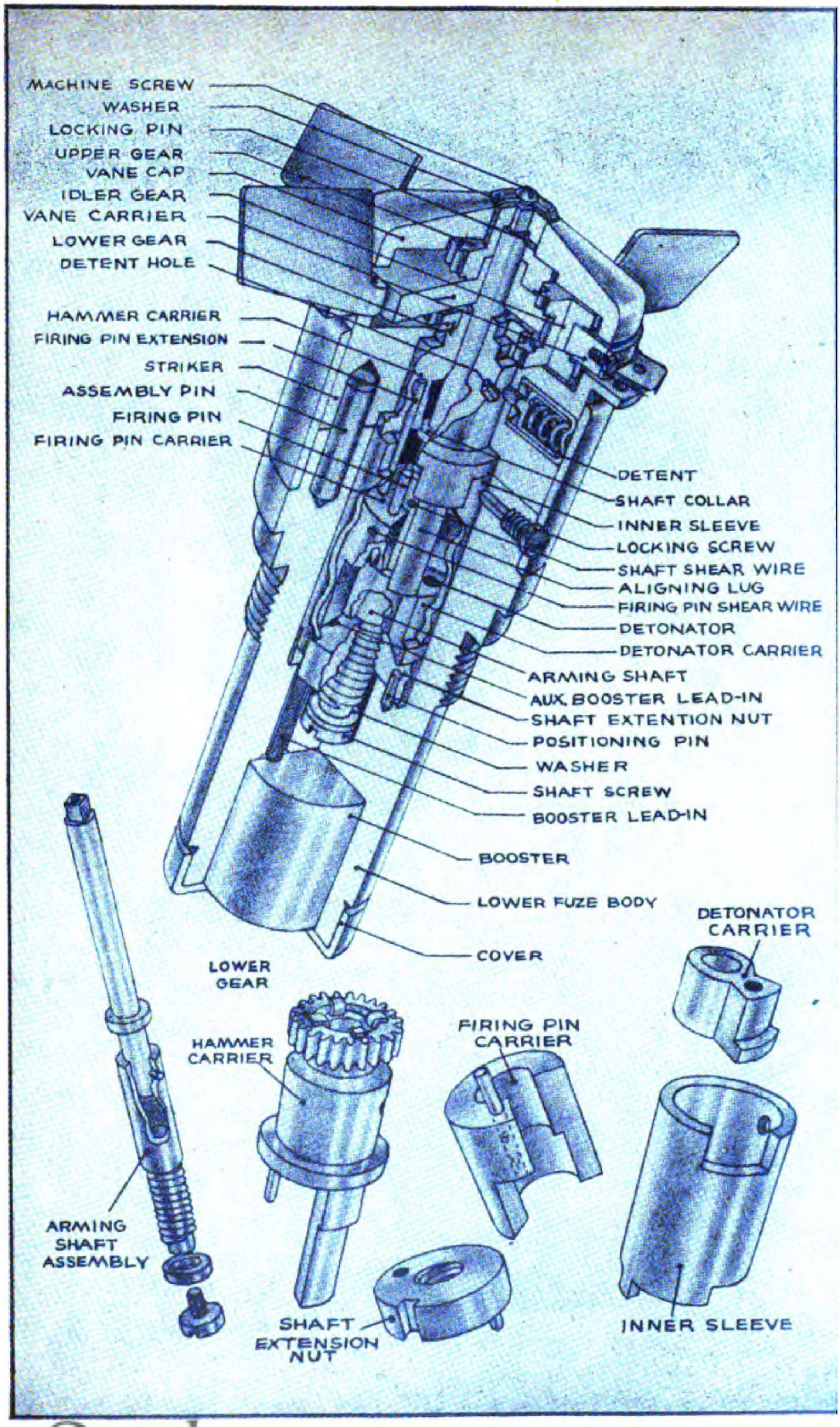

Figure 82. Fuze, Bomb (Nose) AN-MK 219

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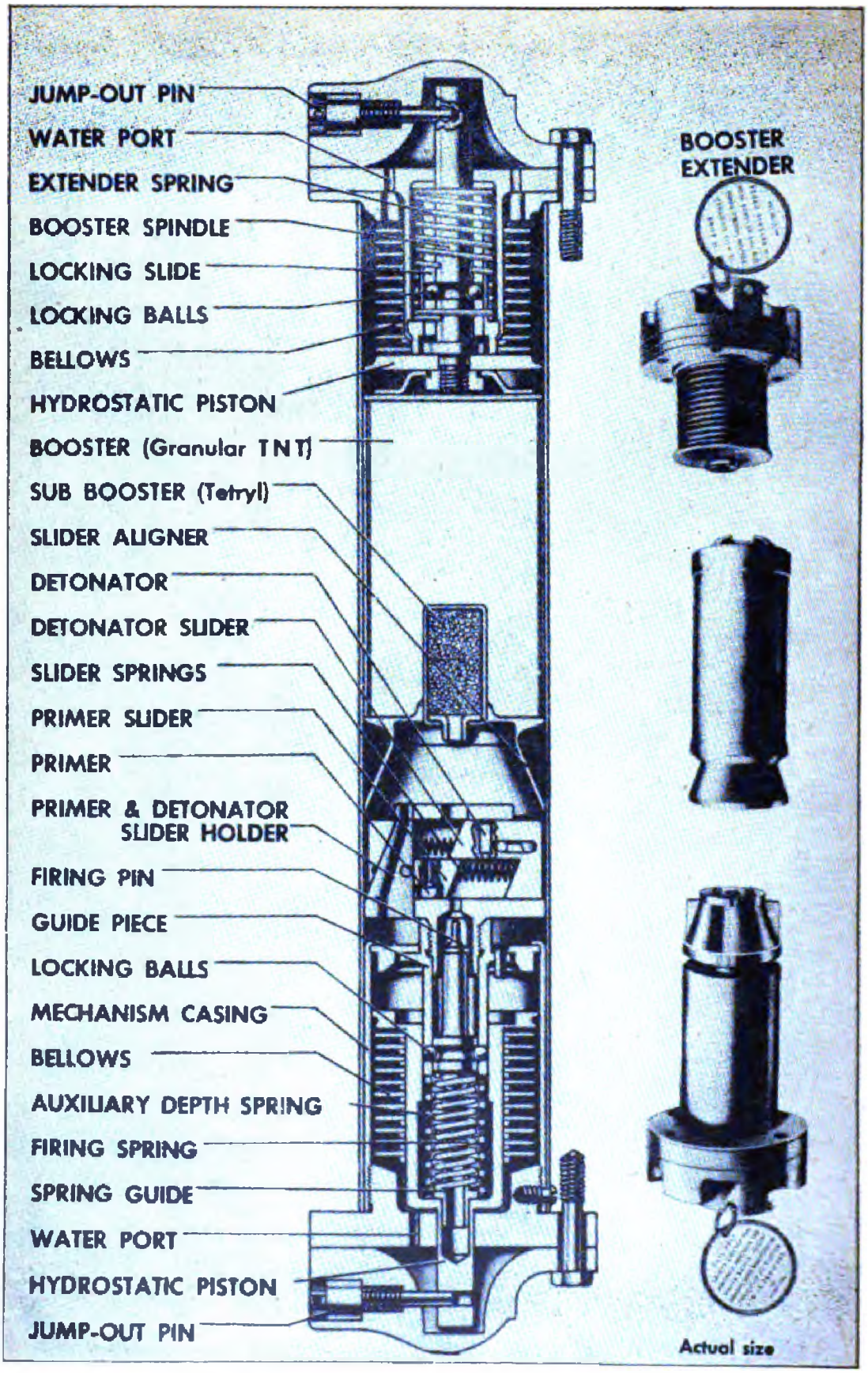

Figure 83. Fuze, Hydrostatic Attewartship AN-MK 124.

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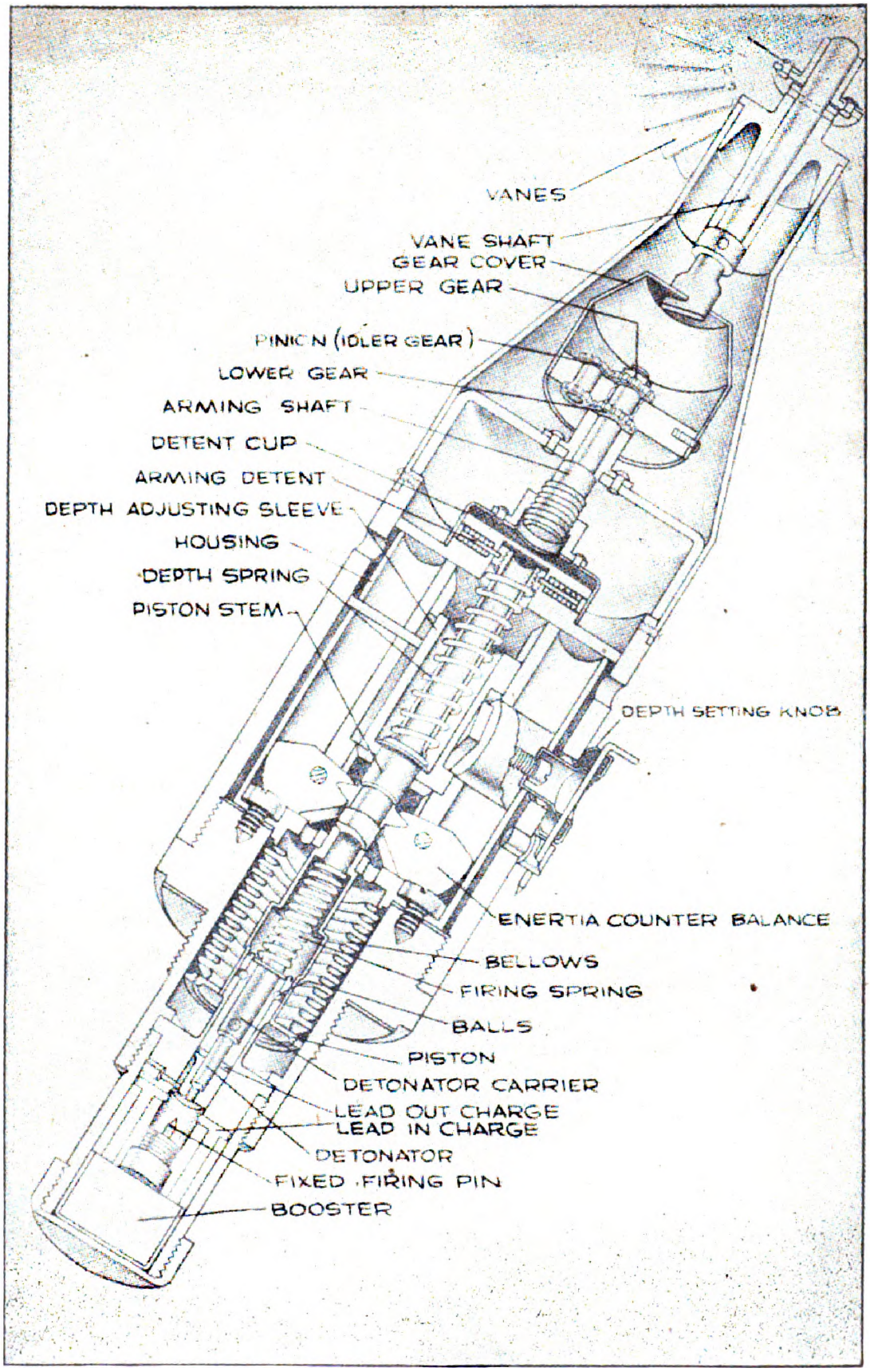

Figure 84. Fuze, Hydrostatic AN-MK 230.

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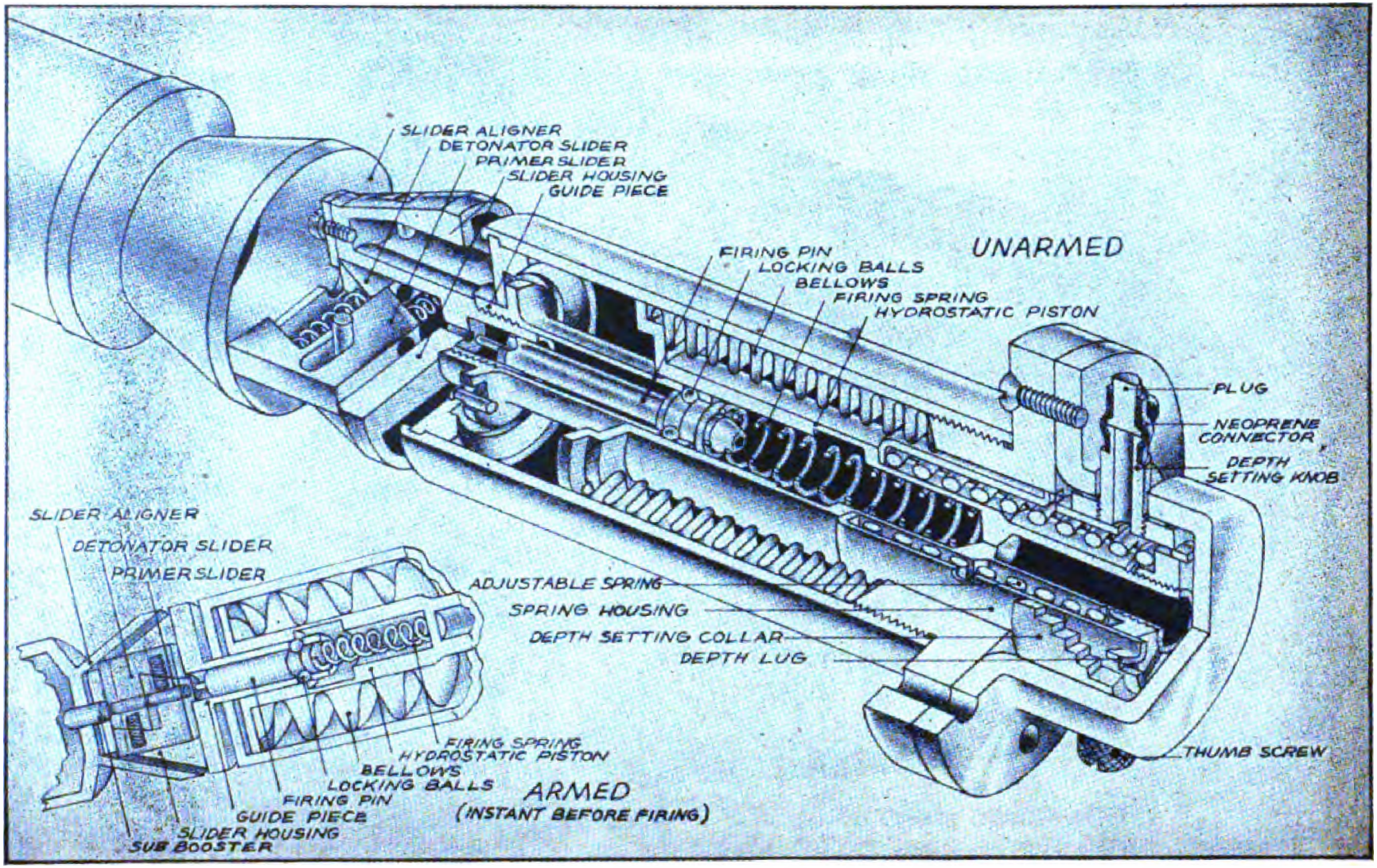

Figure 85. Fuze, Hydrostatic AN-MK 234.

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or battleship gray. If they are painted olive drab, at each end of the bomb body a one-inch yellow band indicates high-explosive filler. The center of gravity is indicated by a ¼-inch yellow band, which may be interrupted for the markings. If the bomb is painted battleship gray, a 11-inch diameter yellow circle is painted in the center of the bomb over the hoisting lug. The bomb body is marked in black with the type, weight, model, and lot number of the bomb, the type of filler, and the manufacturer's symbol.

Packing (Three Separate Units).

Bomb body is packed one per metal crate or with shipping bands.

Fin assembly is packed one per metal crate.

Fuze, hydrostatic, is packed one per crate or four per crate.

AIRCRAFT ROCKETS

Despite their relative lack of publicity, rockets fired from aircraft have proved in the war to date far more effective than their ground counterparts. The reason lies in the greater accuracy of rockets launched from aircraft. The forward speed of the plane gives the rocket greater speed in relation to air at the time of leaving the launcher, and consequently better action of the fins which results

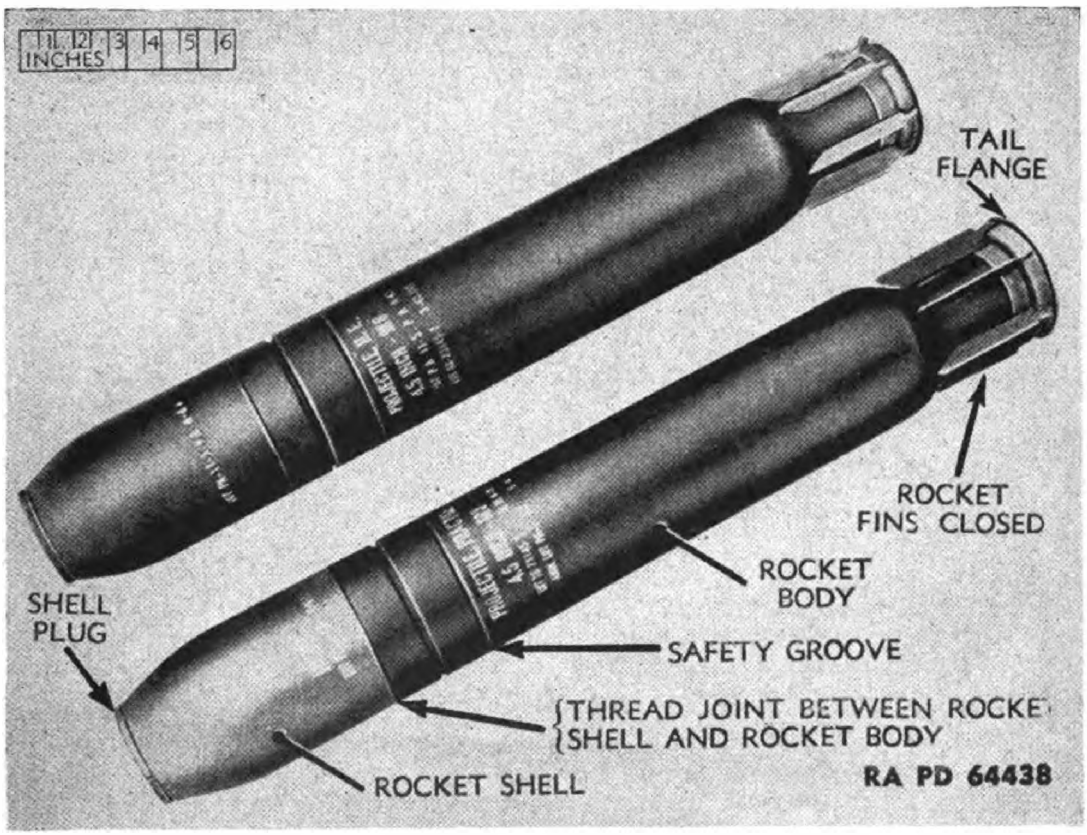

Figure 86. Rocket, 4.5 Inch, 3 Tube, A. C. M10.

in greater stability. By way of comparison, a pilot can expect an average dispersion in his rockets of from 2-4 mils, while the ground forces must anticipate a dispersion ranging from 20-40 mils.

Because of the absence of recoil in rocket firing and the consequent lightness of the launcher required, a fighter plane can be equipped with a weapon that accurately fires a projectile, which is the equivalent of that fired by the 105mm howitzer.

The Air Forces uses only one size of rocket, the 4.5 inch. It fires two rounds. Since this size is also employed by the ground forces, along with other types and sizes of purely ground force rockets, the principles of rocket propulsion and

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CHART XXXIVA
DEPTH BOMBS

Bomb Weight	Nose Round	Nose Flat	Designation	Filler-HE	Fuze Designation Nose	Fuze Designation Tail	Fuze Designation Transverse	Functioning Time Nose	Functioning Time Tail	Functioning Time Transverse
325-lb.	X		AN-Mk17	TNT	AN-Mk219 AN-Mk221 AN-M 103	None	AN-Mk224 AN-Mk234	inst. .1 sec. inst. or .1 sec.	None	25, 50, 75, 100, 125 feet
350-lb.	X		AN-Mk44	TORPEX	AN-Mk219 AN-Mk221 AN-M 103	None	AN-Mk224 AN-Mk234	inst. .1 sec. inst. or .1 sec.	None	25, 50, 75, 100, 125 feet
325-lb.		X	AN-Mk41	TNT	AN-Mk219 AN-Mk221 AN-M 103	None	AN-Mk224 AN-Mk234	inst. .1 sec. inst. or .1 sec.	None	25, 50, 75, 100, 125 feet
350-lb.		X	AN-Mk47	TORPEX	AN-Mk219 AN-Mk221 AN-M 103	None	AN-Mk224 AN-Mk234	inst. .1 sec. inst. or .1 sec.	None	25, 50, 75, 100, 125 feet
325-lb.		X	AN-Mk53	TNT	AN-Mk219 AN-Mk221 AN-M 103	AN-Mk230	None	inst. .1 sec. inst. or .1 sec.	25, 50, 75, 100, 125 feet	None
350-lb.		X	AN-Mk54	TORPEX	AN-Mk219 AN-Mk221 AN-M 103	AN-Mk230	None	inst. .1 sec. inst. or .1 sec.	25, 50, 75, 100, 125 feet	None
650-lb.	X		AN-Mk29	TNT	AN-Mk219 AN-Mk221 AN-M 103	AN-Mk229	AN-Mk224 AN-Mk234	inst. .1 sec. inst. or .1 sec.	25, 50, 75, 100, 125 feet	25, 50, 75, 100, 125 feet
650-lb.	X		AN-Mk37	TNT	AN-Mk219 AN-Mk221 AN-M 103	AN-Mk229	AN-Mk224 AN-Mk234	inst. .1 sec. inst. or .1 sec.	25, 50, 75, 100, 125 feet	25, 50, 75, 100, 125 feet
650-lb.		X	AN-Mk38	TNT	AN-Mk219 AN-Mk221 AN-M 103	AN-Mk229	AN-Mk224 AN-Mk234	inst. .1 sec. inst. or .1 sec.	25, 50, 75, 100, 125 feet	25, 50, 75, 100, 125 feet
700-lb.		X	AN-Mk49	TORPEX	AN-Mk219 AN-Mk221 AN-M 103	AN-Mk229	AN-Mk224 AN-Mk234	inst. .1 sec. inst. or .1 sec.	25, 50, 75, 100, 125 feet	25, 50, 75, 100, 125 feet

NOTE:

1. The AN-M 103 fuze with a special vane will arm on depth bombs having a flat nose or those with flat nose attachments.
2. All round nose depth bombs may be fitted with a flat nose attachment. The attachment prevents ricochet when the bombs are released from low altitudes. They increase the weight of the 325-lb. bomb by 44-lbs., and the 650-lb. bomb by 72-lbs.
3. When using the AN-Mk219 fuze, an adapter and two auxiliary boosters must be inserted into the nose fuze cavity.
4. When using the AN-Mk221 fuze, insert one auxiliary booster into the nose fuze cavity.
5. When using the AN-M103 fuze, insert one auxiliary booster into the nose fuze cavity.
6. When using the AN-Mk224 or AN-Mk234 transverse fuze in 650-lb. depth bombs, a spacer (2 inches long) will be used between the extender and booster assembly.
7. Due to numerous accidents resulting from the use of the AN-Mk224 and AN-Mk234 transverse fuzes, the bombs adapted to receive the AN-Mk229 and AN-Mk230 tail fuzes should be used in place of those adapted to receive transverse fuzes.

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CHART XXXIVB
SPECIFIC FUZES USED WITH DEPTH BOMBS

Designation	Type Nose or Tail Transverse	Type of Arming	Approximate Air Travel to Arm	Arming in Revolutions (approx.)	Functioning Time	Pertinent Facts
AN-M103	Nose	Arming vane with mechanical delay train	For inst: 510 feet For delay: 765 feet	For inst: 230 For delay: 340	Instantaneous or 0.1 sec. delay	The AN-M103, functions on impact. May be set to function instantaneously or 1 sec. delay. The fuze is detonator safe and will not function unless it is armed. A large vane assembly is used with flat nose depth bombs.
AN-Mk219	Nose	Arming vane with mechanical delay train	1,000 feet	170	Instantaneous	This fuze uses the 'rotor system' of arming. It is detonator safe. This fuze may be used when the AN-M103 fuze is not available. It can be used safely on take-offs and landings on decks of carriers.
AN-M221	Nose	Arming vane with mechanical delay train	850-1,100 feet	150	0.1 sec. delay	This fuze is essentially the same as the AN Mk219 except the body is larger and longer and it has a 0.1. sec. delay in functioning.
AN-Mk224	Transverse	Arming pin with hydrostatic arming	Approximately 12-15 feet in water	None	25, 50, 75, 100, 125 feet	Use on depth bombs only. Assembled in three main parts: pistol, booster, and extender. It is detonator safe. Should not be used unless the AN-Mk229 or AN Mk230 are not vailable.
AN-Mk229	Tail	Arming vane with mechanical delay train	400-500 feet	110	25, 50, 75, 100, 125 feet	A change in depth setting is made by an external setting dial without disassembly of the fuze. It is used in all 650 lb. depth bombs.
AN-Mk230	Tail	Arming vane with mechanical delay train	400-500 feet	110	25, 50, 75, 100, 125 feet	This fuze is identical to the AN-Mk229 except it is 1.3 inches shorter in order to be used in the 'G.P.' bombs. The operation and construction is the same.
AN-Mk234	Transverse	Arming pin with hydrostatic arming	Approximately 12-15 feet in water	None	25, 50, 75, 100, 125 feet	The AN-Mk234 differ from the AN-Mk224 in that it has an external setting device and requires disassembly to effect depth variations in functioning.

NOTE:

Detailed information on the above fuzes may be found in the Ordnance Pamphlet No. 988.

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certain detailed information concerning the aircraft rounds will be found in chapter 3, Vol. III Ammunition. In this section, there will be found only information about the type of launcher used in aircraft and the specific difference between ground and air rockets.

The Launcher. In the standard aircraft launcher, three tubes are mounted together in a cluster to form the single launcher; each tube is 10 feet long, and the complete cluster weighs about 80 pounds. If the tubes are plastic, the cluster is designated launcher, rocket, 4.5-inch, 3-tube, A.C. M10; if made of steel, they are designated M14. In mounting in the plane, one launcher is attached beneath the wing on each side of the fuselage. Usually they are hung from the wing bomb racks, although there have been successful mountings farther out toward the wing tips so that bombs could also be carried. In this type of mount, the rockets are aimed by aiming the plane, and the launchers must be carefully aligned with the line of sight. There are also authorized firing tables provided the Air Force for rocket ammunition.

Firing is done electrically from a trigger on the pilot's control stick. The pilot can set a firing selector box in the cockpit for either single firing or for the firing of the entire group of six at .1 second intervals. In addition, there is a provision for jettisoning the launcher if the need should arise.

Authorized Rounds. At present the authorized high-explosive rounds for aircraft are the rockets HE, 4.5-inch, M8A1, M8A2, or M8A3, fuzed with either the M4A1 or the M4A2 point-detonating fuze. The M8, if designated 'for aircraft', may also be used. These rounds are handled unfuzed, and are packed either three per bundle or two per box. The fuze, rocket, P.D. M4A1, SQ-0.015 sec. delay w/booster, auxiliary M1 comes separately, fifteen per wooden box; the same is true of the A2 modification. In the fuzed round, the sole distinction from the round used by the ground forces is the delay time of the fuze—the aircraft fuze has 0.136 grains of black powder for a 0.015-second delay, while the ground troops use exactly the same fuze with the same designation, except that it contains 1.23 grains of black powder for a 0.1-second delay. The rocket M8 (for aircraft) simply has a stronger fin assembly than the M8 (for the ground forces).

The other authorized aircraft round is the rocket, practice, 4.5-inch M9A1, M9A2, or M9A3. It too is packed unfuzed, and may be equipped with the M6 dummy fuze, the M4 fuze, or the M4 fuze with the M1 auxiliary booster, depending on the amount of spotting charge desired.

The M8 is entirely olive drab in color with yellow markings, while the M9 has a dull blue head and olive drab motor.

BOMB HANDLING

Purpose. The purpose of this section is to provide standard methods for training bomb service crews in the exact procedures of servicing bombardment airplanes in the field. These methods have been developed and carefully tested in an endeavor to increase the efficiency of ordnance personnel in the organizations concerned, and to increase the number of crews per squadron by reducing the number of men in a crew from five to four, while at the same time making the best use of existing equipment.

Scope. The scope of this section covers only the 'M' and 'GP' series of bombs. The handling of all bombs in these series is covered with emphasis placed on the handling of bombs of 500-lbs. or over.

Bomb Service Crew. The fundamental unit for bomb service drill is the bomb service crew. This crew consists of a noncommissioned officer or selected private who acts as a crew chief and three munition workers. The three munition workers and crew chief are numbered one, two, three, and four, respectively. Their duties are assigned so as to facilitate simple and complete instruction, covering every operation with a minimum amount of lost motion and back-tracking. Likewise, the responsibility for obtaining, using, and returning *each piece* of bomb handling equipment has been specified as a *duty* for one or more of the crew members in an endeavor to emphasize the proper care and use of this equipment. This procedure will also reduce the possibilities of losing equipment

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while making night deliveries. The bomb service crews are grouped into sections depending on the T/O strength of the company. These form the service echelon of the ordnance troops at a squadron airdrome. The section leader will be the instructor for the drill and he will function as delivery chief in operations. The crew chiefs are assistant instructors in charge of their crews, in addition to being a member of the crew, and having definite duties to perform themselves.

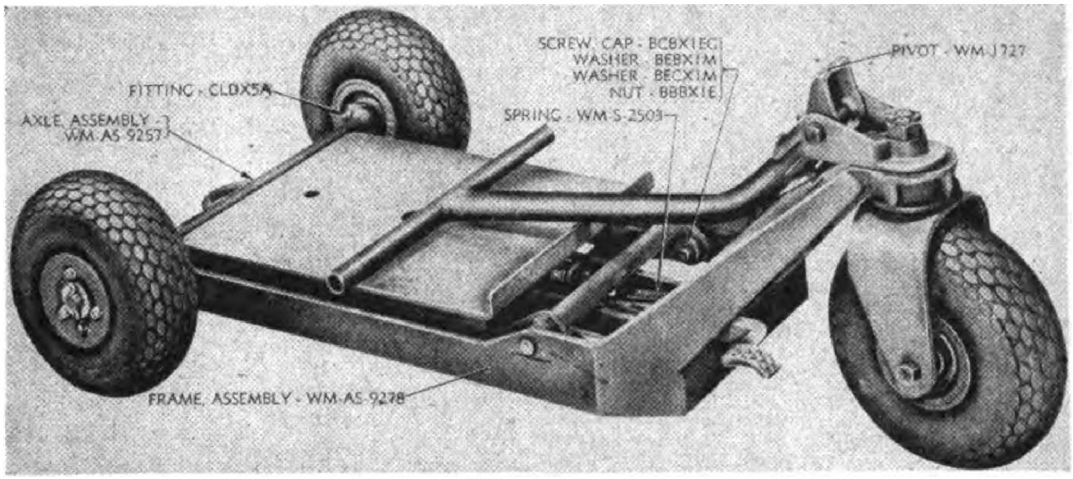

Figure 87. Truck, Bomb Lift M1.

The commands of the instructor have been simplified so that the drill may be given with the several crews each handling different weights of practice or drill bombs at one time; *i.e.*, No. 1 crew performs the drill with 100-lb. bombs, No. 2 crew with 500 to 600-lb. bombs, No. 3 crew with 1000 to 1100-lb. bombs, No. 4 crew with 2000-lb. bombs, and No. 5 crew with 4000-lb. bombs. The noncommissioned

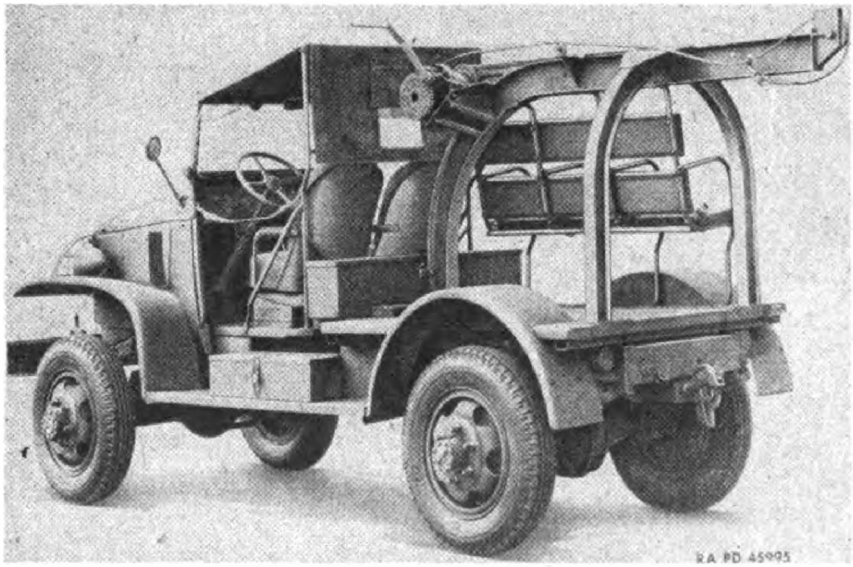

Figure 88. Bomb Service Truck M6.

officer delivery chief, besides having his instructional duties, is the coordinator of the drill performed by the section; the crew chief directs all the work of his crew and assists in loading and unloading operations. Every member of the crew should be trained to perform *all the duties* connected with bomb handling, and as crews become proficient in handling one weight of bomb, they should be rotated to another weight.

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Crew Equipment. Each bomb service crew will be equipped with the following:

1 ea. truck, bomb service, M6, 1¼-ton (4 x 4) (Chevrolet). This special vehicle is essentially a short coupled 4-wheel drive truck with an open body and platform. A crane and winch of 1-ton capacity is mounted on the rear platform. In addition to the usual two seats, there are three seats on the rear platform.

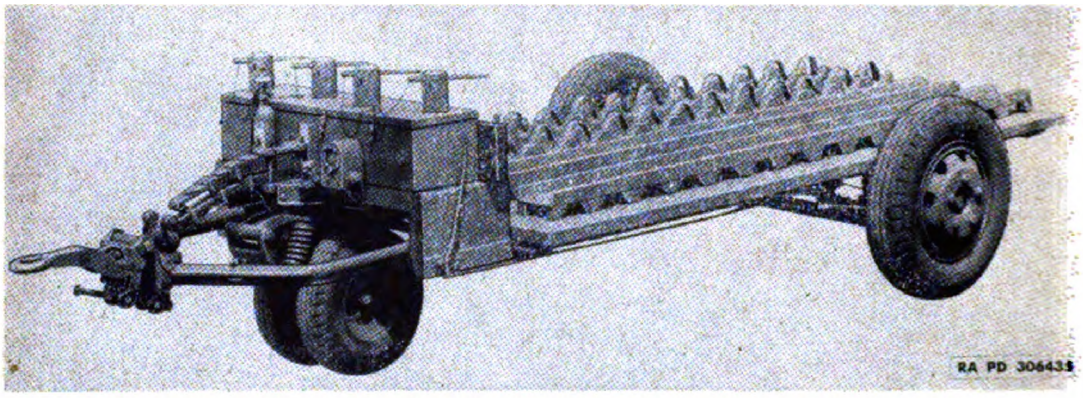

Figure 89. Bomb, Trailer M5. Left Front View.

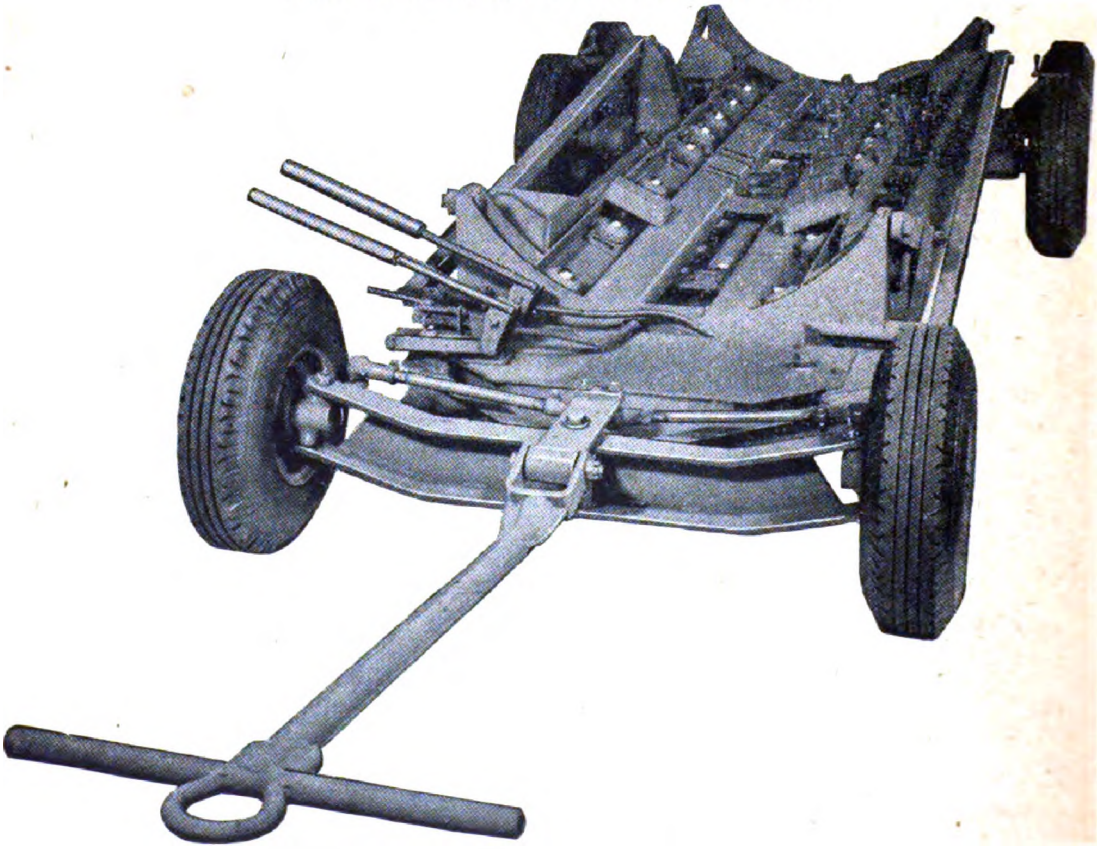

Figure 90. Truck, Bomb Lift M22 With Adapter.

There are two tool boxes, one for bomb handling tools and one for truck tools. A removable canvas top with a tubular steel frame is furnished. The canvas top is removed when making bomb deliveries. A bomb lift truck is carried in special brackets on the rear platform. The truck is designed to carry a bomb service crew of five men and to tow one or two trailers, M5, in normal service. The truck and trailers are equipped with Warner Electric Brake equip-

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ment. The bomb service trucks with their travel load should perform satisfactorily on any type of road except deep mud and sand.

Accessories for bomb service truck, M6 including 2 and 4-man bomb handling bars, danger flag, a bomb assembly kit, and a complete set of tools and other equipment for bomb servicing.

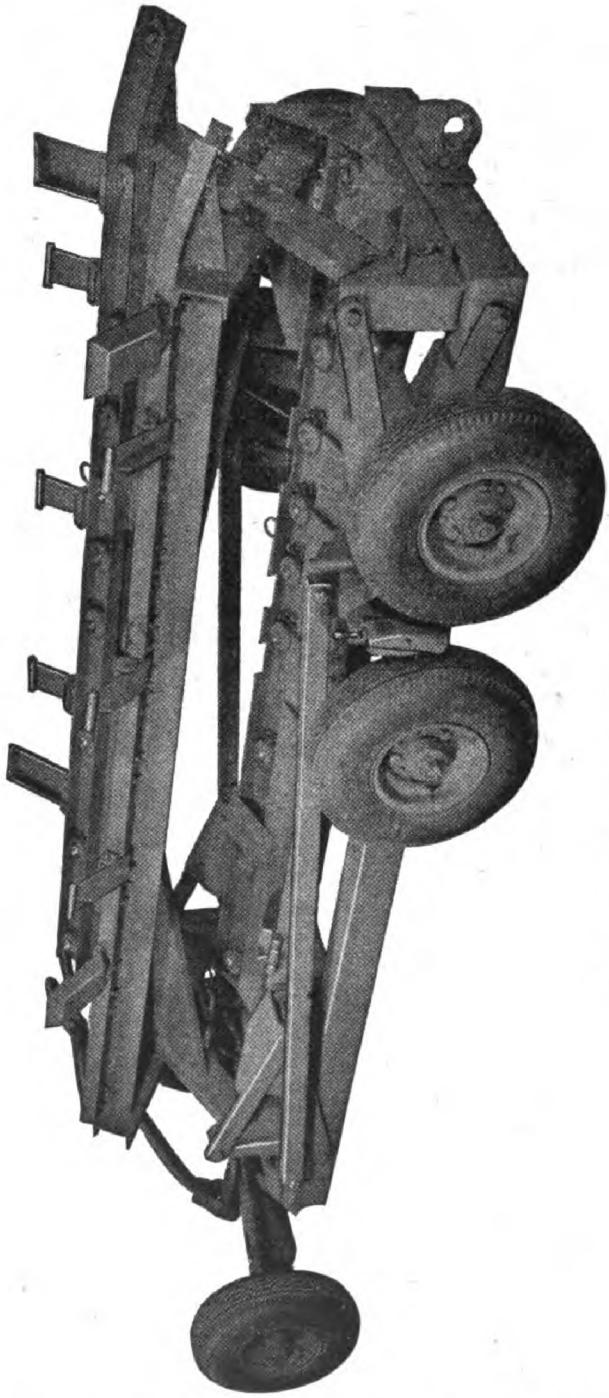

Figure 91. Truck, Bomb Lift M22 Without Adapter.

2 ea. trailer, bomb service, M5. The bomb trailer, M5, is a low-bodied three-wheeled trailer, with special equipment for carrying bombs. The front part of the trailer mounts a chest to carry fins. The vehicle is equipped with Warner Electric Brakes and a hand operated parking brake. Since the castered third wheel is of small diameter, this vehicle has limited mobility in deep mud and

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sand. The vehicle is designed for a maximum load of 5000-lbs. The following maximum bomb loads can be carried:

100-lb. bombs	24
300-lb. bombs	14
500-lb. or 600-lb. bombs	8
1000-lb. or 1100-lb. bombs	4
2000-lb. bombs	2
4000-lb. bombs	1

Accessories for bomb trailer, M5 including racks, bomb loading channel stand, danger flag, strap, bomb handling platform, electric lantern, electric lamp and extra batteries.

The bomb channels on the M5 trailer have been painted with locating marks to expedite positioning of the channel chocks and holding chains for the 500 to 600-lb., 1000 to 1100-lb., 2000-lb., and 4000-lb. bombs. These locating marks also serve as a guide for positioning the 500 to 600-lb., 1000 to 1100-lb., 2000-lb., and 4000-lb. bombs on the channels during the loading process. The proper positioning of these four types will center the load on the trailer, and will eliminate the possibility of the bombs interfering with the loading of the fins on the fin posts in bomb areas where the fins are loaded after the bombs have been placed on the trailers.

The Truck, Bomb Lift, M22 and its accessories, (Optional).

GENERAL INSTRUCTIONS FOR BOMB HANDLING

General procedure for practice bomb handling, showing assignment of crews:

1. Upon receipt of order for bomb deliveries, the munitions section chief will designate the crew or crews responsible for making the necessary deliveries.

2. The bomb handling crew chief will specify the exact duties to each of the members of his crew. This will be done by assigning a 'Number' duty to each of his men at the time he is notified that bomb deliveries have been requested.

3. The driver of each bomb handling truck and trailer or trailers will make a general inspection of the condition of the vehicles, bomb handling equipment, gasoline, tires, lights, oil, water, and engine before leaving the motor pool.

4. The crew chief will be responsible for the safe transportation of his men and equipment at all times while on duty.

5. The crew chief will direct the driver to move the vehicles at any time he sees fit in order to facilitate and expedite loading and unloading.

6. The Truck, Bomb Lift, M1 will be loaded on the service truck by Nos. 1, 2 and 3.

7. The Truck, Bomb Lift, M22 will be loaded on a trailer by the entire crew. The two loading ramps will be attached to the outside trailer channels so that the lift truck can be rolled up on the trailer, rear end first. The brakes will be set and if rough ground is to be traveled, the truck should be tied to the trailer channels with the loading chains. It is important to note that the Truck. Bomb Lift, M22 is not designed to move the bomb or Naval Torpedo for any great distance and is used for hauling the 4000-lb. bomb and the Naval Torpedo from the trailer to underneath the airplane only.

8. When the bomb handling crew or crews arrive at the bomb area for loading the bombs on the bomb trailers, the crew chief will see that his vehicles have come to a complete stop before giving his command, *load*—which will be the standard command for performing all duties connected with bomb loading. At the command, *load*, each member of the crew or crews will immediately dismount from the vehicle and perform his assigned duties without delay or confusion.

9. When the bomb loading has been completed, the crew chief will inspect the load before giving the command, *mount*, which will be the standard command for the crew to take their positions on the vehicle before moving from the bomb area. The crew chief will be the last member to take his position on the vehicle.

10. It should be understood that fins, fuzes, and arming wire will be delivered on the same trip or load as the bombs, and will be loaded in their proper places on the vehicles under direction of the crew chief.

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11. The 100-lb., 250-lb., and 300-lb. bombs should be fuzed and arming wire inserted upon arrival at an open area within the bomb dump or bomb storage area prior to delivery to the desired organization. This, in the text, is considered as part of the loading.

12. Fuzes will be carried at quick time and will be inserted hand tight. It is suggested that one extra nose and tail fuze be carried upon delivery.

13. In handling GP bombs having the third suspension lug, particular care must be taken with the heavier bombs in sliding them on the ramp. It will be necessary for the bombs to be 'worked' over the angle formed by the ramp and trailer bed so as to avoid damaging the suspension lug. This lug should *never* be sawed off to ease handling regardless of the usual type of plane being serviced.

14. When the bombs are delivered to the desired organization or area, the loaded trailers will be spotted in the most desirable location for efficient unloading. The crew chief will give the command, '*unload,*' which will be the order for unloading.

15. After the bombs have been unloaded and all ordnance functions have been completed, the crew chief will be responsible for having the vehicles returned to the motor pool, and will see that the members of his crew are properly accounted for and are present for any reassignment if necessary. When one crew is servicing more than one plane, the crew chief will direct the unloading of bombs as he best sees fit to obtain maximum efficiency.

16. Insofar as bombs cannot be loaded into the bomb bay as rapidly as they are received, and particularly where one bomb service crew with *two* trailers is servicing several ships, it is recommended where possible that the crew of four men be split. In the case of the 100-lb., 250-lb., and 300-lb. bombs it would mean that two men would be unloading from each of the two trailers to respective ships at the same time. For the heavier bombs it will be necessary for the entire crew to service one ship from one trailer with two bombs (except for the 4000-lb. bomb), then to service the other ship from the second trailer with two bombs and to alterate under directions of the crew chief as he best sees fit.

SPECIFIC INSTRUCTIONS FOR BOMB HANDLING

Handling 100-lb. Practice Bombs. It should be understood that under normal operating conditions, the base ordnance organization will be responsible for loading sand, and for inserting spotting charges and arming wires in all practice bombs. However, in cases of emergency, the squadron ordnance department will cooperate and detail men to perform these duties upon the request of the base ordnance organization or other authorized personnel.

Loading. The instant No. 1 man, the driver, stops the bomb service vehicles at the bomb area, No. 4 man, the crew chief, will give the command *load.* No. 2 man will set the trailer brake, open the truck and trailer tool boxes, and will give single hand bomb hooks to No. 1 man and No. 3 man. No. 1 man and No. 3 man will carry the bombs from the bomb dump to the trailer. While No. 1 man and No. 3 man are carrying the bombs, No. 2 man gives two web straps to No. 4 man who will secure the bombs to the trailer as they are being loaded. No. 2 man gets a single hand bomb hook, stands on the trailer, and positions the bombs on the trailer as they are being loaded. After the trailer is loaded, No. 1 man, No. 2 man and No. 3 man will return their single hand bomb hooks to the truck tool box, while No. 4 man inspects the load and releases the trailer brakes. No. 4 man then gives the command *mount.*

Specific Instructions for Unloading. When the truck arrives at its destination and is brought to a stop by No. 1 man, No. 4 man will give the command, *unload.* No. 2 man will set the trailer brake, remove three single hand bomb hooks from the truck tool box, giving one to No 1 man, one to No 3 man, and keeping one for himself. No. 4 man will detach the web straps from the bombs and trailer as No. 1 man, No. 2 man, and No. 3 man carry the bombs to a place designated by No. 4 man. After the bombs are unloaded from the trailer, No. 1 man, No. 2 man, and No. 3 man will return their single hand bomb hooks to the truck tool box. No. 4 man will roll up the web straps, return them to the trailer tool box, release the trailer brakes, and give the command *mount.*

Handling 100-lb. Demolition Bombs. *Loading.* The instant No. 1 man, the

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driver, stops the bomb service vehicles at the bomb area, No. 4 man, the crew chief, will give the command *load*. No. 2 man will set the trailer brake, open the truck and trailer tool boxes, and will give single hand bomb hooks to No. 1 man and No. 3 man. No. 1 man and No. 3 man start carrying the bombs. No. 2 man gives two web straps to No. 4 man who will secure the bombs to the trailer as they are being loaded. No. 2 man gets a single hand bomb hook, stands on the trailer, and positions the bombs on the trailer as they are being loaded. After the trailer is loaded, No. 1 man, No. 2 man, and No. 3 man will return their single hand bomb hooks to the truck tool box. No. 1 man will obtain and insert all nose fuzes. No. 2 man will obtain and insert all tail fuzes. No. 3 man will insert all the arming wires. No. 4 man will supervise and assist as required. He will also inspect all completed work, release the trailer brake, and give the command *mount*.

Unloading. When the truck arrives at its destination and is brought to a stop by No. 1 man, No. 4 man will give the command, *unload*. No. 2 man will set the trailer brake, remove three single hand bomb hooks from the truck tool box, giving one to No. 1 man, one to No. 3 man, and keeping one for himself. No. 4 man will detach the web straps from the bombs and trailer as No. 1 man, No. 2 man, and No. 3 man carry the bombs to a place designated by No. 4 man. After the bombs are unloaded from the trailer, No. 1 man, No. 2 man, and No. 3 will return their single hand bomb hooks to the truck tool box. No. 4 man will roll up the web straps, return them to the trailer tool box, release the trailer brakes, and give the command, *mount*.

Handling 250-lb. or 300-lb. Demolition Bombs. *Loading*. The instant No. 1 man, the driver, stops the bomb service vehicles at the bomb area, No. 4 man, the crew chief, will give the command, *load*. No. 2 man will set the trailer brake, open the trailer and truck tool boxes, and will give a small bomb handling bar to No. 1 man and one to No. 3 man. No. 2 man will also obtain and give two web straps to No. 4 man, No. 1 man and No. 3 man will carry the bombs to the trailer. No. 2 man will assist No. 1 man and No. 3 man in positioning the bombs on the trailer. No. 4 man will secure the bombs to the trailer with the web straps. After the trailer is loaded, No. 1 man will return the bomb handling bars to the truck tool box, and will insert all the nose fuzes. No. 3 man will assemble all fins to the bombs with the assistance of No. 2 man. No. 2 man will insert all tail fuzes. No. 4 man will insert all arming wires, inspect all completed work, release the trailer brake, and give the command, *mount*.

Unloading. When the truck arrives at its destination and is brought to a stop by No. 1 man, No. 4 man will give the command, *'unload'*. No. 2 man will set the trailer brake, open the truck and trailer tool boxes, and will give a small bomb handling bar to No. 1 man and one to No. 3 man. No. 4 man will detach the web straps from the bombs and trailer. No. 1 man and No. 3 man will carry the bombs to a place designated by the crew chief. No. 2 man will assist No. 1 man and No. 3 man as required. After the bombs are unloaded from the trailer, No. 1 man will return the small bomb handling bars to the truck tool box. No. 4 man will roll up and return the web straps to the trailer tool box, release the trailer brakes, and give the command, *mount*.

Handling 500-lb. Demolition Bombs. *Loading*. The instant No. 1 man, the driver, stops the bomb service vehicles at the bomb area, No. 4 man, the crew chief, will give the command, *load*. No. 2 man will set the trailer brakes and remove the cradles from the left side of the trailer, while No. 4 man removes the cradles from the right side of the trailer. No. 1 man and No. 3 man will erect the loading ramp, extend storage dunnage, roll out the first bomb from the bomb dump to the trailer. No. 2 man will open the truck and trailer tool boxes, obtain two small bomb handling bars, and give them to No. 3 man who will insert them in the suspension lugs of the first bomb to be loaded. No. 2 man will prepare the holding chains for securing the bombs to be loaded. No. 4 man will assemble all channel brackets to the channels as the bombs are being loaded. The first bomb, as well as all successive bombs, are loaded by No. 1 man, No. 2 man, No. 3 man, and No. 4 man. In loading the bombs, No. 1 man positions himself on the left front side of the

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bomb, No. 2 man on the right front side, No. 3 man on the left rear side, and No. 4 man on the right rear side. No. 1 man and No. 3 man will always roll out the bombs from the bomb dump prior to loading. No. 2 man will always insert the bomb handling bars in all but the first bomb. No. 1 man and No. 3 man will always erect the loading ramp as required. After the trailer is loaded, No. 1 man and No. 3 man will return the loading ramp to the trailer. No. 2 man will return the small bomb handling bars to the truck tool box. Each man will return a cradle to the trailer:—No. 1 man will return a cradle to the left front side of the trailer, No. 2 man will return a cradle to the right front side, No. 3 man will return a cradle to the left rear side, and No. 4 man will return a cradle to the right rear side. No. 1 and No. 2 man will secure the front cradles and bombs to the trailer with the holding chains, while No. 3 man and No. 4 man secure the rear cradles and bombs to the trailer. No. 4 man will inspect the completed work, release the trailer brake, and give the command, *mount.*

Unloading. When the truck arrives at its destination and is brought to a stop by No. 1 man, No. 4 man will give the command, *unload.* No. 2 man will set the trailer brakes and unhook the trailer from the bomb service truck, after which No. 1 man will drive the bomb service truck about 8 feet ahead of the trailer. No. 1 man, No. 2 man, and No. 3, man will remove the bomb lift truck from the bomb service truck and position it on the ground. In the meantime, No. 4 man will remove the fins from the trailer and position them nearby. He will also detach the holding chains from the cradles and bombs. No. 2 man and No. 3 man will remove the loading ramp and ramp stand from the trailer, and will erect them as required. No. 1 man will position the bomb lift truck to the rear of the trailer, remove one cradle from the trailer and place it on the bomb lift truck. In the meantime, each of the other crew members will remove one cradle and position them near the bomb lift truck for No. 3 man, who will place them on the bomb lift truck as required. No. 3 man will open the truck tool box, obtain two small bomb handling bars, and insert them in the suspension lugs of the first bomb to be unloaded. No. 2 man will remove all channel brackets as required. No. 2 man, No. 3 man. and No. 4 man will unload the bombs from the trailer:—No. 2 man will position himself on the right front side of the bomb, No. 4 man will position himself on the right rear side, No. 3 man will position himself on the left side and will grasp both small bomb handling bars (one in each hand). No. 1 man holds the bomb lift truck and cradle in place as the bombs are unloaded from the trailer and loaded on the cradles. After each bomb is loaded on a cradle, No. 1 man positions each loaded cradle approximately 10 feet to the rear of the trailer. No. 4 man will insert the small bomb handling bars in the suspension lugs of all but the first bomb during the unloading process. After the first two bombs are unloaded, No. 4 man will obtain and deliver one nose fuze, one tail fuze, and one arming wire to the first bomb. No. 3 man will get two fins from the trailer and position one near the first bomb, and one near the second bomb, and will assemble the fin to the first and all successive bombs. No. 1 man will insert the nose fuze in the first bomb, No. 2 man will insert the tail fuze in the first and all successive bombs, No. 4 man will insert the arming wire on the first and all successive bombs, and will insert the nose fuze in all but the first bomb. No. 1 man will deliver the first completely assembled bomb to the plane, and will return with the empty bomb lift truck to assist in the unloading, and to make additional deliveries of completely assembled bombs to the plane as required. After the first bomb is delivered to the plane, all the other bombs will be unloaded, prepared, and delivered to the plane in accordance with the instructions contained in the foregoing sentences. No. 4 man will inspect all completed work, direct the replacement of all bomb handling equipment when the unloading is completed, release the trailer brake and give the command, *mount.*

Handling the 1000-lb. and 2000-lb. Demolition Bombs. General instructions will apply.

Loading. The instant No. 1 man, the driver, stops the bomb service vehicles at the bomb area, No. 4 man, the crew chief, will give the command, *load.* No. 2 man will set the trailer brakes and unhook the trailer from the truck. No. 3

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man will immediately get the crane and winch ready for loading the bombs as No. 1 man is getting the truck into position for hoisting the bombs from the bomb dump. No. 2 man and No. 4 man will remove the cradles from the trailer and store them nearby until the loading of bombs is completed. No. 4 man will open the truck tool box, obtain one spreader bar, and insert it in the bombs and guide the bombs as they are being loaded. In the meantime, No. 2 man will prepare the trailer by placing the brackets and holding chains in position. No. 3 man will operate the crane and winch with the assistance of No. 1 man when hoisting bombs from the bomb dump and when lowering them into position on the trailer. No. 1 man will position the bomb service truck for hoisting and lowering of bombs in accordance with instructions from No. 4 man. After the trailer is loaded, No. 4 man will return the spreader bar to the truck tool box. No. 2 man and No. 4 man will return the cradles to the trailer and will secure the cradles and bombs to the trailer with the holding chains. In the meantime, No. 1 man will position the bomb service truck for attachment to the trailer by No. 3 man. No. 4 man will inspect all completed work, release the trailer brake, and give the command, *Mount*.

Unloading. When the truck arrives at its destination and is brought to a stop by No. 1 man, No. 4 man will give the command, *Unload*. No. 2 man will set the trailer brake and unhook the trailer from the bomb service truck. No. 1 man will drive the bomb service truck about 8 feet ahead of the trailer. No. 1 man, No. 2 man, and No. 3 man will remove the bomb lift truck from the bomb service truck and position it on the ground. In the meantime, No. 4 man will remove the fins from the trailer and position them nearby. No. 4 man will also detach the holding chains from the cradles and bombs, while No. 1 man positions the bomb service truck for unloading with the crane and winch as directed by No. 4 man. No. 3 man will prepare the crane and winch for unloading. In the meantime, No. 2 man and No. 4 man will remove the cradles from the trailer and position them to the rear of the trailer. No. 4 man will open the truck tool box, obtain the spreader bar, and insert it in the bombs for unloading. No. 3 man operates the crane and winch with the assistance of No. 1 man at all times. As the bombs are lifted from the trailer, No. 1 man will drive forward for about 5 feet. No. 3 man will lower the bombs on the cradles which will be placed in position by No. 2 man. After the first bomb is unloaded from the trailer to the cradle, No. 4 man will obtain and deliver one nose fuze, one tail fuze, and one arming wire to the bomb. No. 2 man will obtain and deliver one fin to the first and all successive bombs. No. 3 man will assemble the fin to the first and all successive bombs with the assistance of No. 2 man. No. 1 man will always insert the nose fuzes. No. 2 man will always insert the tail fuzes. No. 4 man will always insert the arming wires, and will inspect completely assembled bombs. No. 2 man, No. 3 man, and No. 4 man will deliver each completely assembled bomb to the plane. In the meantime, No. 1 man locates the bomb service truck in position for unloading the next bomb. After the first bomb is delivered to the plane, all the other bombs will be unloaded, prepared, and delivered to the plane in accordance with the instructions contained in the foregoing sentences. No. 4 man will inspect all completed work, direct the replacement of all bomb handling equipment when the unloading is completed, release the trailer brakes, and give the command, *Mount*.

Handling 4000-lb. Bombs. *Loading*. The instant No. 1 man, the driver, stops the bomb service vehicles at the bomb area. No. 4 man, the crew chief, will give the command, *Load*. No. 2 man will set the trailer brakes in the rear trailer carrying the Bomb Lift Truck, M22, and will uncouple it from the front trailer. No. 1 man positions the truck and trailer directly to the rear of the 4000-lb. bomb, leaving approximately eight (8) feet distance between the rear of the trailer and the tail of the bomb, under direction of the crew chief. During this time No. 3 man will remove the tail plug from the bomb to be loaded and insert a tail plug with an eyelet. When truck and trailer are in position, No. 1 man will open the trailer tool box and prepare the winch for use with the aid of No. 3 man. While No. 3 man is operating the winch, No. 1 man will pull the cable and hook it into the eyelet tail plug. No. 1 man will secure and prepare the brackets and chains with the assistance of No. 3 man. In the meantime, No. 2 man will erect the ramp, ramp stand, and 4" x 4" x 20" blocking on the left side, placing the ramp on

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the left center channel and the blocking between the trailer body and the ground. No. 4 man will do the same on the right rear side. If the bomb is to be loaded from a hard surface, it will be necessary to secure the lower ends of the loading ramps to prevent spreading. This can be accomplished by the use of a chain and binder which would be secured by Nos. 2 and 4. Nos. 1 and 3 will operate the winch while Nos. 2 and 4 will guide and steady the bomb from the side. (Nos. 1 and 3 and Nos. 2 and 4 can change their position when they tire.) When the bomb is centered with the heaviest load forward, No. 1 man will remove the cable hook from the eyelet plug and assist No. 3 man in rewinding the cable. Nos. 2 and 4 will load the ramp, ramp stands and blocking. Nos. 1 and 3 will secure the rear brackets. The entire crew will secure the load with the chains and binder on their respective sides and the equipment will be returned. When loaded, No. 1 man will drive to a position in front of No. 2 trailer carrying the Bomb Lift Truck, M22, where it will be coupled by No. 2 man. No. 4 man will inspect all completed work, release the trailer brake and give the command, *Mount.*

Unloading. When the truck arrives at its destination and is brought to a stop by No. 1 man, No. 4 man will give the command, *Unload.* Nos. 2 and 3 will move to the second or rear trailer and will set the two ramps in position at the two outside channels. The brakes on the bomb lift truck will be released by No. 4 man and the Bomb Lift Truck, M22, will be unloaded with the help of Nos. 1, 2 and 3. Then the second trailer is uncoupled and moved out until after the bomb is loaded on the Bomb Lift Truck, M22. This lift truck will be moved into position so that its rear will be against the rear of the first bomb trailer. The crew chief will make certain that the pintle of the trailer will not come in contact with the lift truck and that the brakes on both lift truck and trailer are set. No. 2 man will uncouple the bomb service truck from the trailer and No. 1 man will position the truck so that No. 2 man can couple the truck to the lift truck. With the brakes set on the service truck there will be little tendency for the three vehicles to move during the unloading process. No. 2 man will set the brakes on the lift truck. In the meantime, Nos. 3 and 4 will place the two pieces of blocking 4" x 4" x 20" under the rear of the trailer and will remove the brackets and securing chains. Nos. 1 and 3 will prepare the winch, while No. 2 man raises the hydraulic lift on the lift truck to the level of the trailer, making certain that the center of the lift is between the two channels. No. 4 man removes the nose plug and inserts a nose plug with an eyelet. He receives the cable hook from No. 1 man and inserts it into the eyelet plug. Nos. 1 and 3 operate the winch and position the bomb on the lift truck. If the bomb is to be moved for any distance it should be secured by the two chains and the binder. It can either be moved by the service truck or be pulled by No. 1 man with Nos. 2, 3 and 4 pushing. To move the bomb, the hydraulic hoist must be lowered and the brakes released. The bomb is brought to the front of the ship to be loaded, where it is finned and fuzed. The securing chains, if used, will be removed by No. 1 man, who also sets the hand brake while Nos. 2 and 3 bring the fin assembly. No. 4 man, the crew chief, will obtain one nose and one tail fuze, the arming wire and arming vane, placing them in their respective positions on the ground. (Fuzes are carried at quick time only.) No. 1 man will insert the nose fuze and after the fin is secured and squared off, No. 2 man will insert the tail fuze. No. 4 man will insert the arming wire and will inspect the completely assembled bomb. The entire crew will pull the bomb under the nose end of the ship and under the bomb bay. The nose end of the bomb must be facing the same direction as the ship. After the lift truck is under the bomb bay and in the proper position for loading, the hand brakes are set, and the bomb is hoisted to the bomb rack and into its station, thus eliminating the need of the winch cable of the airplane's portable winch. After the bomb is secured into position, the hydraulic hoist is lowered, and the lift truck is pulled from under the plane. The crew chief coordinates the bomb service crew's operations with the armanent section of the Air Corps. When the bomb has been delivered, the crew will replace the bomb handling equipment and couple the trailers. No. 4 man will inspect equipment, release the trailer brakes, and give the command, *Mount.*

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THE M27 BOMB SERVICE TRUCK, DESCRIPTION AND USE

To more fully meet bomb-handling requirements in overseas theaters, a bomb-lift mechanism for the 2½-ton, 6 x 6, truck has recently been developed and standardized. This new, special-purpose vehicle, which is capable of handling all bombs up to and including 4,000-lb. bombs, consists of a steel superstructure built over the standard 2½-ton truck chassis and a hoisting mechanism driven from the truck's power take-off. The M27 is capable of loading bombs at storage points, of transporting them over any terrain negotiable by a 2½-ton, 6 x 6, truck, and of servicing aircraft at air fields. To facilitate the latter operation, four 11 ft. sections of straight steel track, one section of curved track, and two dollies are to be supplied with each vehicle. The M27 is also suitable for loading and unloading other types of carriers such as trailers, trucks, and boxcars.

It should be pointed out that the information in this article is the result of experiments with the second pilot model of the M27. The vehicle which will be sent to the field will undoubtedly be modified to the extent that some of the comments made here will no longer apply. This article is merely an informative one for the guidance of interested organizations and personnel.

DESCRIPTION

The vehicle itself is the standard 2½-ton truck, with winch. The steel superstructure consists of an overhead rail of the trolley type, 19 ft. 7 in. long, supported by I-beam arches located near the front and at the rear of the truck body. Tubular diagonal braces connect the front arch to the rear arch and the rear arch to the end of the overhead rail. Channeled within the rail is the trolley which operates on four flanged wheels. A block and hook are suspended from the trolley. The effective length of trolley travel along the rail, measured between the two extreme

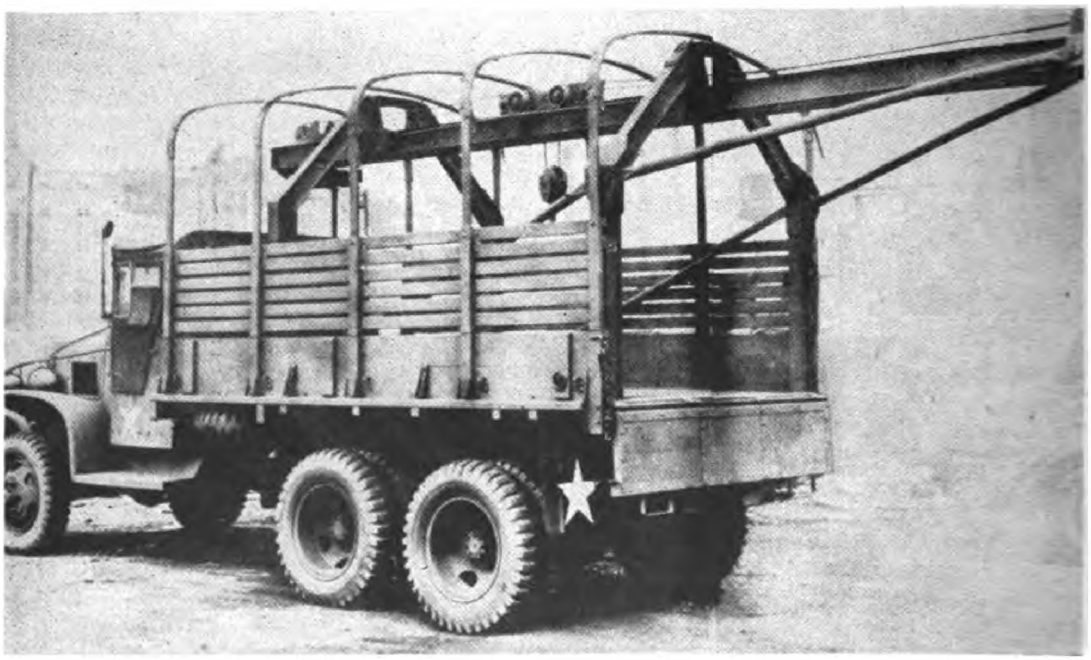

Figure 92. General View of the M27.

positions of the hook, is 15 ft. 3 in. The rail extends 6 ft. 6 in. beyond the rear of the truck although the hook itself can be moved out only 5 ft. 6 in. The clearance between the hook and the truck bed is approximately 4 ft. 7 in.

For hoist and trolley operation, a winch, similar to the type used on C-2 wreckers, is located amidships between the truck cab and cargo space. The winch is of the double-drum reversing type with separately operated and controlled drums. The rated line-pull capacity is 15,000 lb. The reversing mechanism is built

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into the gear case of each winch drum. The drums operate from one power-input shaft and may be independently or simultaneously operated in the same or opposite direction. Either drum may be stopped or started independently without disengaging the engine clutch. The clutch-control mechanism is so designed that the clutch will return to neutral when the control levers are released. Springs assist the release of the clutch and tend to hold it in the neutral position.

To operate the winch, the truck engine is started and the main transmission is placed in neutral. The engine clutch is disengaged and the winch power take-off lever, located just in front of the driver's seat, is pushed to the rear. All other winch operations take place at the controls located behind the cab of the truck. In the following description of the winch controls, assume the operator's position which is behind the cab facing the rear of the truck.

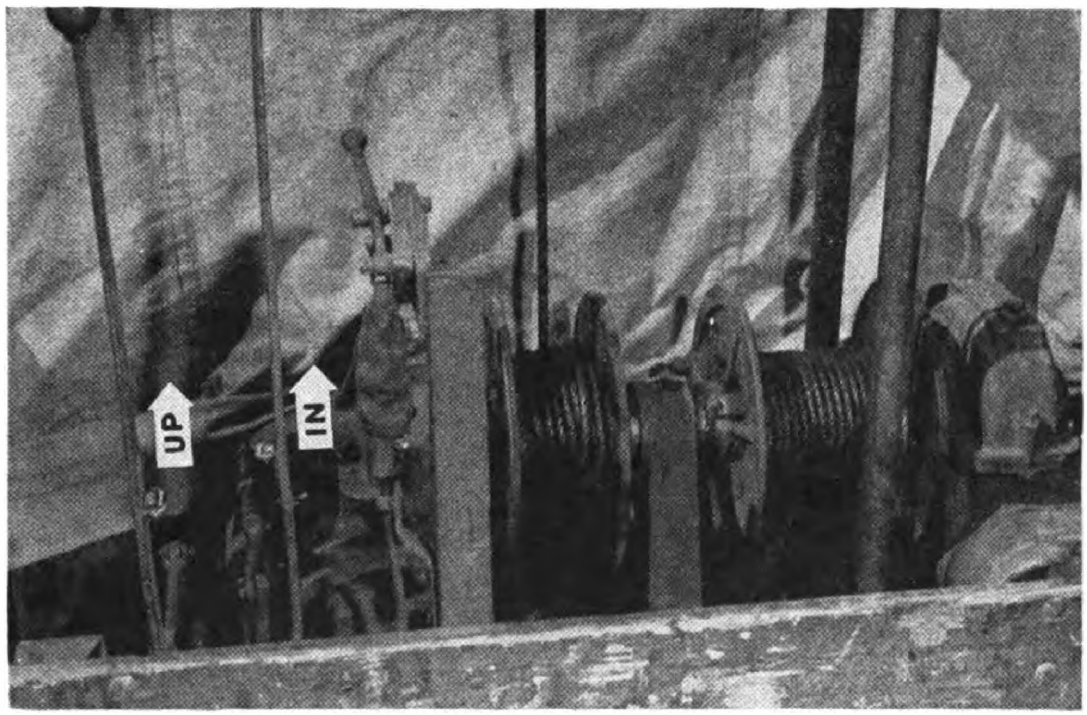

Figure 93. Winch Controls.

The right lever is the hoist-control lever and acts to raise and lower the hook. The hook is lowered when the lever is pushed forward and raised when the lever is pulled back. The center lever controls the trolley. As the lever is pushed forward, the trolley moves out along the overhead rail toward the rear of the truck. When the lever is pulled back, the trolley moves back toward the front of the truck. The left lever is the auxiliary throttle control. When the lever is pulled up, the speed of the winch is increased. To avoid gear clash, the levers should be shifted quickly and held in. As mentioned before, the hoist control lever and the trolley-control lever can be operated simultaneously, *i.e.*, the trolley can be moved to the front or rear at the same time that the hook is being lowered or raised.

An overload clutch of the adjustable spring-loaded saw-tooth type is located in the drive line to prevent breaking the cable in the event a load is lifted beyond operating limits, an excessive load is raised, or the trolley reaches its limit of travel at either end of the overhead rail. The overload clutch is set to trip when a pull is applied equal to a 5,000-lb. load on the hook. The clutch will reset automatically when the overload is released.

The pressed-steel dolly weighs approximately 80 lb. and is designed to carry bombs weighing from 500 lb. to 4,000 lb. One bomb can be moved at a time. The 500-lb., 1,000-lb., or 2,000-lb. bombs can be placed crosswise as well as lengthwise on the dolly. Each of the five sections of narrow-gage track has

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alternating male and female connections which permit end to end reversal of sections. The curved section of track is approximately 6 ft. 4 in. along its inside rail and can be placed anywhere in the track connection for ease in delivering bombs to a plane which may be relatively inaccessible. Each of the four straight sections of track weighs roughly 120 lb. and the curved portion weighs about 110 lb. Rectangular locking pins, chained to the ends of each section of track, connect the sections. End stops, which slip around the heads of the rails, are also provided. The track sections are carried in brackets along each side of the truck body. The dollies, when not in use, can be lashed against the sideboards inside the rear of the truck.

LOADING THE M27

The steel arches and diagonal braces supporting the overhead rail interrupt the uniformity of the width of the cargo space. At the narrowest point, the inside truck width is 5 ft. 8 in. and the widest point 6 ft. 8 in. The length of the cargo space is 10 ft.

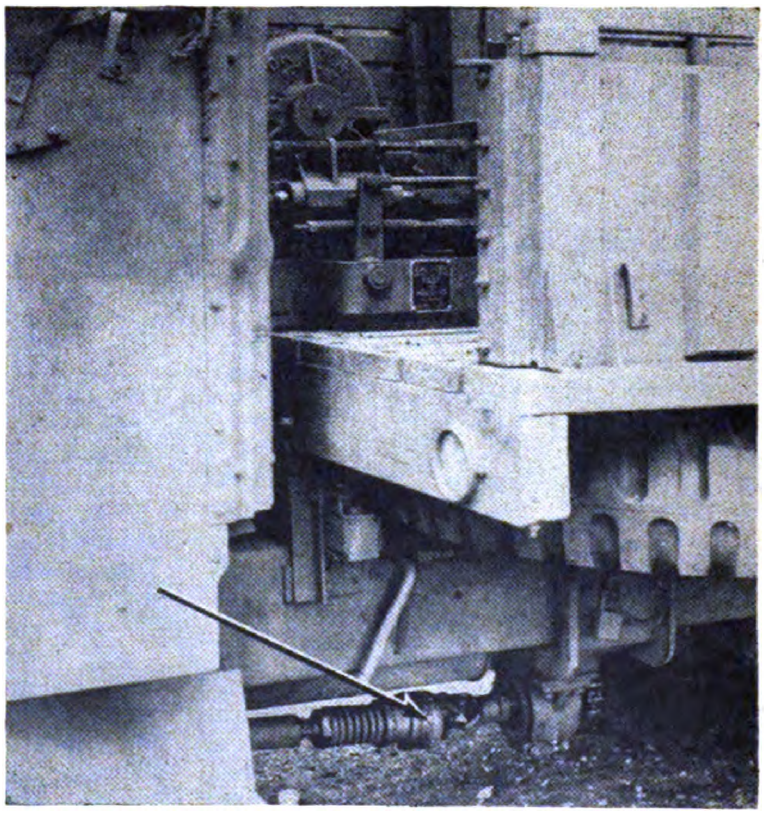

Figure 94. Overload Clutch.

Although there are numerous ways to load and carry high-explosive bombs, mines, and torpedoes in a cargo truck of this type, the following methods were tested and proved sound. All loads were driven over rough terrain, through deep sand, over inclines which tilted the truck laterally, and up to 40 m.p.h. on hard-surface roads. The brakes were applied sharply at forward and reverse speeds to test the stability of each load. In addition to describing the loading methods which proved satisfactory, several faulty methods of loading will be pointed out. Since the M27 was designed primarily as squadron equipment for the transport of heavy bombs, mines, and torpedoes, emphasis will be placed on methods of loading them. Shipping bands are assumed to have been removed prior to loading.

It will be noted that dunnage has been used. In addition to protecting the lugs and giving stability to the loads, dunnage is needed because, as has been

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pointed out, the width of the cargo space is not the same at all points along the truck bed. Light bombs can be maneuvered without great difficulty and can usually be placed directly on the bed of the truck with the lugs at an angle touching neither the floor nor adjacent bombs. Heavy bombs, mines, and torpedoes, on the other hand, are hard to roll, and dunnage will aid considerably in moving them into position. The dunnage used here was 2 in. x 4 in. milled lumber

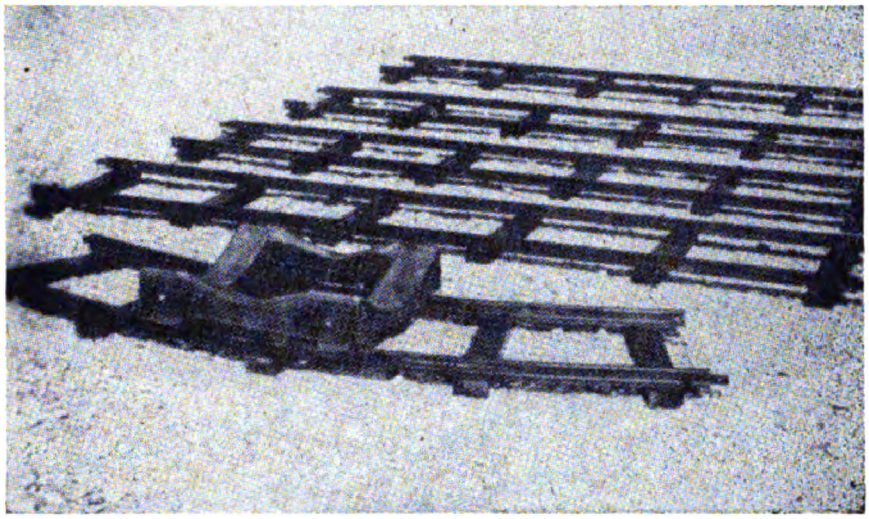

Figure 95. Track Sections and Dolly.

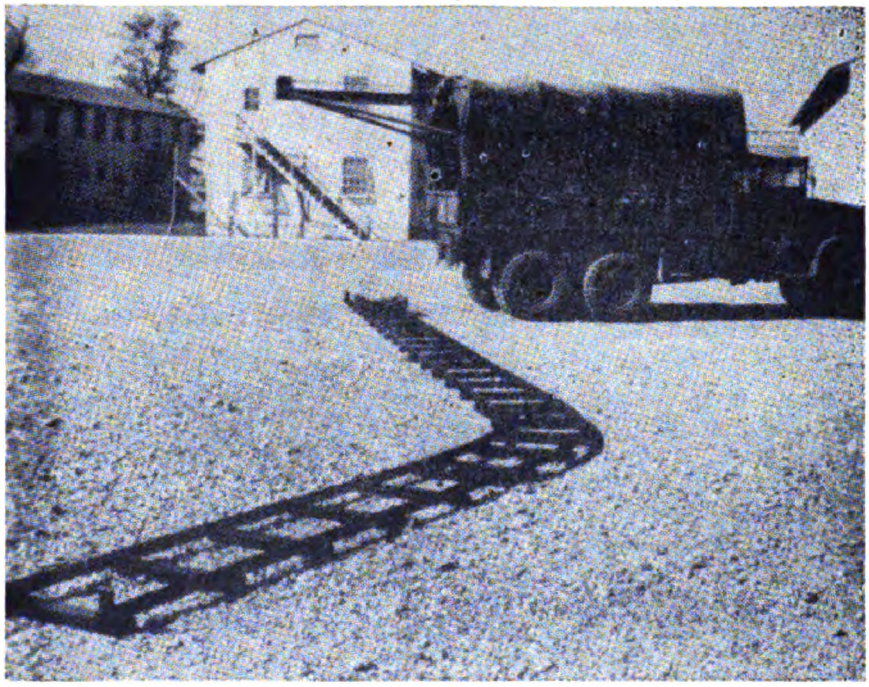

Figure 96. Track Laid for Delivery of Bombs.

and consisted of four 10 ft. stringers and six crosspieces. By using various combinations of this dunnage, every load was carried, with safety to the truck, the operating crew, and the bombs themselves. It is realized that lumber is scarce and in some areas non-existent. In the experiments, lumber was used because it was available. It does not matter what type of dunnage or bracing is used as long as the bombs are properly secured against movement—rocks, sand bags, eye-

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bolts, chains and loadbinders, chocks, saplings—anything will do. The important thing is that the following methods of loading proved successful and are presented as a guide. How the bombs are actually blocked in position is immaterial. In all loads, space for fins was provided in the truck body. Fuze boxes can be carried in the space beside the winch controls. To comply with safety regulations, do not carry fuzes directly in the truck bed with the bombs. It is suggested that, if available, a trailer of some kind be used with the M27 for carrying fins and fuzes.

The following loads can be placed in the truck quickly and carried safely:

General Purpose Bombs		
100 lb.	24-48	(Finned)
250 lb.	12-24	
500 lb.	5-10	
1,000 lb.	3-6	
2,000 lb.	2-3	
4,000 lb.	1	
Armor-piercing Bombs		
600 lb.	5-10	
1,000 lb.	3-6	
1,400 lb.	3-4	
1,600 lb.	2-3	
Semi-armor-piercing Bombs		
500 lb.	6-12	
1,000 lb.	3-6	
Fragmentation Bombs and Clusters		
23 lb. (M72)	38	(boxes, 2 per box)
260 lb. (M81)	12-24	
AN-M1A1 Cluster	18	
AN-M4 Cluster	28	
Depth Bombs		
325-350 lb.	9	
650-700 lb.	6 (unfinned) or 3 (finned)	
Mines		
1,000 lb.	3	
2,000 lb.	2	
Torpedoes		
AN-Mk. 13	2	

100-lb. Bombs. 100-lb. bombs will be carried in three rows of eight bombs each. All nose plugs will face the direction of travel, the plugs of the front row being against the front body board. No dunnage will be laid under the first layer of bombs. Two 10 ft. stringers will be placed, one on its 2 in. edge and one on its 4 in. edge, along the sides of the truck against the front and rear steel arches. Two crosspieces can be placed on top of each row of bombs outside the lugs, and a second layer of bombs can be placed in the truck exactly like the first layer except that the lugs will be down so that they will grip against the crosspieces. The remaining two 10 ft. stringers will be placed along the sides of the truck to wedge the second layer of bombs tightly together.

250-lb. Bombs. 250-lb. bombs will be laid directly on the truck bed in two rows of six bombs each. The nose plugs will face the front of the truck, the plugs of the first row of bombs touching the front body board. Two 10 ft. stringers will be placed, one on its 2 in. edge and one on its 4 in. edge, along the sides of the truck. Two crosspieces can be laid on top of each row of bombs outside the lugs, and a second layer of bombs can be loaded with lugs down. The other two 10 ft. stringers will be placed along the sides as before to wedge in the top layer. Twenty-four fins can be placed in the rear of the truck body.

500-lb. Bombs. 500-lb. bombs will be loaded in one or two rows, one layer high. Five bombs will fit per row. For ease of positioning the bombs and to protect the lugs while rolling the bombs into position, lay crosspieces on the truck floor. The nose plugs of all bombs will be to the front. As long as there is enough room in each row to roll the bombs, position them with the lugs down against the crosspieces. The front portion of the bombs in the front row will fit tightly in

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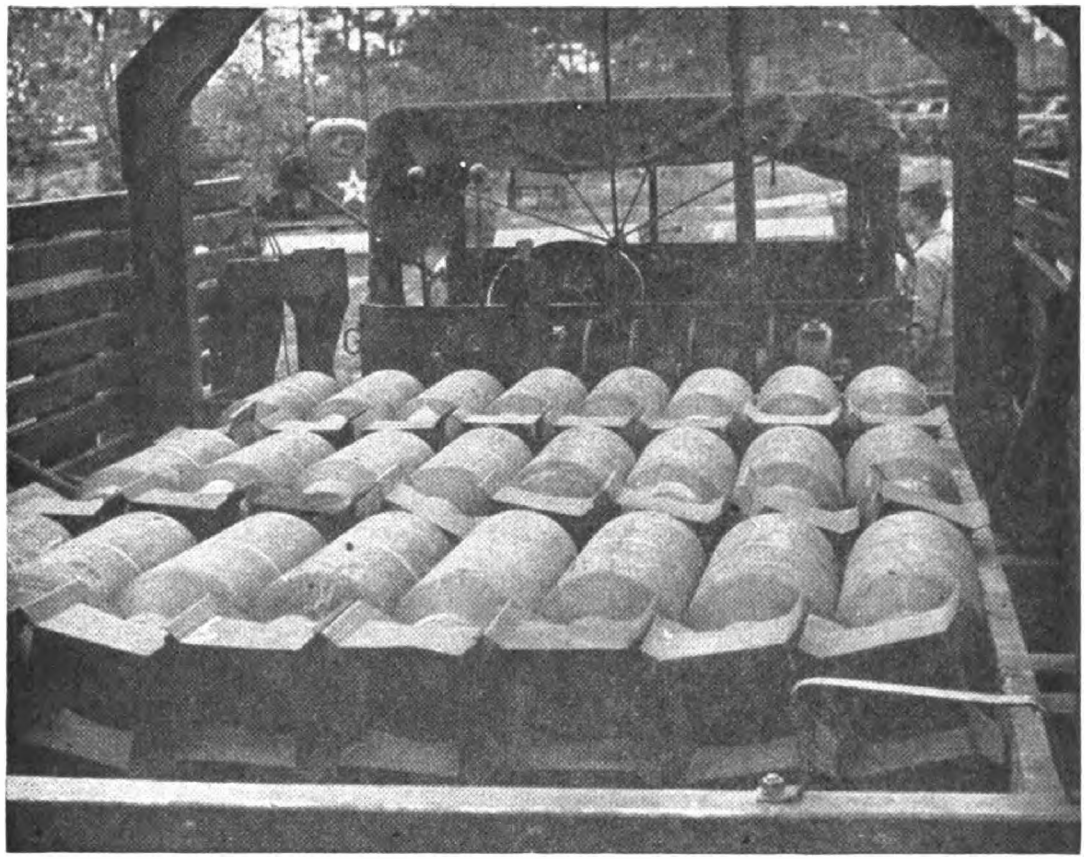

Figure 97. Load of 100-lb. Bombs.

the truck without stringers being placed along the sides. The nose plugs will be approximately 14 in. from the front body board instead of against it. The ogives of the two outside bombs will be wedged against the front arch. The distance from the front body board to the front lugs will be 30 in. This measurement

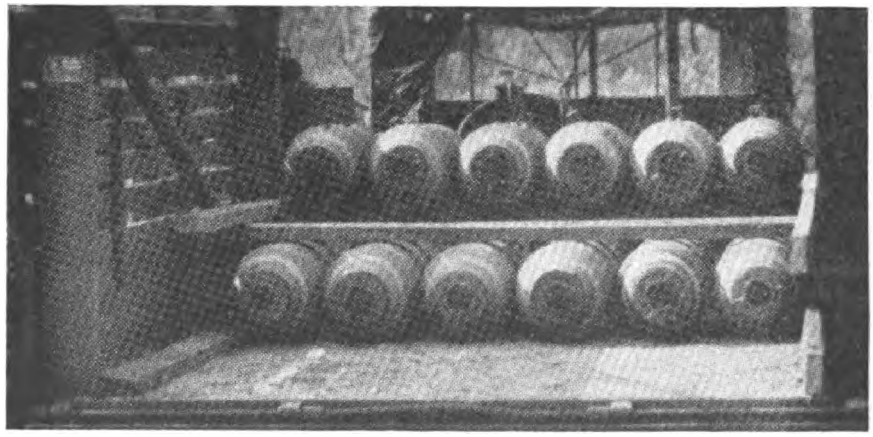

Figure 98. Load of 250-lb. Bombs.

is given so that the first crosspiece can be laid the proper distance from the front body board and serve as a guide for lowering the first row of bombs into position. Since the cargo space is wider toward the rear of the truck, the tails of the front row of bombs and the entire rear row will roll if the remaining two crosspieces

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are not placed lengthwise along the sides of the truck against the outside bombs and nailed to the crosspieces under the bombs. When ten bombs are carried, five fins will go in front of the first row of bombs, and a similar number will fit behind the rear row.

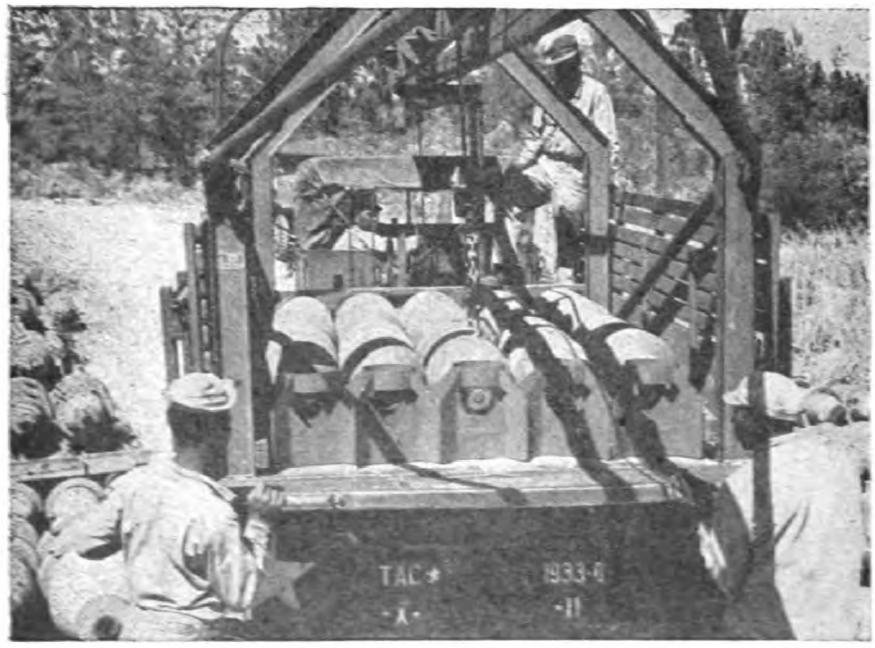

Figure 99. Load of 500-lb. Bombs.

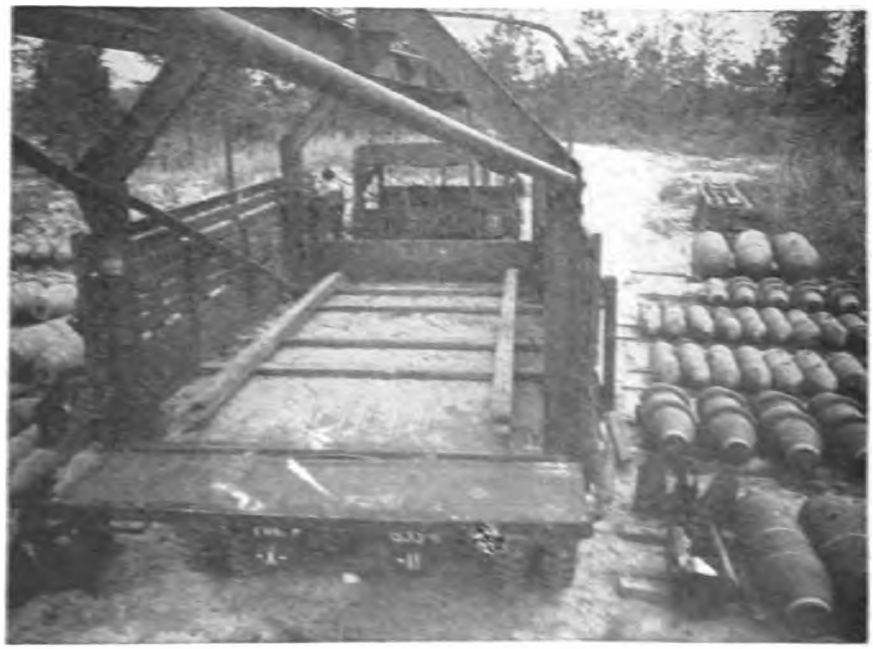

Figure 100. Position of Dunnage for Load of Six 1,000-lb. Bombs.

1,000-lb. Bombs. The front row of 1,000-lb. bombs should be placed in the truck with the nose plugs against the front body board. The result of loading the bombs crosswise in the truck is shown in figure 104. A quick stop at 10 m.p.h. squeezed the front bomb up over the front body board and jammed the hoist

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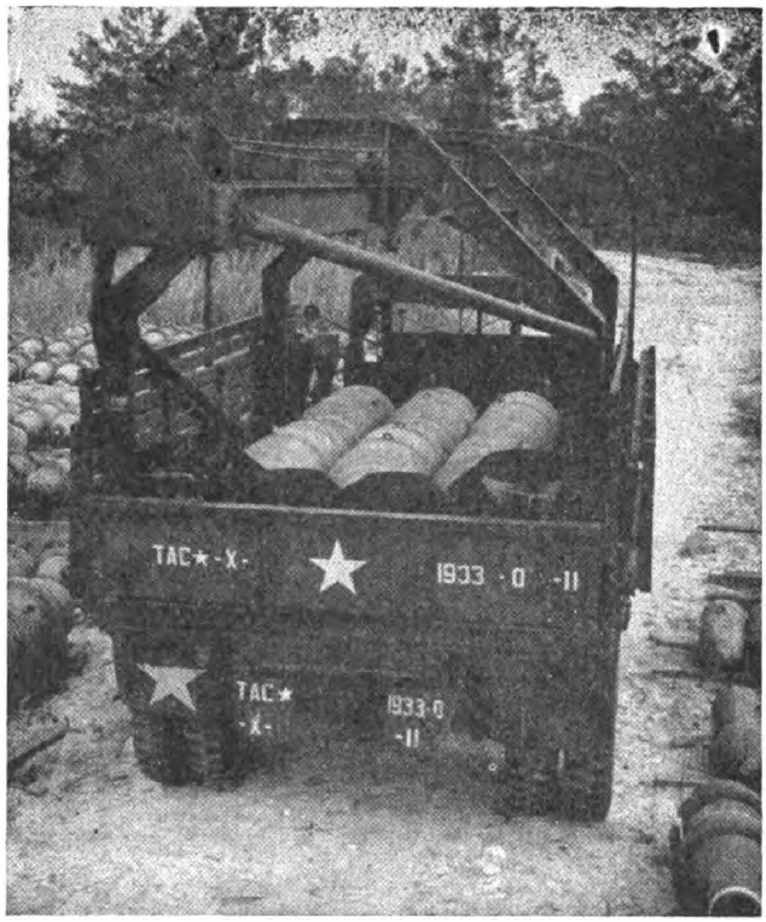

Figure 101. Load of Six 1,000-lb. Bombs.

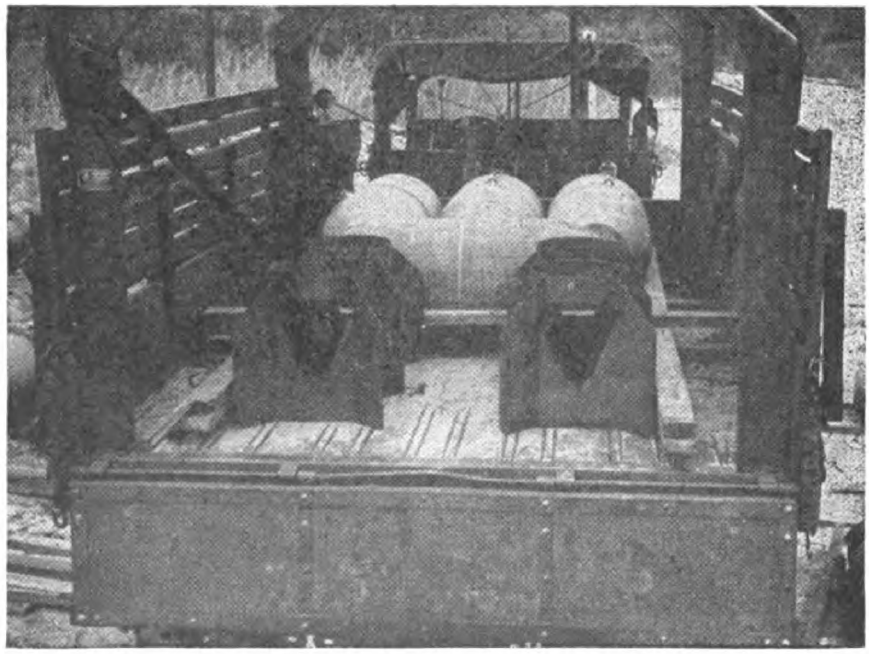

Figure 102. Load of Four 1,000-lb. Bombs.

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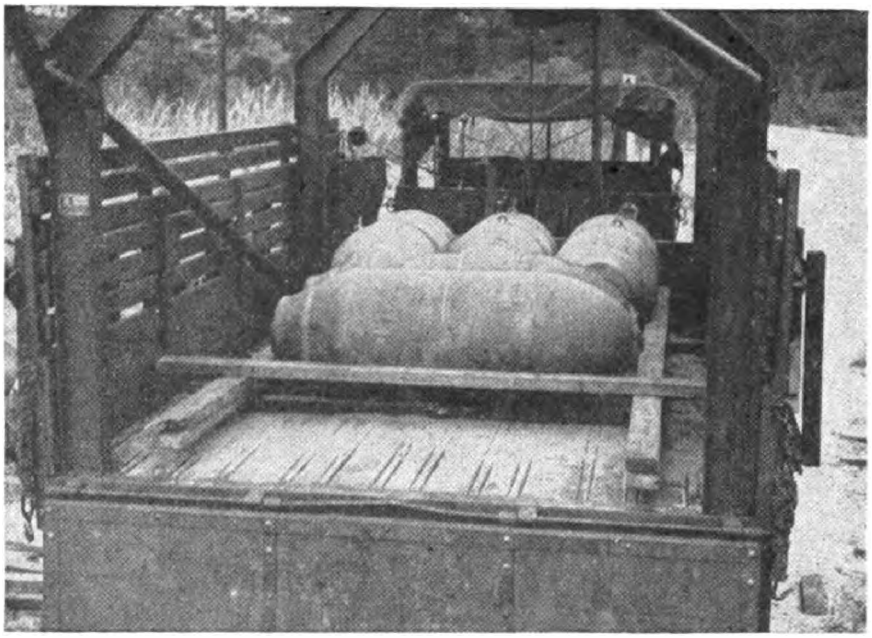

Figure 103. Load of Five 1,000-lb. Bombs.

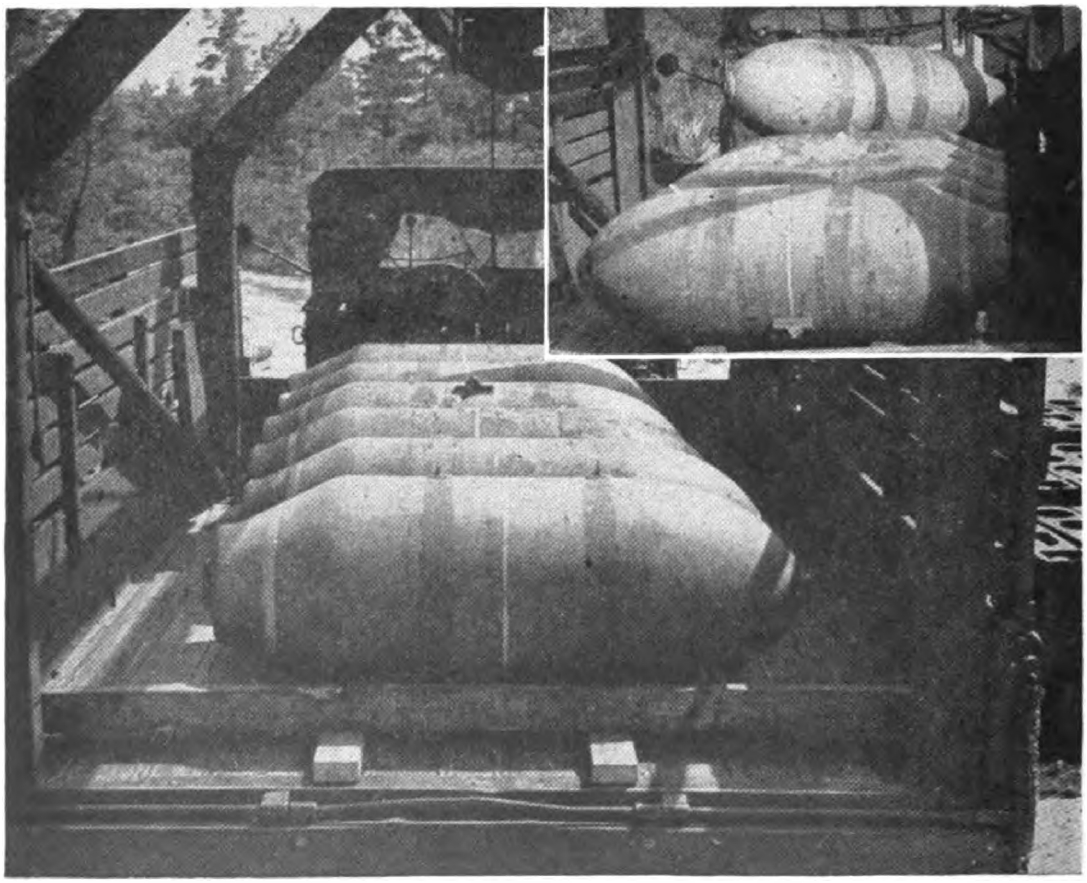

Figure 104. Improper Method of Loading 1,000-lb. Bombs, and the Effect After Stopping Truck Sharply From 10 m.p.h.

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controls. A faster speed and quick stop could easily have shot the bomb into the cab of the truck. Three bombs, loaded nose plugs forward, will leave 11 in. of space on either side of the truck body. Before loading the bombs, nail the four 10 ft. stringers together to make 4 in. x 4 in. stringers. Lay two crosspieces on the truck bed so that they will fit tightly against the lugs. Load and

Figure 105. Load of 2,000-lb. Bombs.

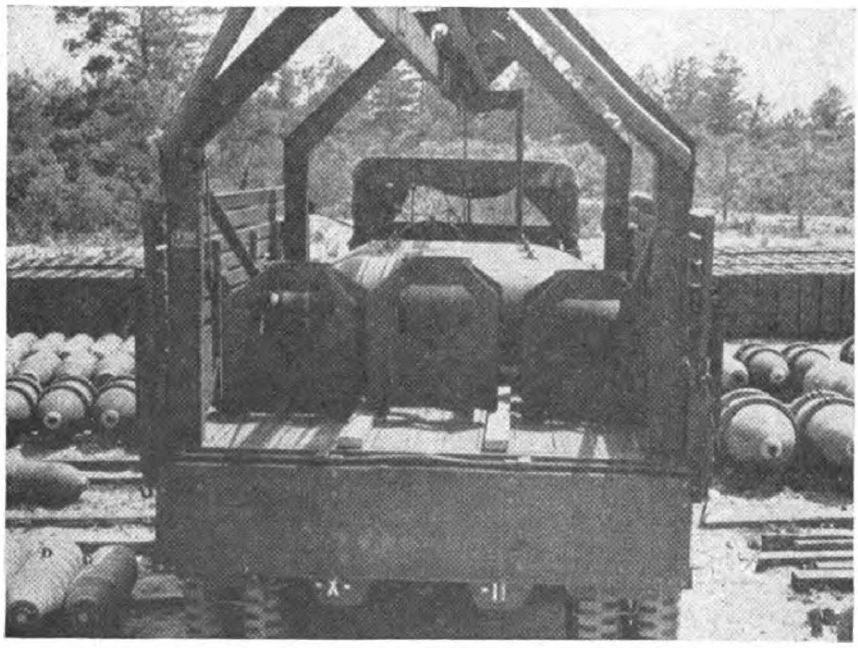

Figure 106. Improper Method of Loading 2,000-lb. Bombs.

roll three bombs into position on the dunnage so that the lugs are down. Wedge the 4 in. x 4 in. stringers against the sides of the bombs and nail them to the crosspieces. If six bombs are to be carried, the rear row will be loaded exactly like the front row. Nail the remaining two crosspieces to the stringers behind

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the tails of the rear bombs to stop any possible rearward movement. When six bombs are loaded, space remains behind the bombs for only four fins. If four or five instead of six 1,000-lb. bombs are carried in the M27, load the front row as already described. Place the fourth and fifth bombs directly on the truck bed crosswise behind the front row and nail a crosspiece to the stringers behind each bomb. It is advisable to put two crosspieces behind the fifth bomb if rough terrain is to be traveled.

2,000-lb. Bombs. Three 2,000-lb. bombs will be loaded into the M27 in the same manner as was the front row of 1,000-lb. bombs. Two stringers will be placed along the sides of the truck bed on their 2 in. edges. Three bombs will fit snugly without the stringers at the front of the truck body, but the tails will move if the stringers are not used to take up the increased width of the cargo space at the rear of the truck. Two crosspieces will be placed under the bombs and, at the tails, the remaining crosspieces will be nailed to the stringers to keep the bombs from sliding to the rear. There is sufficient room at the back of the truck for the fins. When two 2,000-lb. bombs are carried, the dunnage will be placed as it was for 1,000-lb. bombs. It is dangerous and inadvisable to load 2,000-lb. bombs crosswise in the truck, as shown in figure 106.

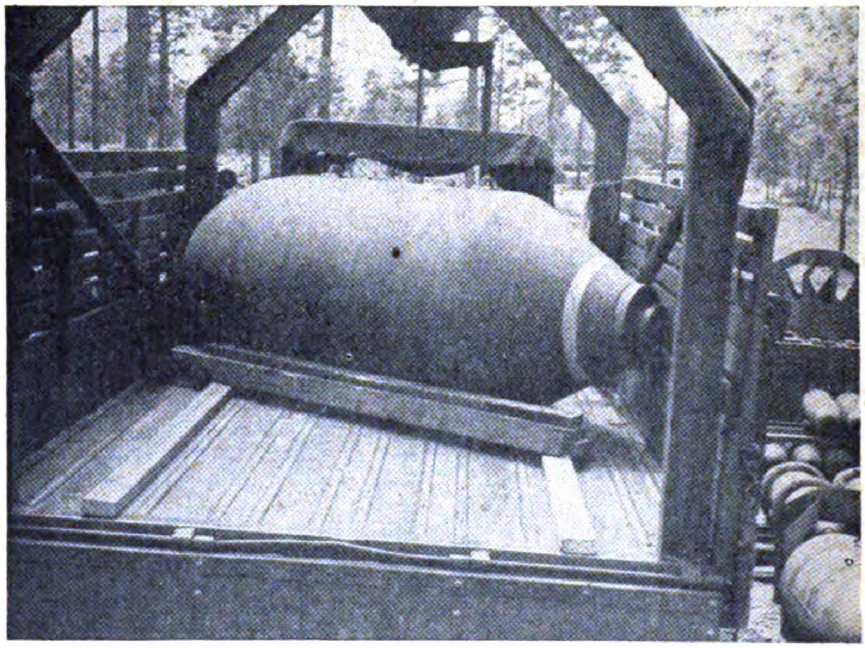

Figure 107. 4,000-lb. Light-case Bomb Loaded on M27.

4,000-lb. Bombs. The 4,000-lb. light-case bomb will be loaded diagonally in the truck. The nose plug will fit into the corner formed by the I-beam of the front arch. Place an upright 2 in. x 4 in. next to the front arch and against the side of the truck so that the nose plug will not damage the side boards. The tail will fit under the diagonal brace on the opposite side of the truck. No dunnage will be placed under the bomb, but wedged tightly along the ogive and tail will be two 10 ft. stringers to which will be nailed the crosspieces to prevent the bomb from swinging away from its nesting spot. One crosspiece will be nailed along the front side of the bomb to hold the stringers in place. The remaining five crosspieces will be nailed to the stringers behind the bomb. The fin will be placed in the rear of the truck. If rough ground is to be traveled, the fins should be braced against sliding and possible damage. The 4,000-lb. bomb should never be loaded with its long axis parallel to the direction of the truck's travel. Bracing is difficult, and the dunnage as well as the bomb will move forward or backward at the slightest jar.

Armor-piercing Bombs. All armor-piercing bombs will be loaded approximately

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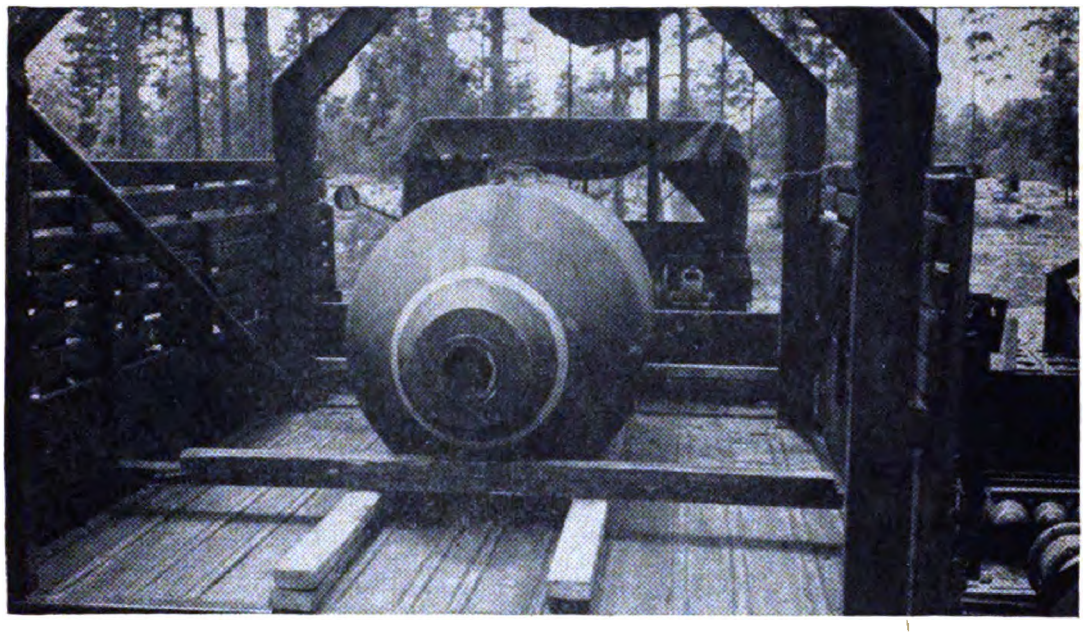
like 1,000-lb. general-purpose bombs. The 600-lb. size will be loaded in one or two rows of five each, the nose plugs of the front row touching the front body board. The four 10 ft. stringers will be nailed together to form two 4 in. x 4 in. stringers and will then be placed along the sides of the bombs and nailed to the crosspieces under the bombs. Bracing behind the rear row of bombs is not necessary.



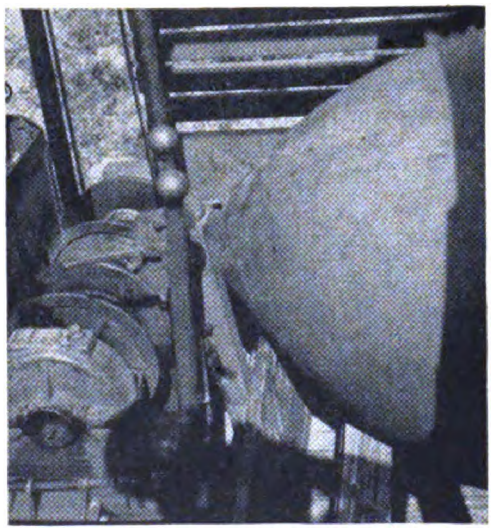


Figure 108. Improper Method of Loading 4,000-lb. Bomb, and the Effect After Stopping Truck Sharply From 10 m.p.h.

Six 1,000-lb. armor-piercing bombs will be placed in two rows of three each and braced like 1,000-lb. general-purpose bombs. If three, four, or five bombs instead of six are carried, place them all in one row. Behind the tails of the bombs nail two crosspieces to the stringers to prevent any rearward movement. Three or four 1,400-lb. bombs and two or three 1,600-lb. bombs will be carried in single rows and braced along the sides and at the rear as already indicated. There is adequate space in the truck for all fins.

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Semi-armor-piercing Bombs. 500-lb. SAP bombs will fit in one or two rows of six each and will be loaded and braced in the truck exactly like 500-lb. general-purpose bombs. The ogives of the outside bombs in the front row will be wedged against the front arch. As in the case of 500-lb. general-purpose bombs, the distance from the front body board to the front lugs of the SAP bombs will be 30 in. The first crosspiece will be placed at this distance, and the bombs will be lowered so that the front lugs are against this crosspiece. After all bombs have been loaded, place two crosspieces along the sides of the rows and nail them to the crosspieces under the bombs. When twelve bombs are carried, six fins will fit at the front of the load, and six will go at the rear.

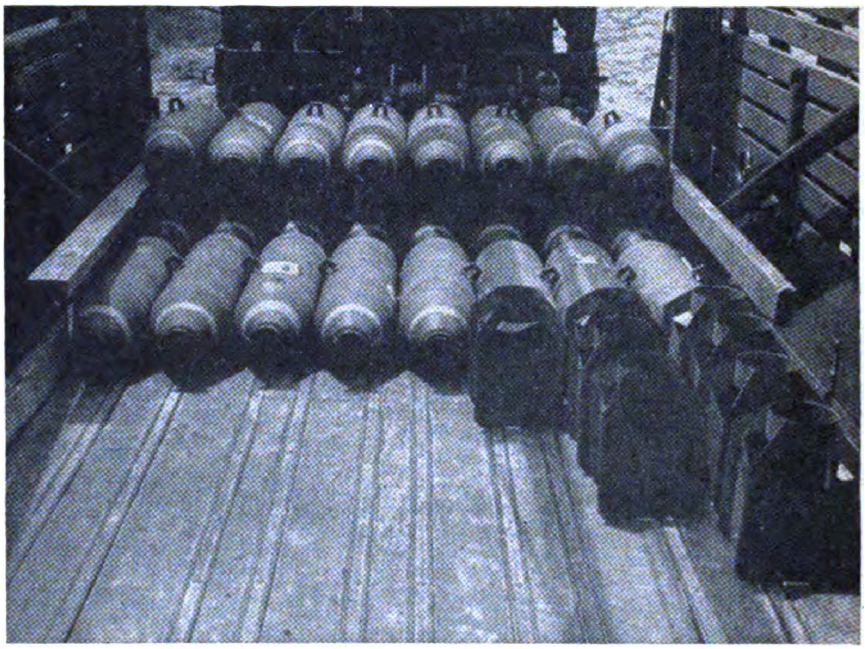

Figure 109. Load of M81 Fragmentation Bombs.

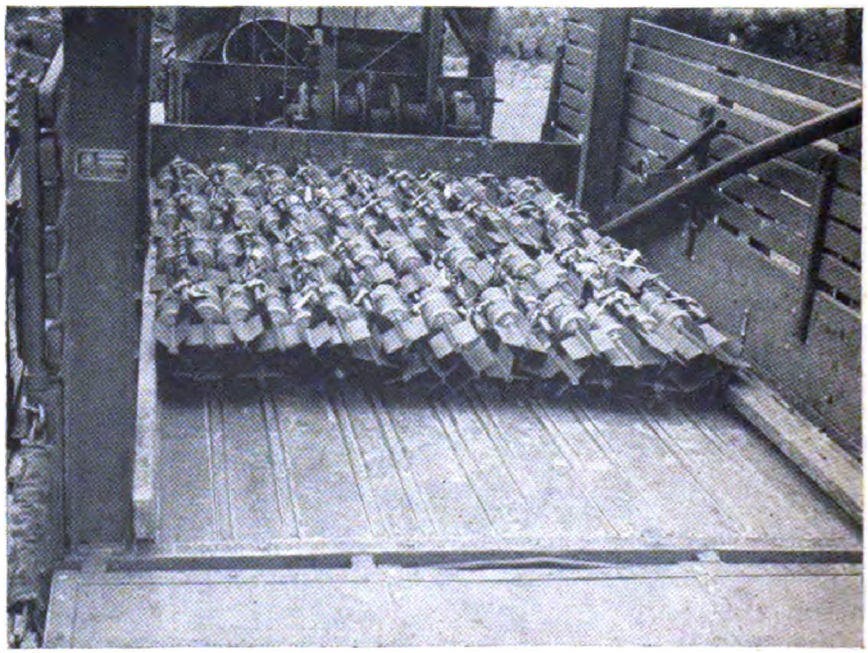

Figure 110. Load of AN-M1A1 Fragmentation Clusters.

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1,000-lb. SAP bombs will be loaded and braced in the truck approximately like 1,000-lb, general-purpose bombs. If three or four are carried, place them in a single row. If five or six are carried, place the fifth and sixth bombs crosswise behind the first four and nail one or two crosspieces behind each. Fins will fit in the rear of the truck.

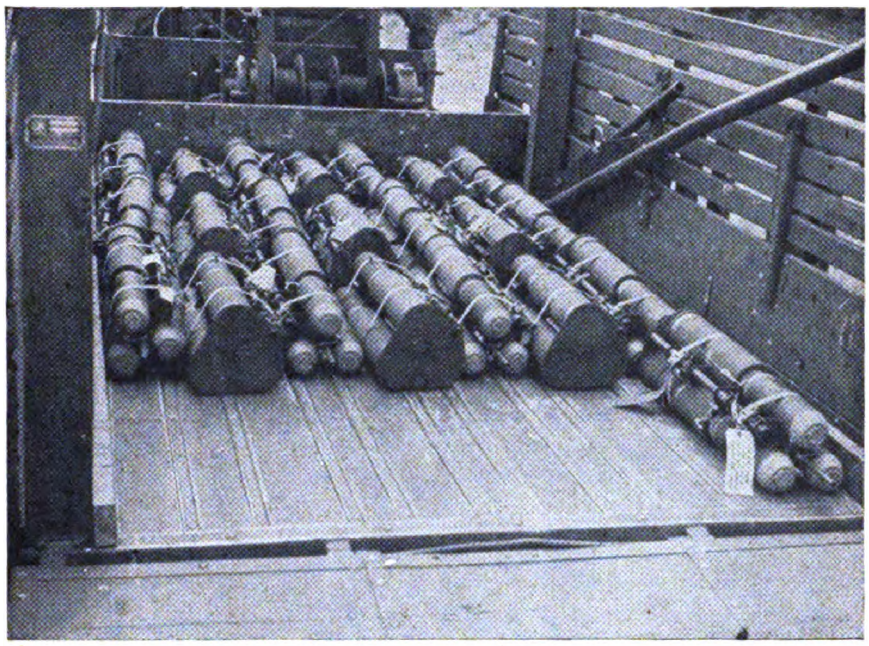

Figure 111. Load of AN-M4 Fragmentation Clusters.

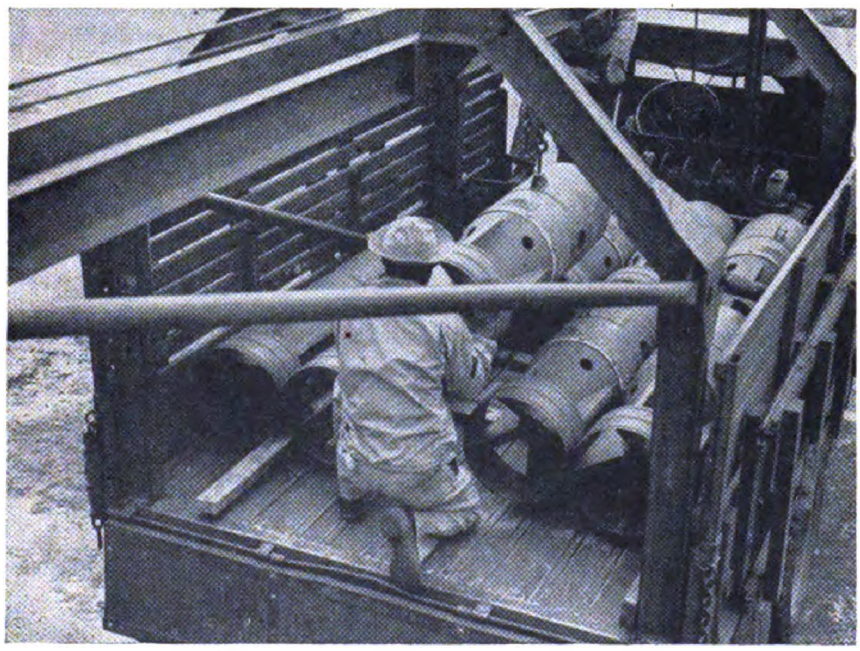

Figure 112. Load of AN-Mk. 41 (325-lb.) Depth Bombs.

Fragmentation Bombs and Clusters. The 23-lb. M72 parachute bomb will be left crated when loaded and unloaded. Two bombs are packed per crate. The crates will be carried by hand and placed lengthwise in the truck. Five boxes will go in the first row and six each in the next two rows. Two boxes will be

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placed crosswise at the rear of the third row. Two layers, or a total of 38 boxes, may be carried in the truck.

M81 fragmentation bombs (260 lb.) will be loaded in the M27 similarly to 100-lb. and 250-lb. general-purpose bombs. Two rows of eight bombs each will be loaded, and, after two crosspieces have been placed on top of the front row, a second layer of eight may be loaded. The bombs will not be loaded two high at the rear row because the overload will be excessive. Two of the crosspieces will be wedged between the front arches and the outside bombs of the top row so that the bombs will not slip.

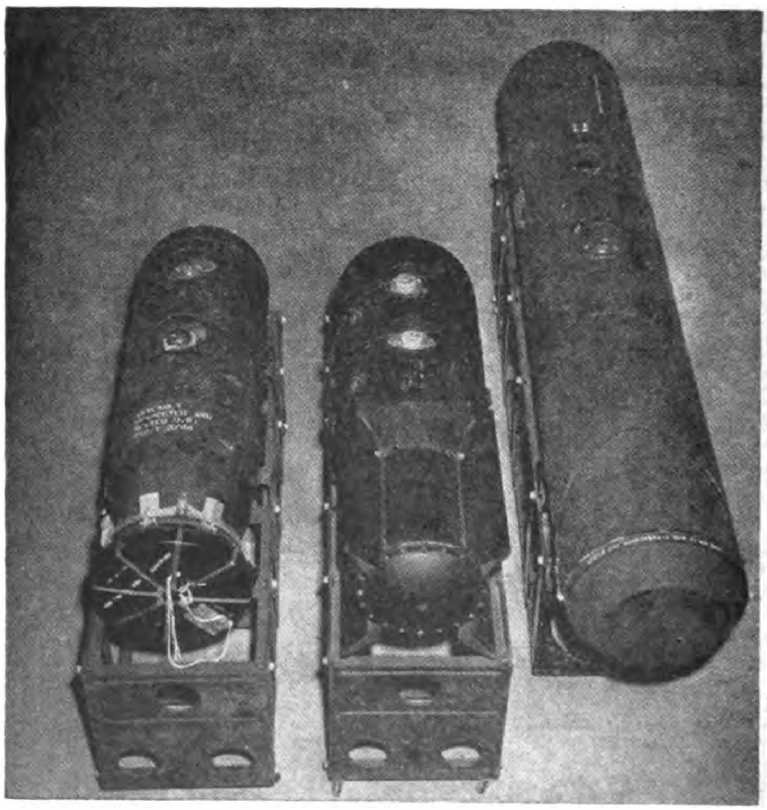

Figure 113. Type Mines: AN-Mk. 26; AN-Mk. 13; AN-Mk. 12.

AN-M1A1 and AN-M4 fragmentation clusters will be loaded on the M27 by hand. At the present time, AN-M1A1 clusters come crated with fuzes already inserted in the bombs. The fins are also attached. Both clusters come with arming wires installed. These bombs, therefore, must be handled very carefully to avoid injurying the cluster adapters, release mechanisms, arming wires, fuzes and fins (or parachutes in the case of AN-M4 clusters). The clusters will not be loaded in the truck in more than one layer. AN-M1A1 clusters will be placed in rows of nine each. The tips of the adapters of the front row will touch the front body board. Four crosspieces, two for each row, will be placed under the bomb bodies to protect the fins. Two 10 ft. stringers will be laid along the sides of the truck, one on its 2 in. edge and one on its 4 in. edge. AN-M4 clusters will be loaded in four rows of seven each. Because the width of this cluster is greater at the parachute than at the bomb body, the clusters will be reversed end to end as they are placed in the truck. Two 10 ft. stringers will be laid along the sides on their 2 in. edges. No crosspieces are necessary under the AN-M4 clusters.

Depth Bombs. Both flat and round-nose depth bombs will be loaded similarly. 325 to 350-lb. depth bombs will be loaded in two rows. The front row will have four bombs and the rear row five. Two crosspieces will be placed under each row. One 10 ft. stringer will be placed along one side of the truck. After the first row is in place, lay a second stringer along the other side of the truck

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against the outside bomb and nail it to the crosspieces. The fifth bomb in the rear row will now fit between the second stringer and the side wall of the truck.

Three 650 to 700-lb. depth bombs are all that can be carried in the truck when finning takes place before loading. If four are placed in one row, the fourth bomb will not fit all the way down because of the steel arches. The finned bombs are too long to fit in two rows and the stringers along the sides of the bombs will interfere with bombs laid crosswise in the rear of the truck. If the bombs are carried finned, load and brace a row of three bombs similarly to 1,000-lb. general-purpose bombs. If the bombs are carried unfinned, six can be carried and will be loaded and braced like six 1,000-lb. general-purpose bombs.

Mines. Two AN-Mk. 12 mines will be carried in the M27 like torpedoes. (See Torpedoes.)

AN-Mk. 13 and AN-Mk. 26 mines will be carried like three 1,000-lb. general-purpose bombs. The length of these mines does not permit a load of more than three to be carried safely. After the crosspieces have been laid, the mines loaded, and the stringers positioned, brace the tails of the mines against rearward movement by nailing two additional crosspieces to the stringers.

Figure 114. First Torpedo (Dummy) Loaded on M27.

Torpedoes. Two AN-Mk. 13 torpedoes can be carried in the M27. Nail the 10 ft. stringers together to form 4 in. x 4 in. stringers, place two crosspieces in the truck, and load the torpedoes. After the stringers are wedged along the outsides of the torpedoes, nail them fast to the crosspieces. The torpedoes will extend approximately 40 in. beyond the rear of the truck. For this reason, it is suggested that the tail gate be placed in the horizontal position before traveling. This load is comparatively unsteady, and the truck should be driven accordingly.

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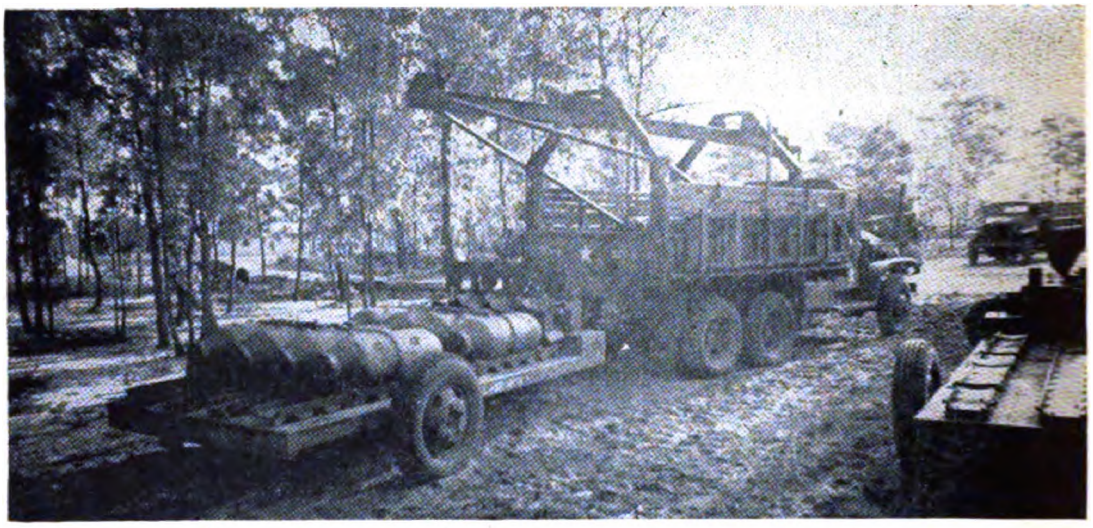

Figure 115. The M27 as a Prime Mover for the M5 Bomb Trailer.

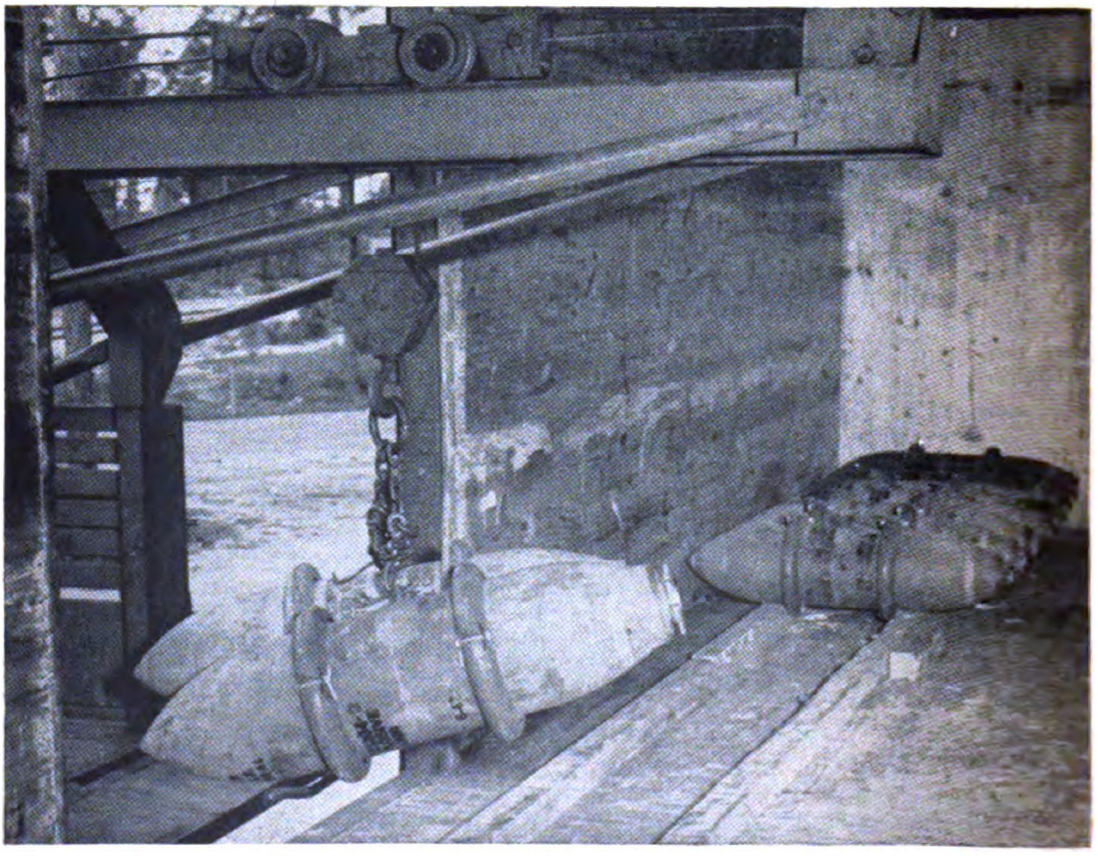

Figure 116. Loading 500-lb. SAP Bombs Into Boxcar.

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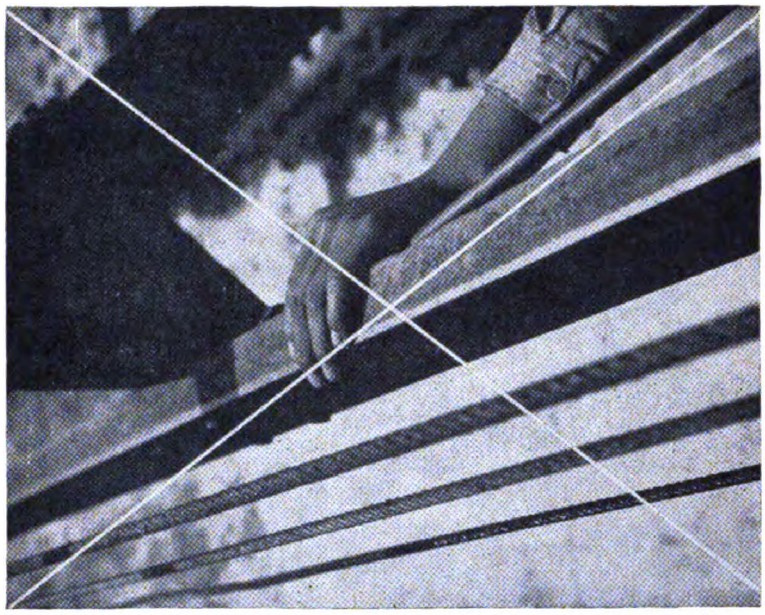

Figure 117. Keep Hands OFF the Overhead Rail. (Improper Use Indicated by White Diagonal Lines).

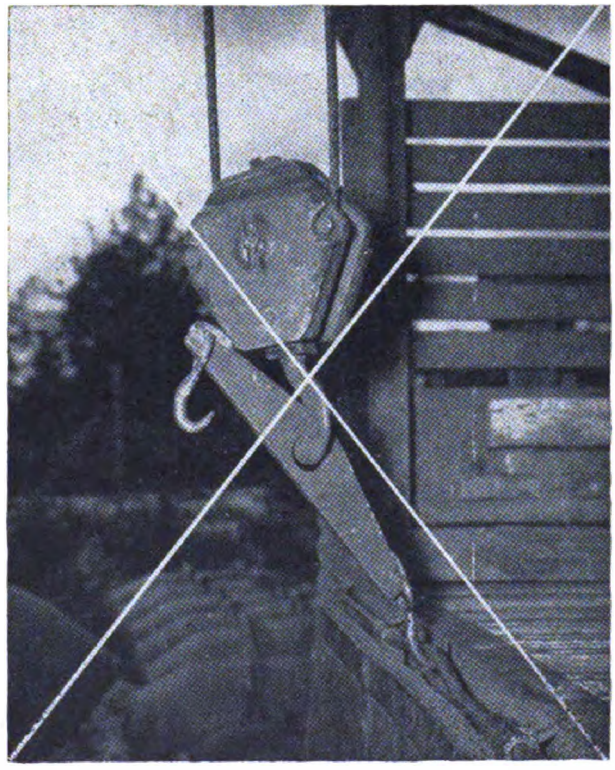

Figure 118. Spreader Bar Hooked Improperly in Tail-Gate Rod.

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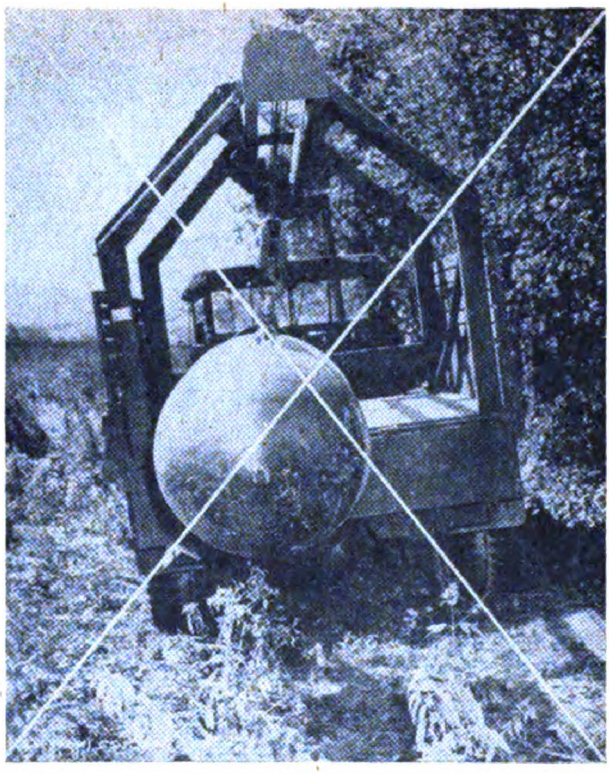

Figure 119. 4,000-lb. Bomb Being Improperly Loaded While Truck is Tilted Laterally.

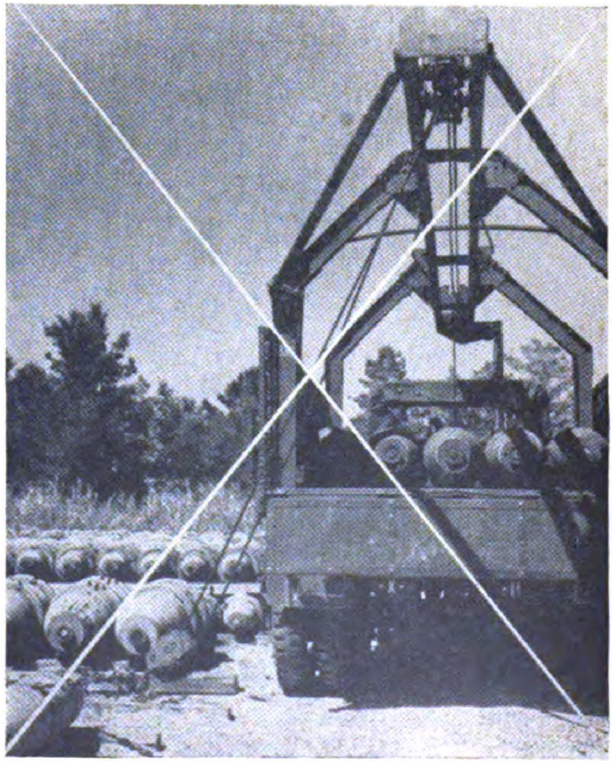

Figure 120. Angle Pull. (Improper Use Indicated by White Diagonal Lines).

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Loading Other Carriers with the M27. In addition to carrying its own payload, the M27 is capable of towing one M5 trailer fully loaded. It is not recommended, however, that the vehicle be put under such strain if deep mud, sand, or rough ground are to be traversed.

The M27 is satisfactory for loading bomb trailers and cargo trucks although it is not designed primarily for bomb storage area operations. The fixed overhead rail is a limiting factor on the speed and ease with which the M27 can maneuver and place the bombs in other vehicles. If an M5 trailer is back up to the M27, the overhead rail will not reach to the front of the trailer bed. It is advisable, therefore, to place the trailer to be loaded near the bomb revetment where it can be positioned perpendicularly to the M27. A load of bombs can then be placed in the M27, driven to the trailer, and unloaded.

As a supplementary unit to load and unload boxcars, the M27 is most suitable. It can load and unload its cargo twice as fast as a tractor crane can empty or fill a truck with the same quantity of bombs. The overhead rail extends well into a boxcar door. Bombs can always be brought off the M27 in the correct position for rolling into the car. It is advisable to build a platform which will raise the rear wheels of the M27 so that the overhead rail will be raised permitting more clearance for maneuvering heavy bombs and for loading the upper layers of light bombs. In a recent test, the M27 unloaded ten 500-lb. bombs into a boxcar in 6 minutes. This time included the time spent positioning the bombs in the car.

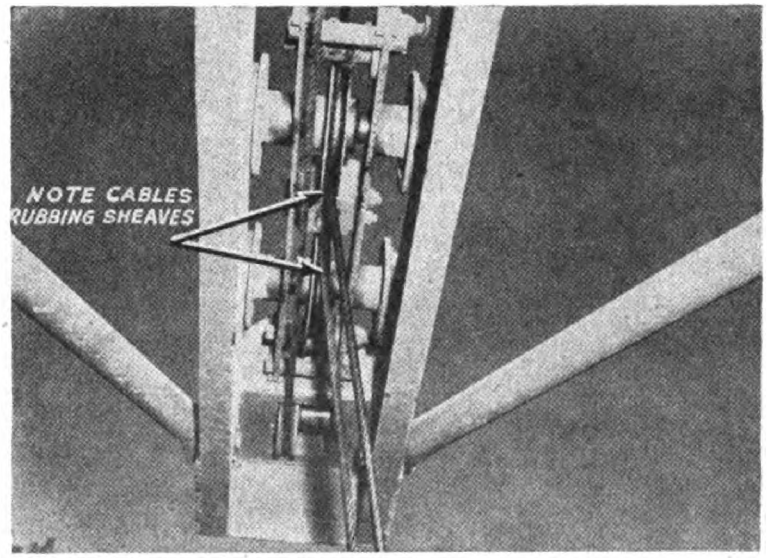

Figure 121. Effect of Truck Tilt or Angle Pull on Cables.

Precautions in Using the M27. Do not place a hand on the overhead rail at any time. This is often done unconsciously by crew members while working in the vehicle body. The trolley can easily crush one's fingers.

When winching in the trolley, be sure the hoisting cable is raised enough for the hooks of the spreader bar to clear the tail-gate rod.

Make sure all the bombs, mines, or torpedoes in a load are tightly wedged and braced before traveling. The front body board on the second pilot model was not reinforced, and a sudden jolt could easily have sent a bomb into the winch gear, damaging it and endangering personnel in the cab of the truck.

Heavy bombs, mines, and torpedoes must be securely braced against rearward movement.

Although cable guards are provided for the trolley, a load should not be placed on the hook if the lateral tilt of the truck is over 8°. It is also common sense not to attempt angle pulls. The cable and sheaves will be damaged if these practices are followed.

When lifting 4,000-lb. bombs, make sure the truck is positioned on as flat ground as possible. On the overhead rail at a point 4 ft. 3 in. beyond the rear of the

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truck body is a mark. Do not place a load of over 2,000 lb. on the hook beyond this mark.

When traveling, the trolley should be positioned at the front of the overhead rail and made tight against the dead-end stop. Caution, however, must be exercised to avoid jamming the trolley against the stop.

Before traveling, draw the block and hook up tightly into the trolley. The upper face of the block is designed to wedge into the trolley. At no time should the hook be left slack to dangle and swing. This practice is dangerous to personnel and cuts down the life of the hoisting cable.

Never drive the truck with a load suspended from the hook.

If a tarpaulin is thrown over the truck, the rear portion of the canvas must be tucked under the rear bow and lashed in place to avoid interference with the movement of the trolley.

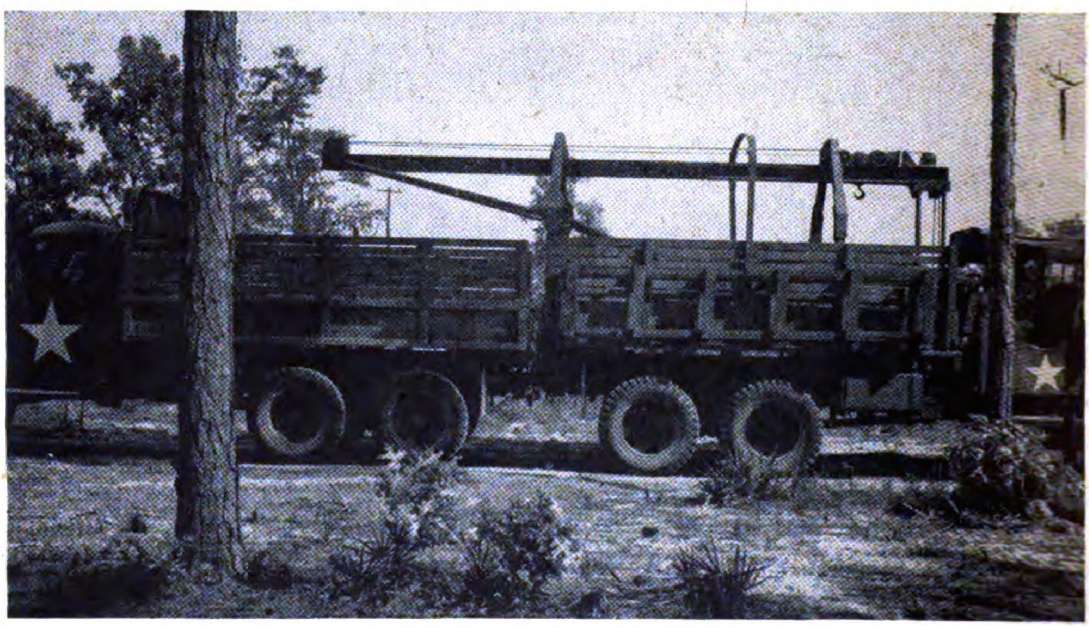

Figure 122. Traveling Position for Trolley and Hook.

In the several cases where bombs can be loaded in two layers, make sure the top layer does not interfere with the operation of the winch controls.

To avoid excessive gear clash and wear, decrease the speed of the winch before shifting the control levers. The connecting rods which are pinned to the lever arms of the controls are threaded at each end and have double hex nuts for spring-tension adjustments. Gear clash may be reduced by occasionally adjusting these hex locking nuts.

There is very little clearance between the chain drive from the winch power-input shaft and the propeller shaft. As the chain loosens up through use, the chain may slap the propeller shaft and cause excessive wear. Be sure the eccentric in the bearing housing of the winch power-input shaft is properly adjusted and the set screws are kept tight at all times.

The links of the chain drive have cotter key connections instead of rivets. Periodically inspect the links for lost or broken keys. It is far easier to replace a cotter key than a link.

The four straight sections of track do not fit interchangeably in the brackets on the sides of the truck body. Only two of the sections will nest correctly in the inside positions, and they must be placed with one particular end toward the front of the truck. The other two sections will nest interchangeably in the outside positions on either side of the truck, either end forward. There are no markings or numbers which will tell which two of the four sections will fit on the inside. It is suggested, therefore, that the words *Inside Front* be stamped or marked on

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the proper ties of the two sections that do fit. If care is not taken to fit the sections in the brackets correctly, the brackets will soon become twisted, bent, or broken.

No provision has so far been made for carrying the curved track section. The best place for it is on either side of the truck hooked over two ties of one of the outside straight sections of track. The bulge of the curve will be approximately on a line with the front arch. Heavy rope or chain should be used to make the rail fast to the arch.

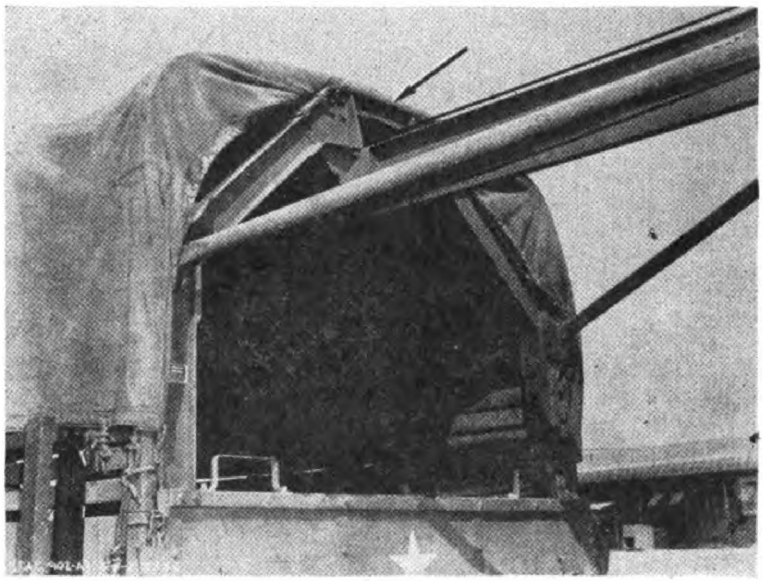

Figure 123. Tarpaulin Tucked Under Rear Truck Bow.

Care must be observed when backing the M5 bomb trailer with the M27. On either side of the truck's towing pintle are bumpers that project beyond the pintle. If the trailer is jackknifed, the bumpers will press against the trailer yokes causing them to snap their lunette connections. When the trailer is backed by the M6 bomb service truck, there is more clearance and such a break is less likely to occur.

BOMB HANDLING DRILL

General Instructions. The fundamental unit for bomb handling with the M27 is the service crew of four men, consisting of a crew chief, a driver, and two munition workers. For the purposes of training, the driver, munitions workers, and crew chief will be numbered 1, 2, 3, and 4, respectively. Duties and responsibilities are assigned to facilitate simple and complete instruction covering every operation so that there will be a minimum of lost motion and back-tracking.

In drill as well as in actual bomb deliveries, No. 1, the driver, will make a general inspection of the condition of his vehicle, bomb handling equipment, gasoline, tires, oil, water, battery, and engine before leaving the motor pool. (See AR 850-15.) In addition, No. 1 will be responsible for first echelon maintenance on the winch, trolley, and cables.

Before the truck and crew move out, No. 4, the crew chief, will see that all track sections are securely mounted on the truck, that the dollies are lashed in place, and that the proper bracing or dunnage for loading the bombs is available in the truck.

The crew chief will be responsible for the safe transportation of his men and equipment at all times while on duty.

The crew chief will direct No. 1 to move the truck at any time he sees fit to facilitate and expedite loading and unloading.

When the crew arrives at the bomb loading area, the crew chief will direct the

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positioning of the truck for loading and will see that the truck has come to a complete stop before giving the command *Load*—which will be the standard command for commencing all bomb loading drill. At the command *Load*, each crew member will dismount and perform his assigned duties without delay or confusion.

When loading has been completed, the crew chief will inspect the bombs and fins in the truck to see that they are properly positioned and braced for traveling. He will also make sure that the trolley and hook are in the traveling position before giving the command *Mount*—which will be the standard command for the crew to take positions in the truck. The crew chief will be the last member to take his position.

When the crew arrives at the unloading point, the crew chief will direct the spotting of the truck for efficient unloading, will direct the laying of the track, and will give the command *Unload*.

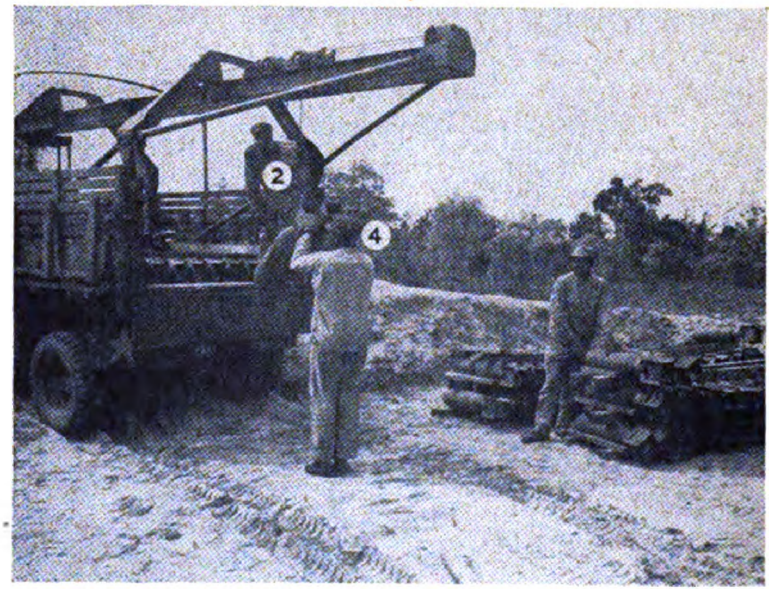

Figure 124. Loading 100-lb. Bombs with Winch.

The crew chief, and only the crew chief, will be responsible for designating the crew member who will direct the winch operator. In general, the crew chief himself will direct No. 1 during winch operations that take place at the rear of the truck. No. 2 will usually direct No. 1 during winch operations that take place inside the truck.

Loading Drill for 100-lb. Bombs. The instant No. 1 has positioned the truck for loading, No. 4 will give the command *Load*. No. 1 will set the truck brakes, shift the main transmission into neutral, engage the winch power take-off, and take his position at the winch controls. No. 3 will lower the tail gate. No. 2 will place a double-hook chain* or spreader bar on the trolley hook, and No. 1 will run the trolley out to receive the first bombs. No. 2, assisted by No. 3, will position the dunnage required in the truck. No. 4 will roll out and position all bombs to be loaded, will engage the chain hooks or spreader bar in the lugs of the bombs, and will guide the bombs as they are raised. No. 2 and No. 3 will place the bombs in the truck as they are loaded. Each row of bombs will be loaded from the sides of the truck toward the center so that the last bombs lowered into each row can be positioned with a minimum of handling. If the bombs are to be loaded in two layers, it is advisable to load both layers of the first row before proceeding to the second row, etc. No. 2 and No. 3 will place crosspieces between the bombs and stringers along the sides of the rows as needed. At the completion of loading,

* A double-hook chain was used in all handling of 100-lb., 250-lb., and 500-lb. bombs. (See fig. 127.) The chain permits handling two 100-lb. bombs and two 250-lb. bombs at once, and is easier to use with 500-lb. bombs than is the spreader bar.

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No. 3 will close the tail gate. No. 2 will remove the chain or spreader bar from the trolley hook. No. 1 will return the trolley and hook to the traveling position and disengage the power take-off. No. 4 will thoroughly inspect the load to see that the bombs are tightly braced and that the lugs and fins will not be damaged

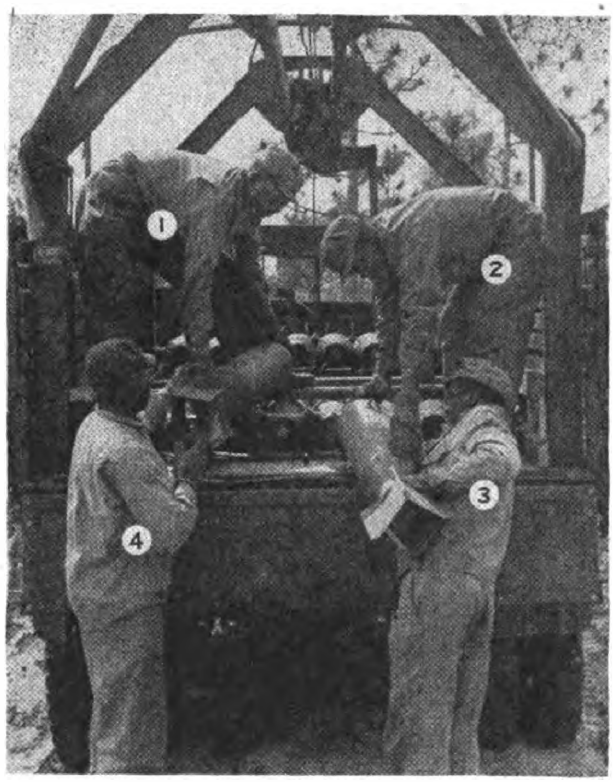

Figure 125. Loading 100-lb. Bombs by Hand.

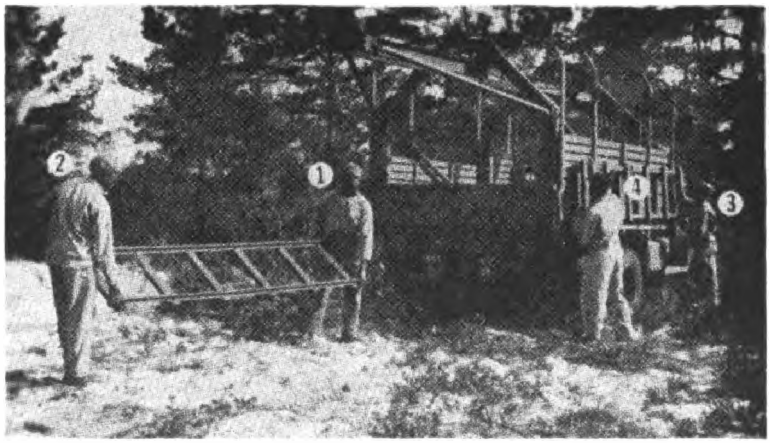

Figure 126. Positioning Track for Unloading Drill.

or bent in transit. The crew will take positions on the truck at the command *Mount*, given by the crew chief.

If 100-lb. general-purpose bombs are to be loaded on the M27 by hand instead of with the winch, No. 1 and No. 2 will handle all operations in the truck, and No. 3 and No. 4 will work on the ground.

Unloading Drill for 100-lb. Bombs. When the truck has reached the unloading point, No. 1, directed by No. 4, will position the truck for most efficient unloading. No. 4 will determine the amount of track needed for the unloading. No. 1

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with No. 2, and No. 3 with No. 4 will work as teams in removing the track sections from the left and right sides of the truck respectively and in positioning and fastening the sections together with the track locking pins. After the track has been laid, No. 1 will engage the winch power take-off and take his position at the winch controls. No. 2 will place the chain or spreader bar on the trolley hook, and No. 3 will lower the tail gate. No. 2 will work in the truck engaging the chain hooks or spreader bar in the lugs of the bombs and guiding the bombs as they are removed from the truck bed. No. 3 and No. 4 will receive the bombs as they are lowered and guide them so that they will come to rest crosswise on the track rails. No. 3 and No. 4 will then roll the bombs along the track to the point of deposit. After the unloading has been completed, No. 1 will prepare the winch gear for traveling, return to the truck cab, and disengage the power take-off. No. 3 will raise the tail gate. To actually complete unloading drill, the track sections should be picked up and replaced on the truck. The point of deposit of the unloaded bombs, therefore, should be off the end of the track. In replacing the track, No. 1 will work with No. 2, and No. 3 will team with No. 4 in returning the sections to the left and right sides of the truck respectively. No. 4 will supervise all operations and, before giving the command *Mount*, will see that all equipment and dunnage have been replaced in the truck and that the track sections are properly nested in their carrying brackets. If 100-lb. bombs are unloaded by hand and carried to the point of deposit, No. 1, No. 3, and No. 4 will work on the ground receiving the bombs from No. 2.

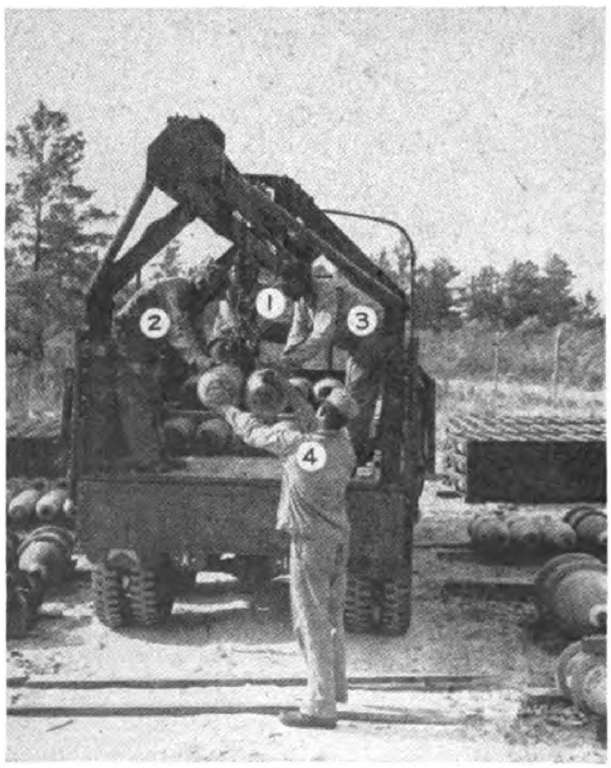

Figure 127. Loading 250-lb. Bombs Using Doublehook Chain.

Loading Drill for 250-lb. Bombs. The procedure will be similar to that for loading 100-lb. bombs. Again it is suggested that a double-hook chain be used so that two bombs can be handled at once. No. 2 and No. 3 will work in the truck. No. 4 will roll the bombs into position, engage the chain hooks or spreader bar in the lugs, and direct No. 1 in raising the bombs into the truck. After all operations have been completed, No. 4 will inspect the load and give the command *Mount*. No. 1 will drive the truck to the fin stacks. No. 3 and No. 4 will carry the fins, and No. 2 will place them in the rear of the truck.

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Unloading Drill for 250-lb. Bombs. After the truck has been positioned at the unloading point and the track has been laid, No. 3 and No. 4 will remove the fins and place them near the point of bomb deposit. The first two bombs will be lowered to No. 3 who will roll them down the track and fin them. No. 4 will receive the next two bombs and roll them out to No. 3 who will continue finning

Figure 128. Unloading 250-lb. Bombs.

the bombs as he receives them. If the bombs are lowered faster than No. 4 can handle them on the track, No. 3 will assist No. 4 and then return to his job of finning. When all the bombs have been unloaded, No. 2 will dismount from the truck and will work with No. 3 to complete the finning. No. 4 will assist and inspect the assembled bombs. No. 1 will prepare the truck for traveling and return all equipment and dunnage to the truck. The track sections will be returned to the truck carrying brackets as already explained.

Figure 129. Loading Fins for 500-lb. Bombs.

Loading Drill for 500-lb. Bombs. 500-lb. bombs will be loaded similarly to 100-lb. and 250-lb. bombs except that only one bomb will be handled at a time. Either a double-hook chain or a spreader bar may be used. Before the first bomb is lowered, No. 2 will see that one crosspiece is laid in the truck bed 30 in. back from the front body board and that a second crosspiece is placed so the rear lugs of all bombs in the row will be against it. After two rows of bombs are in place,

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No. 3 will nail dunnage along the sides of the rows to the crosspieces under the bombs. No. 2, directed by No. 4, will line up the bombs and force them tightly together before No. 3 nails down the dunnage along the sides of the rows. No. 1 will hand fins to No. 2 who will place them in the front of the truck, and No. 4 will hand fins to No. 3 who will place them behind the rear row of bombs.

Unloading Drill for 500-lb. Bombs. 500-lb. bombs will be unloaded like 250-lb. bombs. Care should be exercised in rolling the bombs down the track. If they are not guided carefully and kept straight, they may roll off, thus slowing considerably the unloading process. No. 3 will do the finning, completing the job with the assistance of No. 2. No. 4 will also assist and will inspect the assembled bombs.

Loading Drill for Heavy Bombs. When heavy bombs are loaded, the crew chief will direct operations to insure maximum efficiency and minimum effort on the

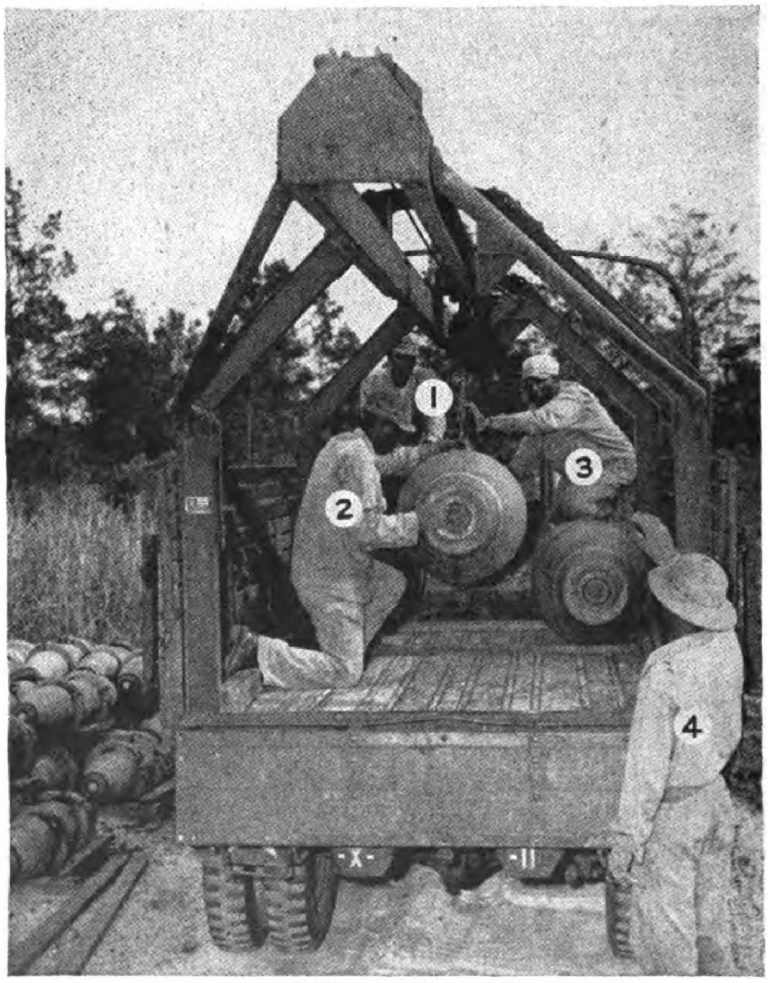

Figure 130. Lowering 2,000-lb. Bomb into Truck.

part of the crew. If the truck is positioned correctly, if adequate dunnage is laid on which to roll the bombs out from their stacks, and if crosspieces are placed in the truck under the bombs, loading will be speeded up and the job will be made easier.

1,000-lb. bombs will be rolled into position for loading by No. 4. No. 2 and No. 3 will work in the truck, placing the bombs as they are loaded. Three bombs will be placed in one row. As the first two bombs are being lowered onto the dunnage, they should be forced toward the sides of the truck on which they will finally rest. If this is done, a minimum of manhandling and rolling the bombs into position will be necessary, and the lugs will not 'roll up' and interfere with the center bomb as it is lowered. After the third bomb in the first row is in place, No. 2

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will trim the load in the center of the truck, and No. 3 will nail two stringers, made into 4 in. x 4 in. size, along each side of the row. After the remainder of the load is in place, four, five, or six bombs as the case may be, No. 3 will brace the load by nailing several crosspieces to the stringers behind the rear bombs. No. 1 will prepare the winch gear for traveling, and No. 3 will raise the tail gate.

2,000-lb. bombs will be rolled into position for loading by No. 3 and No. 4. No. 2 will lay dunnage in the truck for the bombs to rest on. While No. 4 is engaging the spreader bar in the lugs of the first bomb, No. 3 will take his place in the truck to assist No. 2 in positioning the bombs as they are lowered. When three 2,000-lb. bombs are carried, the first two bombs should be forced as they are lowered toward the sides of the truck on which they will finally rest. As in the case of 1,000-lb. bombs, this maneuver will cut manhandling and rolling to a minimum and will prevent the lugs from 'rolling up' and interfering with the center bomb as it is lowered into position. After the three bombs are in place, No. 2 will lay a stringer along each side of the row, and No. 3 will brace the load at the rear by nailing crosspieces to the stringers.

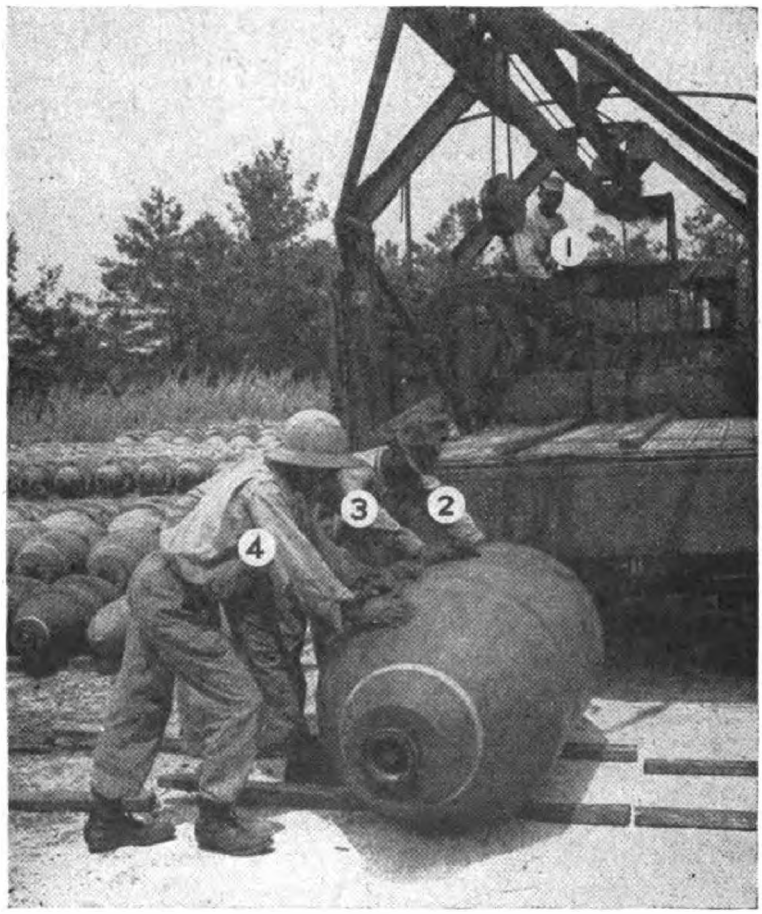

Figure 131. Rolling 4,000-lb. Bomb Into Position for Loading.

A *4,000-lb. bomb* will be positioned for loading by No. 2, No. 3, and No. 4. No. 2 and No. 3 will then mount into the truck while No. 4 hooks the spreader bar into the bomb lugs. As the bomb is lowered into the truck, No. 2 and No. 3 will swing it to the oblique. The nose plug of the bomb will rest against an upright chock placed by No. 2 against the truck side boards behind the front steel arch. No. 3 will guide the tail under the tubular diagonal brace on the opposite side of the truck. As the bomb comes to rest, No. 1 will hold it tightly in place with the winch while No. 2 and No. 3 position stringers and crosspieces. After the crosspieces have been nailed to the stringers in front of and behind the bomb, No. 1

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will slacken the trolley cable, and No. 2 will disengage the spreader bar. No. 3 and No. 4 will hand the fin to No. 2 who will position it in the truck and, if necessary, brace or lash it in place. No. 4 will carefully inspect the load to see that the bracing is adequate. No. 1 will prepare the truck for traveling, and No. 3 will raise the tail gate.

Figure 132. Loading 4,000-lb. Bomb.

Unloading Heavy Bombs. *1,000-lb. bombs* may either be unloaded to the dollies or be rolled down the track. If the track is laid on rough or soft ground, No. 4 should see that the sections are tightly fastened together and positioned as levelly as possible. All low spots in the ground should be filled in and high spots smoothed off. If the bombs are rolled on the track, particular care must be taken to guide them and keep them straight. Any slight jar will pitch the bombs off. No. 3 and No. 4 will receive the bombs from No. 2 who will work in the truck. After he has rolled the first bomb out to the point of deposit, No. 3 will begin the finning. When the last bomb has been removed from the truck, No. 2 will dismount and assist No. 3 in completing the finning. No. 4 will inspect the work and help where needed. No. 1 will return dunnage and equipment to the truck and prepare the winch gear for traveling.

2,000-lb. bombs will be carried on the dollies. After the track has been laid, No. 3 and No. 4 will position a dolly and receive the first bomb from No. 2. If the track is on hard surface, No. 3 and No. 4 can handle the dolly and bomb. On rough ground, No. 2 will have to dismount and assist No. 3 and No. 4 in pushing the load out to the point of deposit. No. 3 will fin the bomb while No. 2 prepares the second bomb for unloading, and No. 4 places the second dolly on the track. No. 2 will assist No. 4 in pushing the second bomb out to the finning point. Since there are only two dollies, the drill will be limited to two bombs. If the bombs were actually being delivered to a plane, the first dolly would probably be free for repositioning at the rear of the truck by the time No. 2 had the third bomb ready for unloading. No. 2 will fin the second bomb. No. 4 will assist and inspect the assembled bombs.

4,000-lb. bombs will be carried on the dollies. No. 3 and No. 4 will place the

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fin near the rear of the truck and position the dolly on the track. No. 2 will engage the spreader bar in the bomb lugs. No. 3 will mount the truck and assist No. 2 in guiding the bomb as it is raised. After the bomb has cleared the truck, both men will take positions on the ground and guide the bomb onto the dolly. No. 4 will supervise the unloading and assist if necessary. No. 2 and No. 4 will hold the fin in place while No. 3 tightens the fin locking nut. No. 1, meanwhile, will prepare the winch gear for traveling and then will assist the rest of the crew in pushing the bomb and dolly to the point of deposit.

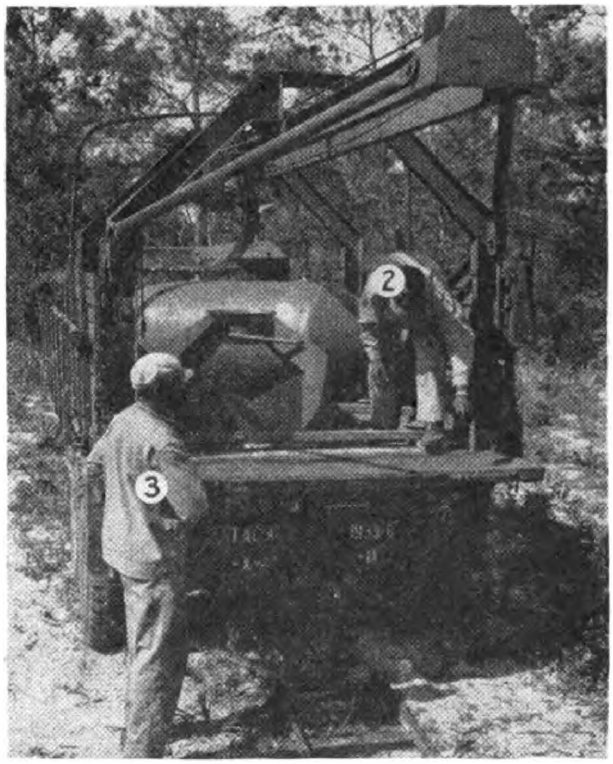

Figure 133. Preparing to Unload 4,000-lb. Bomb.

Although the above paragraphs have assigned specific duties to each crew member, it is obvious that conditions may alter cases. Heavy bombs are hard to maneuver, and the terrain may be such that more men than the number prescribed will be needed to move the bombs during loading and unloading. It will be the responsibility of the crew chief to direct the men to assist where needed and alter the drill to meet the situation.

In all loading and unloading of heavy bombs, No. 1 can greatly assist the remainder of the crew by intelligent operation of the winch controls and regulation of the speed of the winch gear.

Note: During the tests, it was found that the dolly undercarriage interfered with the track pins when the pins were driven entirely in. Although this defect has probably been corrected, a test should be made with the dollies unloaded so that if the interference is present steps can be taken to correct it before a heavy bomb is pitched off its dolly possibly injuring personnel and considerably delaying the unloading.

Fuzing Drill. In some theaters, fuzing will be accomplished by Ordnance personnel before the bombs are loaded into the bomb bays of the planes. When fuzing as well as finning is part of unloading, the drill procedure will be as follows:

After the M27 has been loaded with bombs and driven to the fuze storage point, No. 1, No. 2, and No. 3 will dismount from the truck at the direction of No. 4 and obtain the correct number and type of fuzes, arming wires, and arming vanes. Crew members carrying fuzes will walk at quick time. Fuzes will be

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inserted hand tight. No. 4 will be responsible for the manner in which the fuzes are transported in the truck. It is suggested that an 18 in. x 18 in. x 24 in. container be obtained and carried in the space beside the winch controls. Brackets can be bolted to the truck sideboards and the front body board to hold the container in place. Since the fuzes will normally be loaded into the truck last and unloaded first, this container will not interfere with the movements of the winch operator. Fuzes should not be carried in the cargo space with the bombs. Upon arrival at the unloading point, No. 1 will unload the fuzes if they are carried beside the winch controls and place them near the point where fuzing and finning will be done. If the fuzes are carried elsewhere in the truck, No. 4 will be responsible for unloading them.

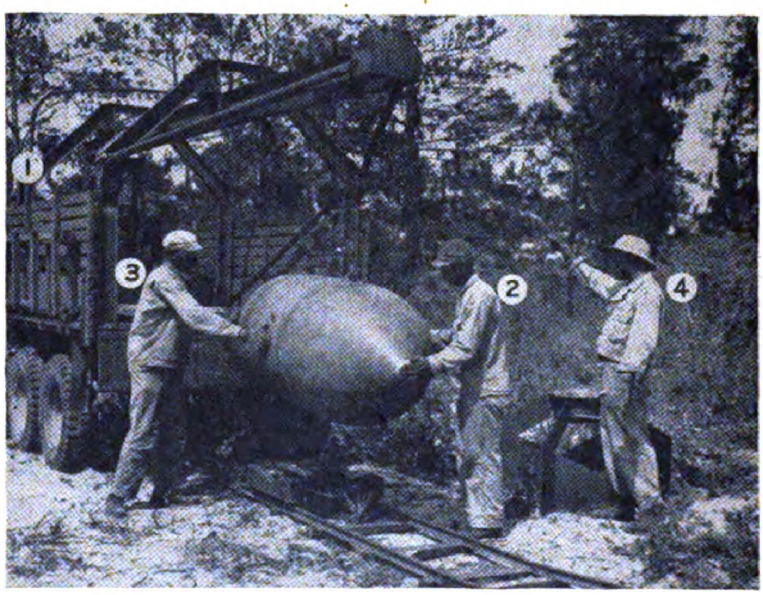

Figure 134. Lowering 4,000-lb. to Dolly.

100-lb., 250-lb., and 500-lb. bombs will all be fuzed similarly. No. 3 will receive the first bombs, or bomb, from the truck and roll them down the track to the point of deposit. He will obtain one nose fuze, one tail fuze, the arming wire, and the arming vanes and fuze the first bomb. No. 4 will receive succeeding bombs and roll them out to the point of deposit where No. 3 will continue to fin and fuze them. After all bombs have been unloaded, No. 1 and No. 2 will dismount from the truck and work with No. 3 to complete the finning and fuzing. No. 4 will assist where needed and will inspect all assembled bombs.

When heavy bombs are fuzed on the ground, they will be carried to the point of deposit on the dollies. Fuzing drill with 1,000-lb. and 2,000-lb. bombs will be limited to two bombs since there are only two dollies.

No. 3 will deliver the first 1,000-lb. bomb on the dolly to the point of deposit and fin the bomb. No. 4 will bring out the second bomb and begin finning it. No. 1 and No. 2 will dismount from the truck and obtain the nose fuzes, tail fuzes, arming wires, and arming vanes for the bombs. No. 1 will work with No. 3, and No. 2 will work with No. 4 in completing the assembly of the two bombs. During actual plane deliveries, No. 1, No. 2, and No. 3 will be ready to unload the third bomb from the truck by the time the first dolly is free for repositioning at the rear of the truck. No. 4 will remain at the plane and assist the armament crew in positioning and raising the second bomb into its station. He will then reposition the second dolly at the truck to receive the fourth bomb.

2,000-lb. bombs will be unloaded and fuzed like 1,000-lb. bombs except that No. 4 will assist No. 3 in delivering the first bomb. No. 3 will fin the first bomb. No. 4 will return to the truck and position the second dolly. As soon as the second bomb has been lowered, No. 1 will dismount from the truck and assist

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No. 3 in fuzing the first bomb. No. 2 and No. 4 will deliver the second bomb and fin and fuze it. In actual plane deliveries, the first dolly will be repositioned at the truck to receive the third bomb as soon as the first bomb has been raised into the plane. The crew will be free to handle the third bomb

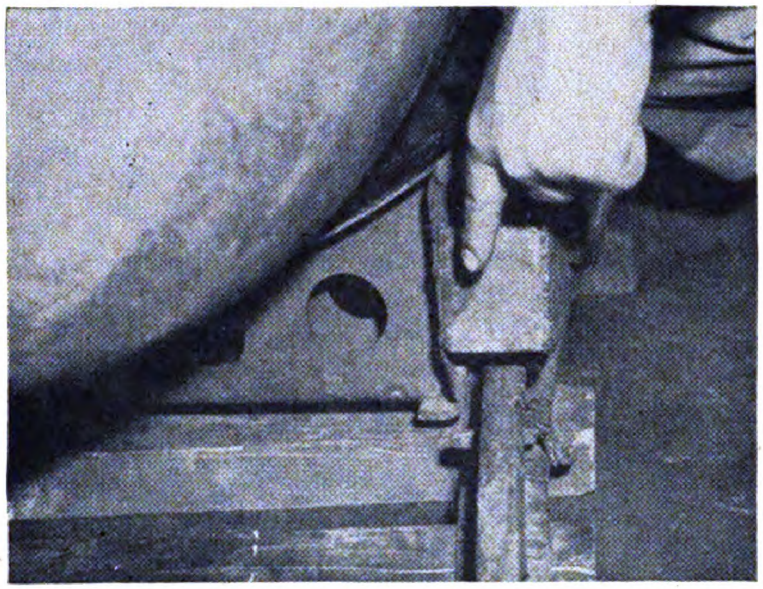

Figure 135. Interference of Track Locking Pins with Dolly Undercarriage.

by the time the first dolly is available. No. 4 will inspect the bombs to make sure they are correctly assembled.

The *4,000-lb. bomb* will be lowered to the dolly and finned before it is pushed out to the point of deposit. No. 2 and No. 3 will guide the bomb onto the

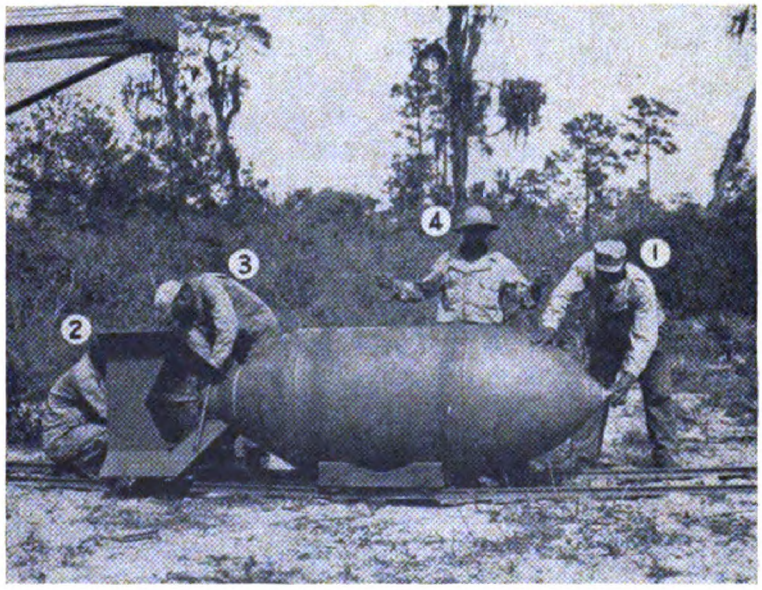

Figure 136. Fuzing 4,000-lb. Bomb.

dolly, assisted and directed by No. 4. While No. 2 and No. 3 fin the bomb, No. 4 will obtain the fuzes, arming wire, and arming vanes, and carry them to the point of deposit. No. 1 will make the winch gear ready for traveling. The entire crew will then roll out the bomb and fuze it. No. 1 will insert the nose fuze.

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No. 2 will insert the tail fuze. No. 3 will assist No. 4 in attaching the arming wire and vanes. No. 4 will inspect the completely assembled bomb.

Plane Delivery. In addition to the general instructions for bomb handling drill, the following special instructions will apply when bombs are delivered to aircraft:

Upon receipt of the order for bomb deliveries, the section chief will designate the bomb service crew or crews, responsible for making the necessary deliveries.

Each crew chief will specify the exact duties of each of the members of his crew. This will be done by assigning a number duty to each man at the time that bomb deliveries have been requested.

In general, drill procedure will be followed. Each crew, however, should be so familiar with each crew member's duties that actual operations will proceed efficiently and smoothly. Flexibility should be the goal so that no man is idle or overworked at any moment. The principles of drill should be so automatic that the varied conditions of actual plane deliveries can be met without confusion or delay. The crew should work as a team, always helping where necessary. Resourcefulness and thought on the part of each crew man, particularly the crew chief, will speed up deliveries, cut bad bomb handling to a minimum, and reduce the chances of accidents.

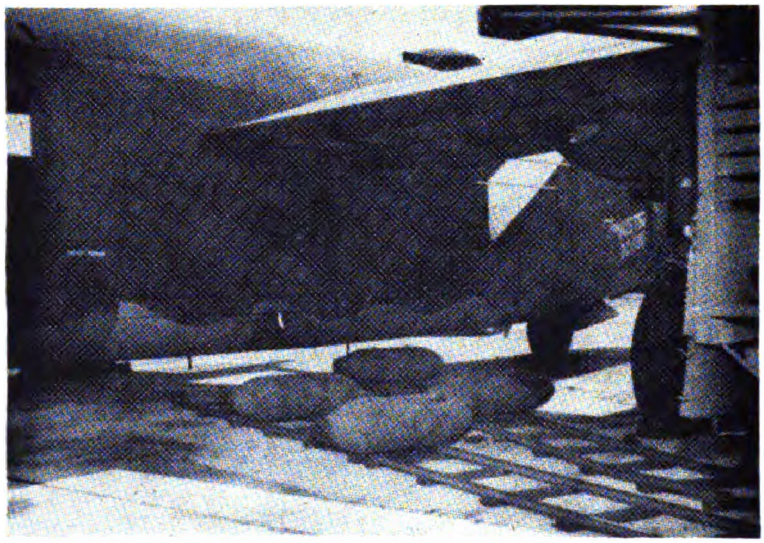

Figure 137. Double Track Laid Perpendicularly to B-24 for Delivery of 500-lb. Bomb.

When fuzes are being issued for a particular mission, it is imperative that a careful check be made so that the proper primer detonator with the correct functioning time is used. This check must be repeated when the fuze is being installed in the bomb. The use of a primer detonator with instantaneous functioning time might prove hazardous on a mission calling for a primer detonator with time delay.

It is wasted effort to transport a bomb with injured lugs to a plane and then find that the bomb cannot be fitted to the shackle. The lugs of all bombs should therefore be checked carefully before the bombs leave the storage area.

After the bombs have been unloaded and all Ordnance functions have been completed, each crew chief will be responsible for having his vehicle returned to the motor pool and will see that the members of his crew are properly accounted for and are present for any reassignment if necessary.

Inasmuch as bombs cannot be loaded into the planes as fast as they are unloaded from the M27 and delivered, it is recommended that several planes be serviced at one time where practicable.*

In many cases, all the track will not be needed to reach from the truck to a single plane. The crew chief should be familiar with the dispersal areas and the

* In many cases, the M27 can carry more bombs than are needed for one plane. The crew chief will decide how many bombs within load limits are to be carried each trip to insure maximum efficiency in plane delivery.

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positions of planes so that the bombs can be unloaded rapidly and moved as short a distance as possible.

If fuzing is to be done in the planes, the Ordnance crew can unload the truck, fin the bombs, and return to the storage area for another load, leaving the track in place. By the time the second load is brought to the field, the armament crew should have cleared the first load of bombs from the track. The sections can then be picked up and moved to the next plane. If fuzing is to be done on the ground, the crew will, of course, remain on the line until the last bomb is made ready for hoisting. When fuzing is part of the Ordnance function, the crew will assemble the bombs rapidly enough to keep up with the speed of the plane's hoisting gear.

All bombs will be delivered to planes with noses to the front. When bombs are rolled on the track sections, the track will usually be laid perpendicular to the plane's fuselage. When the dollies are used, the track will usually be laid as directly as possible to the plane from the left or right front or rear. For example, bombs up to 1,000-lb. can best be rolled to B-24 type planes by laying double track perpendicularly to the plane's fuselage so that both bomb bay cells can be reached at once without changing the position of the truck or the track. Heavy bombs, on the other hand, can best be delivered to B-17 type planes by laying the track to the plane from the right or left front. In all deliveries, No. 4 will direct the laying of the track so that its repositioning during the unloading will be kept to a minimum. In some cases it may not be advisable to lay the track entirely under a plane's bomb bay because of its interference with hoisting operations. This will be a matter for local decision.

Handling of Bombs Other than General-Purpose Bombs. Semi-armor-piercing and armor-piercing bombs, depending on their weight, will be handled like 500-lb., 1,000-lb., or 2,000-lb. general-purpose bombs.

260-lb. fragmentation bombs will be loaded, unloaded, finned, fuzed, and delivered to planes like 250-lb. general-purpose bombs.

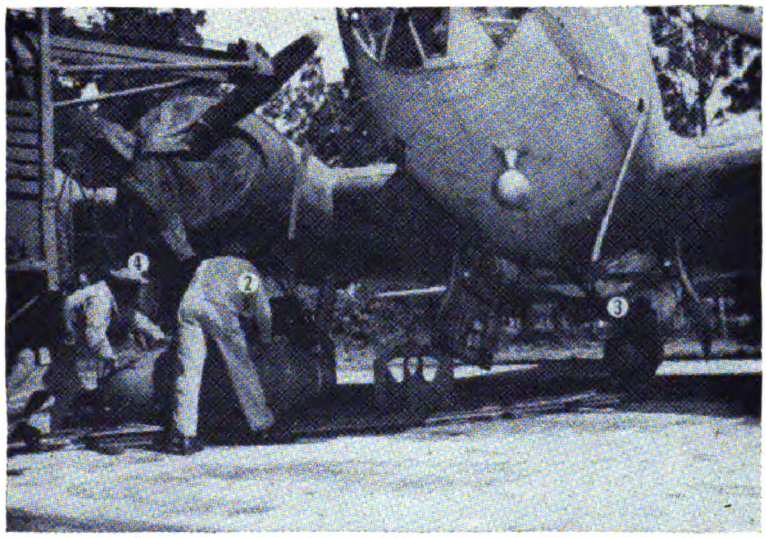

Figure 138. Delivering 2,000-lb. Bomb to B-17 from Left Front of Plane.

AN-M4 and AN-M1A1 clusters will be loaded, unloaded, and delivered to planes by hand. No. 3 and No. 4 will work on the ground, receiving the clusters from No. 1 and No. 2 who will work in the truck. If fuzing is to be done before the clusters are raised into their stations, the entire crew will assist in the fuzing operation at a rate rapid enough to keep ahead of the armament crew.

Depth bombs will be handled like 500-lb. general-purpose bombs. Since the fins and the hydrostatic fuzes will normally be assembled to the bombs prior to plane delivery, particular care should be taken when rolling the bombs along the track to the planes.

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When torpedoes are handled, the truck will be positioned perpedicularly to each torpedo to be loaded. No. 2 will secure a chain or rope around the torpedo at the center of gravity and will engage the trolley hook in the rope or chain. No. 4 at the tail, and No. 3 at the nose will guide the torpedo. After the torpedo has been raised, No. 3 and No. 4 will slowly swing the nose into the truck first.

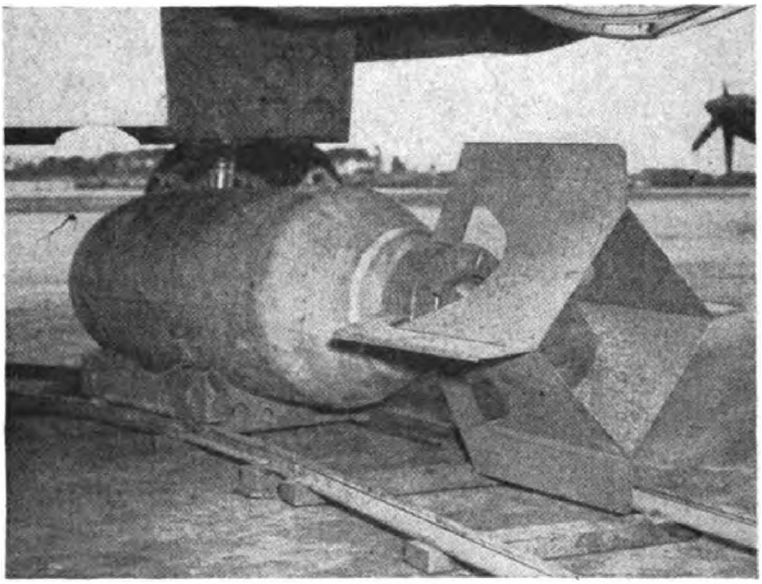

Figure 139. 2,000-lb. Bomb Under Bay of B-25.

No. 2 meanwhile will position crosspieces in the truck and will assist in guiding the torpedo into the truck. After two torpedoes have been lowered to the truck bed, No. 3 will place stringers along each side of the load and nail them to the

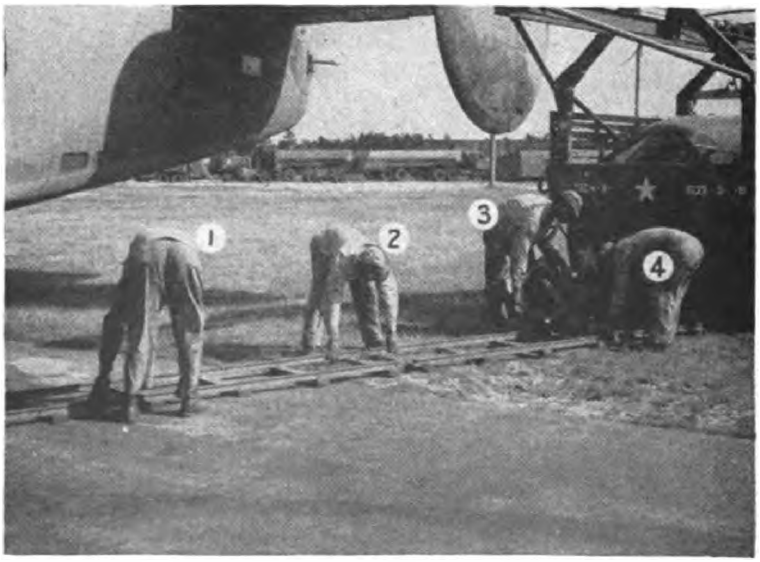

Figure 140. Laying Track for Delivery of 4,000-lb. Bomb to B-24.

crosspieces under the torpedoes. The M27 will carry the M22 to the airfield on the M5 trailer.

AN-Mk. 12 mines will be loaded, unloaded, and delivered like torpedoes. AN-Mk. 13 and AN-Mk. 26 mines will be handled like 1,000-lb. demolition bombs. The dollies will be used to unload and deliver them to the planes.

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Loading and Unloading M5 Bomb Trailers with the M27. The use of the M27 with the M5 trailer should be limited to loading and delivery of heavy bombs. Under normal circumstances, it will be a waste of time to use the M27 to load and unload light bombs, frags, clusters, and depth bombs on the M5. Drill procedure will be as follows:

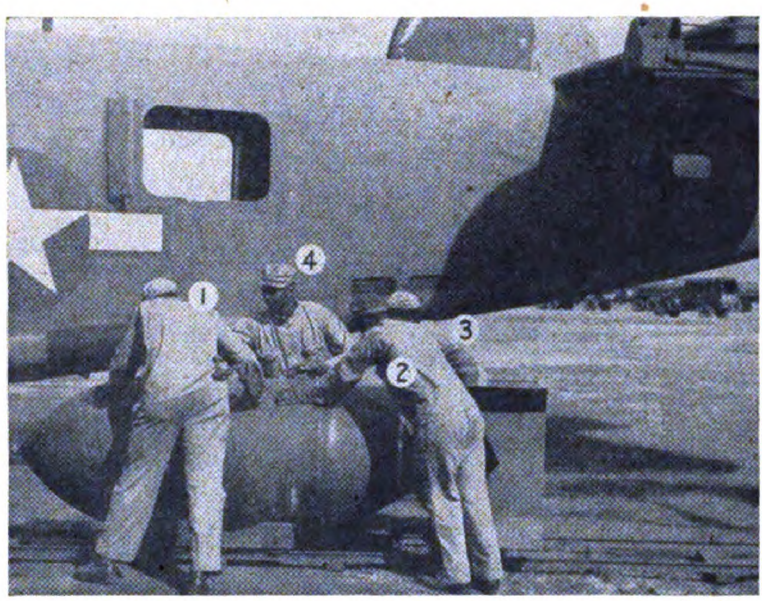

Figure 141. Delivering Assembled (Finned) 4,000-lb. Bomb to B-24.

No. 1, directed by No. 4, will position the trailer near the revetment in such a way that the M27, after being loaded with bombs, can be backed up to the trailer perpendicularly to the trailer bed. No. 2 will set the trailer brakes and uncouple the truck from the trailer. The truck will be loaded with bombs and

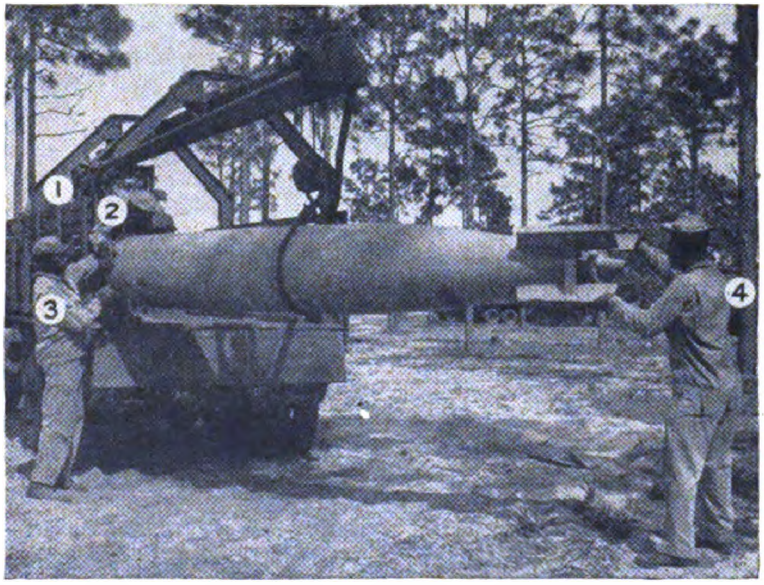

Figure 142. Loading Dummy Torpedo into M27.

will be backed to the trailer. No. 4 will direct No. 1 in positioning the truck for trailer loading and will make sure the trailer brakes are set. No. 2 and No. 3 will position the brackets and holding chains on the trailer. No. 3 will

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lower the truck tail gate. No. 2 will handle the bombs in the truck, and No. 3 and No. 4 will receive and position the bombs on the trailer as they are lowered. No. 2 and No. 3 will secure the load with the holding chains and load binders. After the trailer is loaded, the M27 itself will be loaded and will be positioned for coupling to the trailer. No. 2 and No. 3 will couple the truck and trailer. No. 3 will insert the electric brake cable. No. 4 will inspect the load and release the trailer brakes.

When the crew arrives on the line, No. 4 will direct the positioning of the trailer so that the track can be laid parallel to the trailer. The truck will then be positioned so that the overhead rail will extend across both the track and the trailer. In cases where the M27 will have to be maneuvered slightly both to reach a bomb and to lower it to the truck, No. 2 will handle the winch gear to permit No. 1 to remain in the truck cab. No. 4 will direct all operations and assist No. 3 in guiding the bombs as they clear the trailer and are lowered to the track. The dollies will be used to deliver all bombs. In the case of the 4,000-lb. bomb, the trailer can be drawn away as soon as the bomb has cleared the trailer bed. This will give the crew more freedom to handle the bomb and will eliminate moving the truck.

Plane delivery after the bombs are on the dollies will proceed as already described.

Figure 143. Loading 1,000-lb. Bombs on M5 Trailer with M27.

Loading and Unloading Cargo Trucks with the M27. Any bombs over 100 lb. can advantageously be loaded into cargo trucks with the M27 provided there is enough room to maneuver the vehicles. When loading bombs weighing less than 1,000 lb., the cargo truck and the M27 can be backed toward each other. The overhead rail will not reach the front of the truck's cargo space, but the bombs can be maneuvered into position after they are lowered. The bombs will be rolled out between the two vehicles by No. 4 who will attach the spreader bar or double chain in the lugs. No. 4 will direct all hoisting operations and instruct the driver of the cargo truck to move his vehicle when necessary. No. 2 and No. 3 will position the bombs in the cargo space of the truck performing the same duties as when loading the M27 itself. Where possible when bombs of 1,000 lb. and over are loaded, the cargo truck will be backed perpendicularly to the M27 so that the bombs can be lowered into position with a minimum of manhandling necessary. Where space is limited, it may be necessary to load the M27 completely, drive to the cargo truck, and transfer the bombs. In transferring the bombs, No. 2 will work in the M27 while No. 3 and No. 4 work in the cargo truck. No. 4 will super-

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vise all operations and inspect the load. The driver of the cargo truck, directed by No. 4, will move his vehicles as required.

When unloading light bombs, the M27 and the cargo truck will be backed toward each other and the track laid between. The track should be laid far enough away from the tail gate of the M27 so that the bombs will clear the rear of the truck when they are lowered. The driver of the cargo truck will move his vehicle as required. No. 2 will handle the bombs in the cargo truck, and No. 3 and No. 4 will receive the bombs on the ground and perform their regular duties incidental to unloading. When heavy bombs are unloaded, the cargo truck will again be maneuvered while the M27 remains stationary. The track will be laid perpendicularly to the M27. The cargo truck will back over the end of the track to unload each bomb.

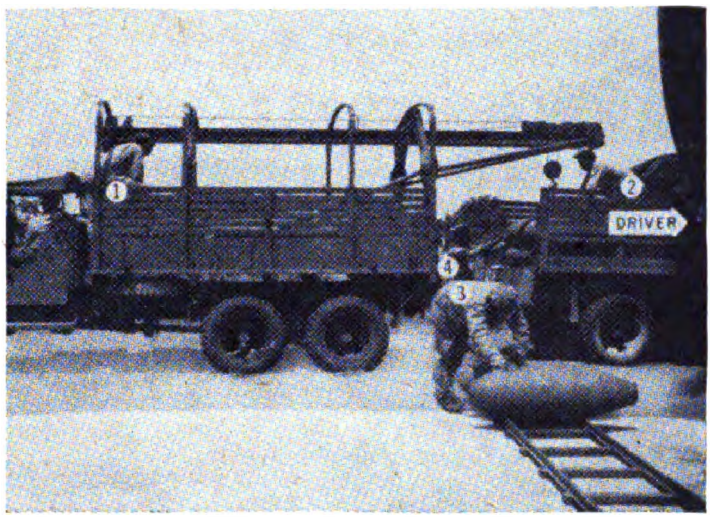

Figure 144. Delivering 500-lb. Bombs to B-24 from Cargo Truck Using M27.

Time Tests with the M27. An effort has been made to determine the length of time involved in loading the M27 with various quantities and types of bombs, transporting the bombs over various types of roads, laying the track sections, and delivering the bombs to planes. It is not intended that the data presented be used as anything but a rough guide. The times quoted here are undoubtedly neither the fastest nor the slowest that can be accomplished with the M27. The crew used for the experiments was not highly trained. In no cases were the crew members told to work any faster than they normally would. The following paragraphs outline the conditions under which the time tests were conducted.

A total of 762 bombs were handled in the tests. All weights of standard general-purpose bombs were loaded and unloaded a minimum of three times each. 100-lb. bombs were handled both with the winch and by hand. It was assumed that under normal circumstances the times involved in handling other types of bombs would be similar to the handling times of corresponding weights of general-purpose bombs. The loadings, quantities of bombs transported per load, dunnage used, unloadings, and plane deliveries follow exactly the methods presented in this article on the M27.

Finning times only were considered in bomb deliveries since fuzing on the ground is not correctly a part of the time involved in unloading the M27 on the line. If the Ordnance crew fuzes as well as fins the bombs on the ground, the time involved after the first bomb is assembled is almost entirely dependent upon the speed with which the plane's hoisting gear can operate. The only exceptions to this may be in torpedo or mine handling, or when depth bombs are assembled at the planes instead of in the storage area.*

Loading times do not include positioning the truck but begin at the moment

* The delivery of 500-lb. fragmentation clusters is a problem by itself and was not considered at all in the time tests.

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the truck was brought to a stop. Bomb revetments were of the open type with double entrances for vehicle drive through. All shipping bands and crates were removed from the bombs prior to the time tests. To a large extent, it is possible for the winch operator to set the pace of loading. The crew under normal conditions will keep up with the speed of the winch gear.

Twenty-three traveling times were clocked with the truck under load. The distances ranged from .3 mile to 1.6 miles and were over primary roads, secondary roads, very poor roads, and cross country. Primary roads mean two-way concrete, macadam, or asphalt. Secondary roads mean one-way macadam, or improved dirt roads with washouts and ruts. Very poor roads mean dirt and mud, or rutted sand four inches to one foot deep. Cross country means underbrush from a few inches to four feet high usually with a sand base. Very little rock, deep mud, streams, or steep hills were available for the road tests.

The track sections were laid eleven times. Times were checked for positioning one to four straight track sections with and without the curved section. In approximately half the cases, the truck and plane were considered fixed objects with the track laid between them. In the rest of the cases, it was assumed that the track could be laid and the truck positioned to the track.

Unloading times were begun at the instant the track was laid. Bombs up to and including 1,000-lb. bombs were rolled on the track to the plane and, after each bomb was positioned and finned, it was rolled off the end of the track to make room for the next bomb. There was no appreciable time difference in unloading bombs up to 1,000-lb. whether the track was laid on hard surface or on soft, uneven ground; 1,000-lb. bombs, however, were harder to maneuver on the rails when the ground was uneven and soft. Rolling was slower and the bombs had to be carefully guided.

2,000-lb. and 4,000-lb. bombs were handled on the dollies. The time difference between bomb deliveries over hard surface and soft ground using the dollies will not vary greatly if the track sections are firmly locked and the ground surface is checked for excessively high, low, or soft spots.

As in loading, the physical unloading of the bombs from the M27 will proceed as fast as No. 1 operates the winch. The entire operation, however, was not considered finished until the finning was completed. As will be remembered, fuzing has not been included in the tests.

No time tests of bomb handling with the M27 were conducted at night. It is obvious that all times would be greatly increased under blackout conditions.

Loading Times

Weight of bomb	*Ave. time per bomb*	*No. of fins*	*Fin loading time*
100 lb. (w/winch)	35 sec.†	..	.....
100 lb. (by hand)	20 sec.	..	.....
250 lb.	40 sec.†	24	1 min. 30 sec.
500 lb.	1 min. 20 sec.	10	1 min. 15 sec.
1,000 lb.	3 min. 10 sec.	6	1 min.
2,000 lb.	4 min. 40 sec.	3	45 sec.
4,000 lb.	7 min. 30 sec.	1	30 sec.

† Two bombs handled at one time using double-hook link chain.

Traveling Times

Primary roads 3 min. to 3 min. 20 sec. per mile (18 to 20 m.p.h)
Secondary roads 5 min. to 6 min. per mile (10 to 12 m.p.h.)
Very poor roads 7 min. 30 sec. to 8 min. 30 sec. per mile (7 to 8 m.p.h)
Cross country 12 min. to 20 min. per mile (3 to 5 m.p.h.)

Track-laying Times. The track sections were layed in anywhere from 4 min. 30 sec. to 12 min. It is estimated that on concrete with room to maneuver the truck that all track can be laid in 4 min. 30 sec. or less, and that on soft ground with minimum movement of the truck possible that all sections can be laid in 10 min. or less.

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Unloading and Delivery Times

Weight of bomb	*Ave. time per bomb*
100 lb. (w/winch)	25 sec.†
100 lb. (by hand)	15 sec.
250 lb.	50 sec.†
500 lb.	1 min. 10 sec.
1,000 lb.	3 min.
2,000 lb.	4 min. 20 sec.
4,000 lb.	7 min.

† Two bombs handled at one time using double-hook link chain.

Provided the conditions are not too unusual, the following problem will serve to illustrate how the above data can be used. A squadron of 12 B-25 type airplanes are to be bombed up with 500-lb. semi-armor-piercing bombs. Two M27 trucks are available. How long will it take to have the bombs ready (finned) at the planes? It will be assumed the run to the airfield is .7 of a mile over very poor roads. The distance from the motor pool to the revetments over secondary roads is .2 of a mile.

12 B-25 planes will demand a load of 72 500-lb. S.A.P. bombs.
72 bombs (carried 12 per trip) means 3 trips per M27 truck.
Travel time to revetment: .2 mile @ 5 min. per mi. = 1 min.
Loading time: 12 bombs @ 1 min. 20 sec. per bomb = 16 min.
Loading 12 fins—1 min. 30 sec.
Travel time to airfield: .7 mile @ 8 min. 30 sec. per mi. = 6 min. (app.)
Laying track (3 sections, concrete limited room) = 3 min. 30 sec. (est.)
Unloading and finning time: 12 bombs @ 1 min. 10 sec. per bomb = 14 min.
Travel time back to revetment: .7 mile = 6 min. (app.)
Total time per truck load = 48 min.
All bombs delivered = 2 hours 24 min. (48 min. × 3 trips)

On this basis, it can be reasonably stated that two M27 bomb service trucks could service the 12 B-25 planes with 72 500-lb. S.A.P. bombs in 2½ hours. It is admitted that many variables have not been considered in the time table just presented. It would be virtually impossible to set up tables that would cover and be correct for all conditions. It is suggested, therefore, that tests along the lines suggested in this article be made with the M27 wherever it is used. Knowing the roads, their condition, and the distances that must be traveled, an M27 crew could tell within seconds how long running and turnaround times will be. Knowing the conditions at the dispersal areas would permit the crew to estimate accurately the time needed to position the truck and lay the track.

AIRCRAFT ARMAMENT

Aircraft armament is the equipment mounted in airplanes to enable the plane to destroy its target and to achieve mastery of the skies. In the present war there are four main weapons used by our air force. They are the cal .50 machine gun M2, AC, the 20mm automatic gun, the 37mm automatic gun, and the 75mm gun. These weapons are mounted in various positions and combinations depending on the type and size of the plane. Caliber .50 Aircraft machine guns are discussed in Chapter 1, Small Arms.

The first instances of aircraft armament being used came early in World War I when a British flying observer fired a shotgun at a German observation pilot and another British pilot fired a pistol at a German plane. Soon after this, pilots began mounting rifles on their planes. From this humble beginning came the fast-firing, hard-hitting weapons we know today. It soon became apparent that planes could be used in a new role other than that of fighting off enemy observation planes, and so light caliber machine guns mounted on the fuselage began to appear. It was necessary to install these guns in some manner so that the pilot could control the plane and at the same time fire the weapons. The Germans had the advantage at first, because in 1913 Fokker had invented a synchronizing system that allowed the weapons to fire between the blades of the propeller or air screw as it was then known. He had offered it first to the British, but they

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had turned it down, and then he sold it to Germany. With this type installation the German pilots could attack their targets head-on while the British had to come alongside their targets before opening fire. The British answer came soon in the form of planes with the machine guns mounted on the top wing and a new type plane with pusher type motors and with the guns installed in the nacelles. From this came the idea of mounting the guns in various positions. The first planes generally carried two guns and in a few cases only one.

The armament used in aircraft in World War I was basically the cal .30 machine gun. Against the wood and fibre aircraft of World War I the cal .30 machine gun was effective, and it possessed the necessary fire power to deliver 'the goods both as an offensive as well as a defensive weapon.

After the war the manufacturers of aircraft continued to improve and perfect their planes. During this period, commercial aircraft also came into its own, and it progressed by leaps and bounds. Since this was peacetime, however, armament for aircraft was more or less stagnated. The Ordnance Department, of course, continued its research and it continued to improve the standard aircraft weapons. With the invasion of China by the Japanese, the taking of Ethiopia by the Italians, and later the Spanish Revolution, most of the more important world powers, through their observers and from unofficial sources, were able to keep abreast of the recent developments in both military aircraft and armament for such planes. The Spanish Revolution served as a proving ground for military aircraft. By now the modern war plane was coming into its own, and with the development and use of metal planes, of protective armor, and of self-sealing gas tanks, the cal .30 machine gun had become less and less effective. The newest trend was towards the use of a heavier weapon. Our cal .50 machine gun was really coming into its own. Today the cal .50 has really proved itself to be our best aircraft weapon. But with the development of the plane also came the newer uses of military aircraft. We now have the dive bombing plane, the torpedo plane, the attack or skip bombing plane, and also more recently the fighter bomber. Today the fighter plane, that was formerly known as a pursuit plane and used as a defensive weapon, is being used more and more as an offensive arm of the Air Force; hence we have finally reached the stage where the medium bomber and fighter planes have become literally 'flying artillery.' The first large aircraft weapon to be developed was the 37mm gun M4. Research had been working on this weapon even before 1927. The 20mm made its first appearance as an aircraft weapon in the Spanish Revolution; then came in rapid succession the 37mm guns M9 and M10 and, finally, we achieved the impossible, a 75mm gun mounted in an airplane and mounted in such a way that the recoil of the gun and the force of the explosion has little or no effect on the plane itself.

Let us look into the reason for the development of so called 'flying artillery.' First of all, the 20, 37, and 75mm all use high-explosive ammunition, which upon impact of the projectile, detonates, and instead of making a small hole in the plane it will blast quite a large hole. Not only is this type of a weapon used in plane-to-plane combat, but with the development of the modern tank and blitzkreig action on the part of ground forces, the modern airplane is used in plane-to-ground attack not only with bombs but with 'flying artillery,' since the .30 and .50 cal. machine guns proved to be more or less ineffective against armored vehicles. The use of 'flying artillery' in air-to-ground combat proved itself during the desert campaign in Africa, and effectively demonstrated that it could well handle that problem of breaking up the tank thrusts of the so called blitzkrieg warfare.

The effectiveness of the 20, 37, and 75mm guns in plane-to-plane and plane-to-ground combat can be approximately compared to the two types of boxers: the jabbing type of a fighter, who keeps pecking away at his opponent until finally the foe goes down under the flurry of light blows, or the strong arm type, who with the delivery of one well-placed and well-timed blow knocks his opponent reeling. There is a definite job, plan, and the time, however, for all of our aircraft weapons. In our air force we deliver the K.O. punch in a number of different ways. Circumstances will dictate as to how, when, where, and what weapons we will use or put to use. The results speak for themselves, as a glance at the toll which our plane-mounted guns have exacted from our enemies will reveal.

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Let us look a little further into a few of the uses of our aircraft weapons, starting with the 20mm and going through to the 75mm gun. Space limits the amount of information covering the performance and results of all of our aircraft weapons. We will therefore discuss only a few of the high points pertaining to each type of weapon, relative to its use, installation, operation, and probable future.

At the present time we install our weapons as flexible guns, fixed guns, and in turrents. A flexible gun is a gun that is manually fired and manually aimed without regard to direction of flight. A fixed gun is one mounted in a location and in a position fixed relative to the airplane. These guns are usually mounted in the wing or fuselage and are fired by remote control. When mounted as a synchronized gun, the weapon is fired by means of a synchronized mechanical trigger motor which causes the gun to deliver timed shots. Any gun mounted in a turret regardless of whether locally or remotely controlled is referred to as a turret gun.

GUN, AUTOMATIC, 20MM M1 AND AN-M2 AIRCRAFT

The Gun, Automatic, 20mm, M1 and AN-M2 is a full automatic weapon, operating on a combination gas and blowback principle. It is aircooled and fed from either the belt feed mechanism in the AN-M1 (using a distintegrating metallic link belt), or the sixty-round drum type magazine. The gun may be mounted as a fixed gun in the wing or fuselage of a plane or as a turret installed weapon. It may also be mounted to fire through the hub of the propeller. The gun is not synchronized to fire through the arc of the propeller because of the variation of time between the sear release and the instant of firing. This weapon is fired from what is known as the 'open bolt' position. It is fired by remote control by means of an electrical solenoid.

Types. The *basic gun* is an M1 or AN-M2 gun without an adapter or recoil mechanism, charger, and sear actuating mechanism.

Type A is the basic M1 or AN-M2 gun with the AN-M1 adapter, AN-M1 electric trigger and the M2 manual charger. Used by the U. S. Army Air Forces.

Type B is the basic M1 or AN-M2 gun with the M6 adapter, AN-M1 electric trigger and the M2 manual charger. Used by the U. S. Army Air Forces.

Type C is the basic M1 or AN-M2 gun with the M7 adapter (with thread protector), AN-M1 electric trigger and the M2 manual charger. Used by the U. S. Army Air Forces.

Type D is the basic M1 or AN-M2 gun with the M7 adapter, muzzle brake, AN-M1 electric trigger, and the M2 manual charger. Used by the U. S. Army Air Forces.

Type E is the basic AN-M2 gun with the AN-M1 adapter, AN-M1 electric trigger, and the M1 hydraulic charger. Used by the U. S. Navy.

Type F is the basic M1 gun with the M7 adapter (with thread protector) and the M1 sear mechanism. Used by the British.

Type G is the basic AN-M2 gun with the M7 adapter (with thread protector) and the M1 sear mechanism. Used by the British.

General Data.

Weight of basic gun, M1 and AN-M2	102.0 lbs.
Weight of tube	47.5 lbs.
Weight of 60 rd., drum-type magazine	22.0 lbs.
Weight of AN-M1 feed mechanism	19.0 lbs.
Rate of automatic fire	600-700 rpm
Number of lands and grooves	9
Combat Range (Approx.)	200-400 yards
Strafing Range (Approx.)	1000-1200 yards
Maximum Range	6400 yards

Typical installation of 20mm automatic aircraft gun

Plane	*Position*	*Number of weapons used*
P-38	Nose	1
P-39	Nose	1
P-61	Nose	4

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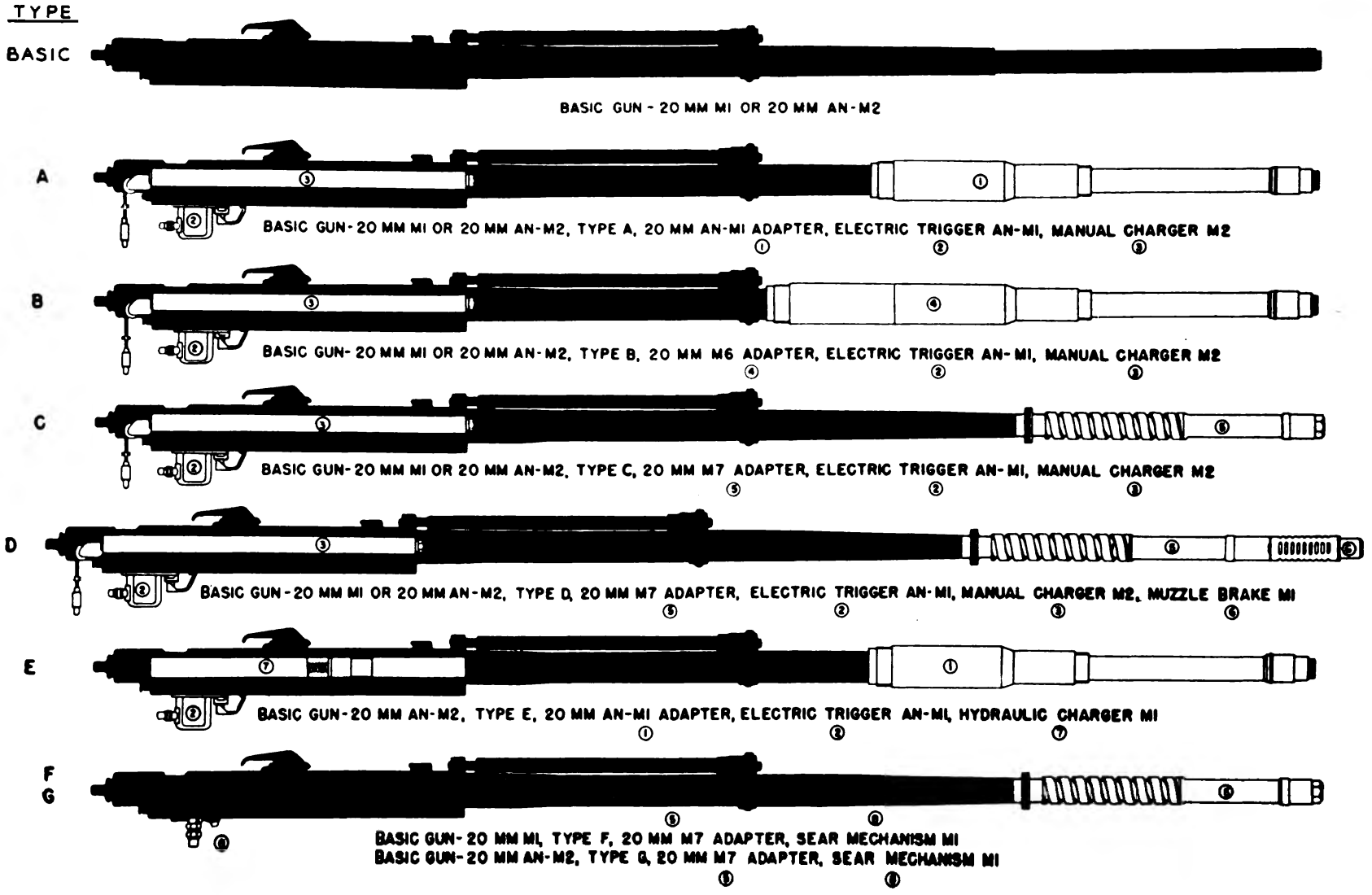

Figure 145. 20mm Gun AN-M1 and AN-M2 Type Designation Chart.

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DISASSEMBLY AND ASSEMBLY

Removal of Groups. *Remove Magazine or Feed Mechanism,* and make sure no ammunition remains in the chamber.

Driving Spring Guide Group. Breechblock group should always be completely forward before attempting to remove driving spring guide group. Straighten retainer assembly and use driving spring assembling tool and rear buffer wrench to remove group from gun, always keeping forward pressure on wrench. Check that driving spring guide plunger is either removed from gun or far enough forward in the breechblock group in order not to interfere with the removal of the rear buffer group.

Rear Buffer Group. Release the rear buffer lock assembly and slide the rear buffer group either up or down and remove it from the gun.

Magazine Slide Group. The magazine latch is removed with the magazine latch tool. (The rear end of the magazine slide lever inserted in the hole of the magazine latch may be used to insure that the latch and spring do not spring forward). After the ejector is removed, the magazine slide is removed from the gun by sliding it to the rear. Note that there are two washers on the ejector stud.

Breechblock Group. Using the breechblock unlocking tool or the manual charger, unlock the breechblock group. Slide the group to the rear, taking care that the breechblock lock and inertia blocks are not dropped as the group is removed from the receiver.

Gas Cylinder and Sleeve Group. Unscrew gas cylinder guide, vent plug, and bracket plug, and lift gas cylinder group from tube. Proper sized wrenches should be used to prevent rounding of the hex heads.

Sear Cover Plate Group. Turn gun upside down, remove the sear spring and plunger, and unscrew the sear cover plate screws. Remove sear cover plate by lifting to the rear and up. Sear spring should be removed first to prevent binding of screws when they are unscrewed.

Sear Block Group. Insert the sear block retaining tool until the shoulder on the tool is flush with the sear block. Lift up to remove group from gun. To prevent personal injury, do not remove tool without using proper holding fixture.

Muzzle Brake Assembly. Use muzzle brake wrench and unscrew assembly from tube (thread protector is also unscrewed with muzzle brake wrench).

Recoil Spring and Mounting Sleeve Group. All components of this group are removed from the tube by sliding them forward (if the AN-M1 or M6 adaptors are used, they are removed in a like manner).

Tube Assembly. Place receiver (upside down) in receiver vise. Remove the tube locking pin with the tube locking pin removing tool. Place tube clamp between the gas cylinder bracket and the rear of the tube and unscrew the tube from the receiver.

Special Points to Observe in Disassembly of Groups. *Rear Buffer Group.* Never attempt to remove the rear buffer threaded sleeve unless you use the rear buffer wrench. The rear buffer group should be protected in a vise by wooden blocks or soft metal plates.

The rear buffer lock bushing is never removed except for replacement. If it is removed, drive it out toward the front, using soft hammer.

Breechblock Group. When removing breechblock slides, place breechblock group on flat surface and grasping the slide near front end, pull straight out from bolt body.

Extractor must be removed before attempting to remove firing pin.

Sear Block Group. To remove sear buffer springs and plungers (held in sear block by retaining tool) from sear block, place assembly in sear block assembling tool or soft jawed vise. Compress springs only far enough to allow removal of retaining tool. Release pressure on springs and remove sear block from assembling tool.

Muzzle Brake Group. The muzzle brake is never disassembled except for the replacement of component parts. If replacement is necessary, the muzzle brake washer must be straightened before the muzzle brake rear ferrule is unscrewed from the muzzle brake body.

The muzzle brake baffles are never removed from the muzzle brake sleeve. In the event the baffles become damaged or loose, the muzzle brake body is replaced.

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Mounting Sleeve Group. This group is not used in later type installations; however, they will be found on older installations.

Always remove mounting sleeve plug before attempting to unscrew the dashpot cylinder from mounting body.

Dashpot piston ring is never removed except for replacement.

Receiver Group. The receiver plate is never replaced except by arsenals and base shops with the necessary equipment.

Special Points to Observe in the Assembly of Groups. *Receiver Group.* In most cases the breechblock locking key must be hand fitted in the receiver. Great care must be taken to insure that a drive fit is obtained. Use only very fine emery cloth and stones.

Holes in the breechblock locking key plate must line up with the holes in the locking key. There should be no clearance between ends of plate and receiver. Make sure lock washers are replaced to prevent breechblock locking key plate screws from projecting into receiver.

Mounting Sleeve Group. When assembling the mounting body, dashpot cylinder, and dashpot cylinder bushing, make sure the holes for the mounting sleeve plug are perfectly aligned before screwing in the plug.

In replacing dashpot piston ring, care must be taken to prevent breakage of the ring.

Care must be exercised when replacing dashpot piston and ring in cylinder to prevent burring of cylinder or chipping of ring.

Muzzle Brake Group. When muzzle brake front ferrule is replaced, make sure it is staked to the muzzle brake body.

Make sure the muzzle brake washer is placed between the muzzle brake body and the rear ferrule and bent over flat surfaces on the body and ferrule.

Sear Block Group. The buffer spring plungers are assembled with the hole in the plunger next to the sear buffer springs.

Always use the sear block assembling tool or soft jawed vise when assembling sear buffer springs and plungers into sear block. The sear buffer spring retaining tool must be inserted into the block so the shoulder on the tool is flush with the sear block.

Assemble the sear to the sear block so the nose of the sear and the flanges of the sear block are opposite.

Breechblock Group. When replacing breechblock slide key taper pin, it is inserted from top to bottom.

The firing pin must be replaced before the extractor is assembled to the bolt body.

Rear Buffer Group. Always stake the rear buffer lock bushing to the rear buffer housing.

OPERATION

The 20mm automatic gun operates on a combination of gas and blowback principle. When the gun is fired, the propellent gases thus formed position (by means of the gas cylinder and sleeve group) certain parts of the breechblock group. At the proper time, the pressure in the chamber acting upon the empty cartridge case in the face of the bolt body unlocks the breechblock group. The remaining pressure in the chamber forces case and breechblock group to the rear.

Extraction and ejection of the empty cartridge case is accomplished during the recoil of the breechblock group. The rearward movement of the breechblock group is stopped by the rear buffer spring and driving spring, which also force the breechblock forward in counterrecoil. On counterrecoil, the breechblock strips another round from the magazine or feed mechanism, loads it into the chamber, locks and fires the chambered round.

The entire gun recoils, with the exception of the magazine slide group (which secures the magazine or feed mechanism to the gun) and certain parts of the front mounting group. There are various types of front mountings, which are covered in subsequent paragraphs.

The shock of recoil and counterrecoil of the gun is absorbed in various ways, depending upon which recoil adapter is used.

Firing is stopperd by the release of the sear, which moves into the receiver, due to the sear spring and engages the breechblock lock as the breechblock

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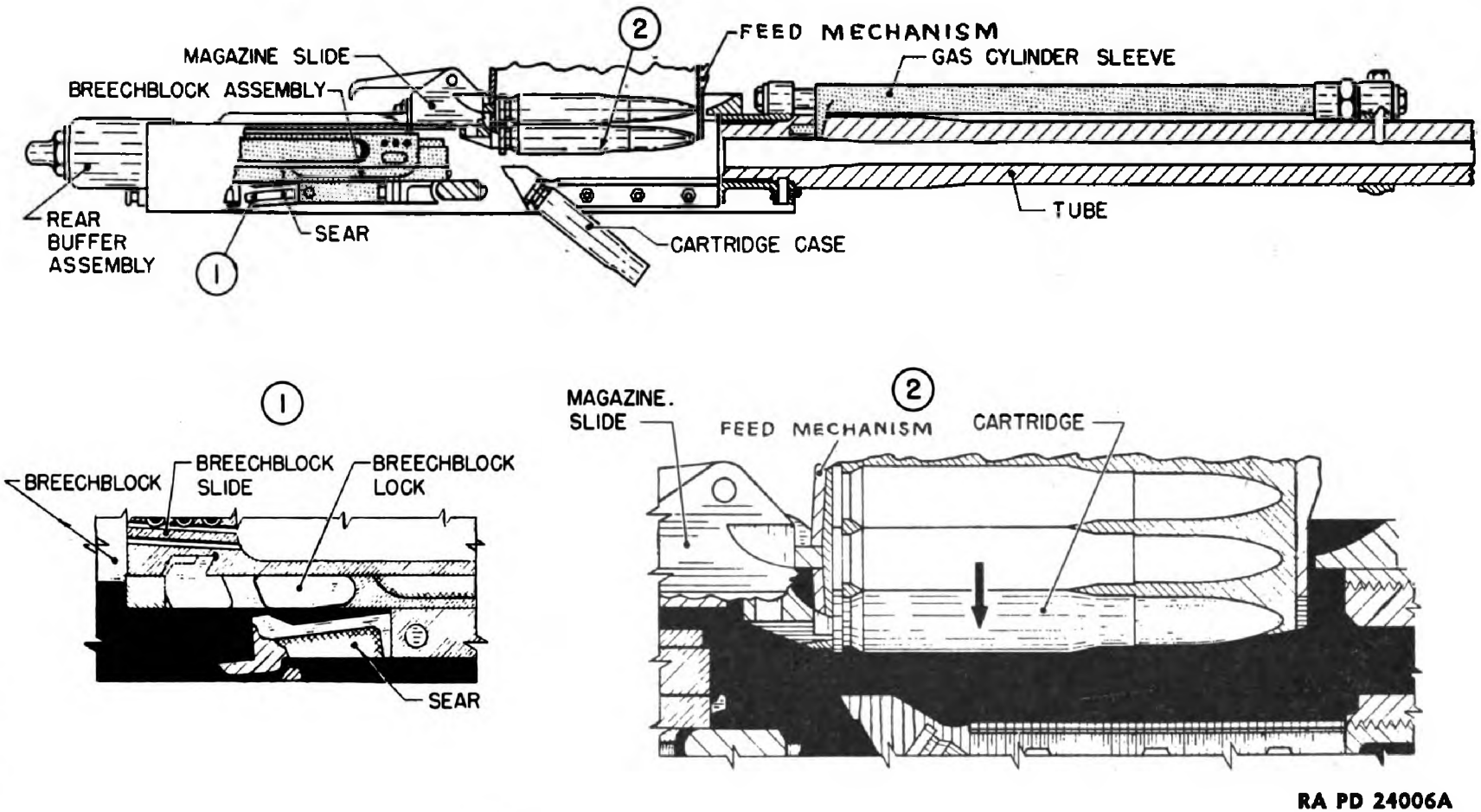

Figure 146. Gun Mechanism. Breechblock in Rearmost Position.

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group starts forward in counterrecoil. Therefore, the gun stops in the 'open bolt' position, that is, with the breechblock group held to the rear.

Charger. Before the weapon can be put in operation, the breechblock group must be retracted until it can be caught and held to the rear by the sear. This is accomplished either by the manual charger M2, or the hydraulic charger M1. With either charger the action of the parts of the gun are the same.

As the charger piston moves, either manually or hydraulically, to the rear, it engages the charger lug on the right breechblock slide. Since the right and left breechblock slides are connected through the bolt body by the breechblock slide key, both slides are moved to the rear together. This action withdraws the firing pin from the face of the bolt body since it rests over the breeckblock slide key. At the same time the breechblock slide springs are compressed between the breechblock slides and the breechblock pins. After the slide has moved to the rear about 0.60 inch, the cams on their lower edges engage cam projections on top of the breechblock lock and lift the lock out of engagement with the breechblock locking key and into engagement in the bottom of the bolt body. The slides are prevented from further movement to the rear, with respect to the bolt body, as the breechblock slide key contacts the rear of its slot in the bolt body.

The charger piston, therefore, forces the breechblock group to the rear, compressing the driving spring. The breechblock is retracted to a position where the sear engages a notch in the bottom of the breechblock lock, thereby holding the breechblock group to the rear, that is, in the cocked position.

Feeding. Feeding is accomplished by either the belt feed mechanism AN-M1, or the 60-round magazine, M1, whose functioning will be covered at the end of this section. The feed mechanism is held on the gun by the magazine slide group.

With the breechblock to the rear, the loaded magazine or feed mechanism is placed on the gun with the mouth projecting into the receiver through the opening in the magazine slide, allowing the magazine latch to engage the catch plate on the rear of the magazine mouth. The two lugs on either side of the magazine or feeder are engaged in the hook-shaped projections on the front of the magazine slide. The ball shaped projection on the bottom of the magazine slide lever fits into a chambered hole in the magazine latch; therefore, when the lever is pulled upward, the latch is drawn to the rear, compressing the magazine latch springs. The front ends of the springs are housed in the magazine latch so that they exert pressure against the latch. The latch is above the catch plate of the magazine or feed mechanism, holding it into position in the magazine slide.

Description and Functioning of 20mm 60-round Magazine M1. The 20mm 60-round Magazine M1 consists essentially of an outer casing closed by front and rear plates and containing a tensioning spring in a spring casing in the front plate. A hole in the rear plate accommodates the feed arm axis tube. The inner end of the spring is attached to the tensioning tube. On the inside of the plates are spirals which act as guides for the ammunition.

The magazine is operated by the spring tension. Initial tension is applied during assembly. Further tension is applied progressively during the loading operations. The tensioned spring acts through the tensioning tube, feed arm axis tube, and feed arm to maintain the platform or follower in contact with the last round. Thus a round is always in position in the magazine mouth. As soon as this round is loaded, the next round is brought into position by the spring.

Loading. With the breechblock held to the rear by the sear and the loaded magazine or feed mechanism attached, the gun is ready to fire. The operation cycle is begun by pulling the sear downward out of the recess in the breechblock lock. The sear is depressed by means of a solenoid assembly which is attached to the sear cover plate. (Older installations and the British installations have the M1 sear mechanism, which utilizes the Bowden connection shaft and a manually operated cable to depress the sear). The lugs on the upper end of the solenoid shaft engage in the fork on the rear of the sear, so that when the solenoid shaft is actuated, it pulls down the sear, disengaging it from the recess in the breechblock lock.

Thus released, the breechblock moves forward under the action of the driving spring. The raised portion on top of the bolt body strikes the rim of the cartridge, strips it out of the mouth of the magazine or feed mechanism, and seats it

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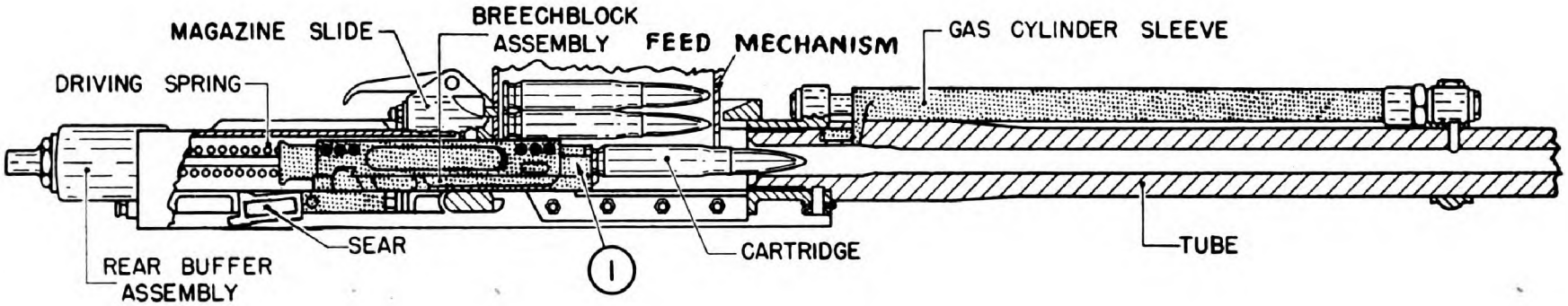

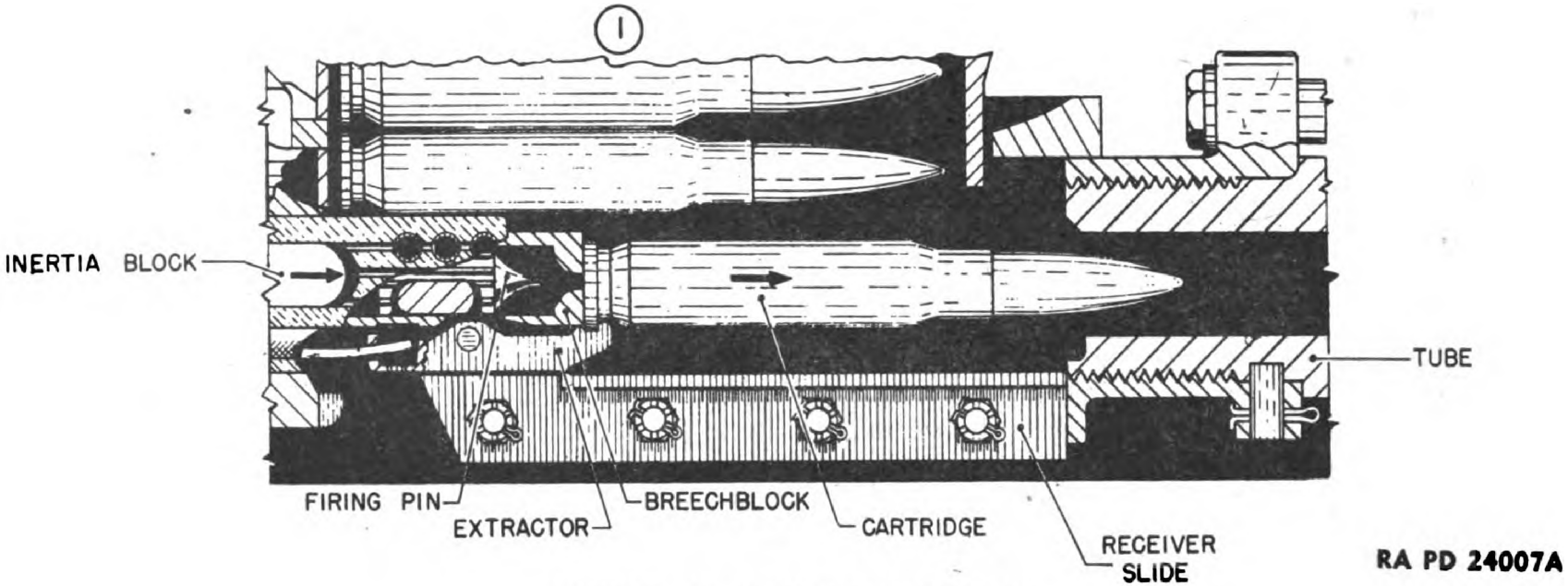

Figure 147. Gun Mechanism During Ramming.

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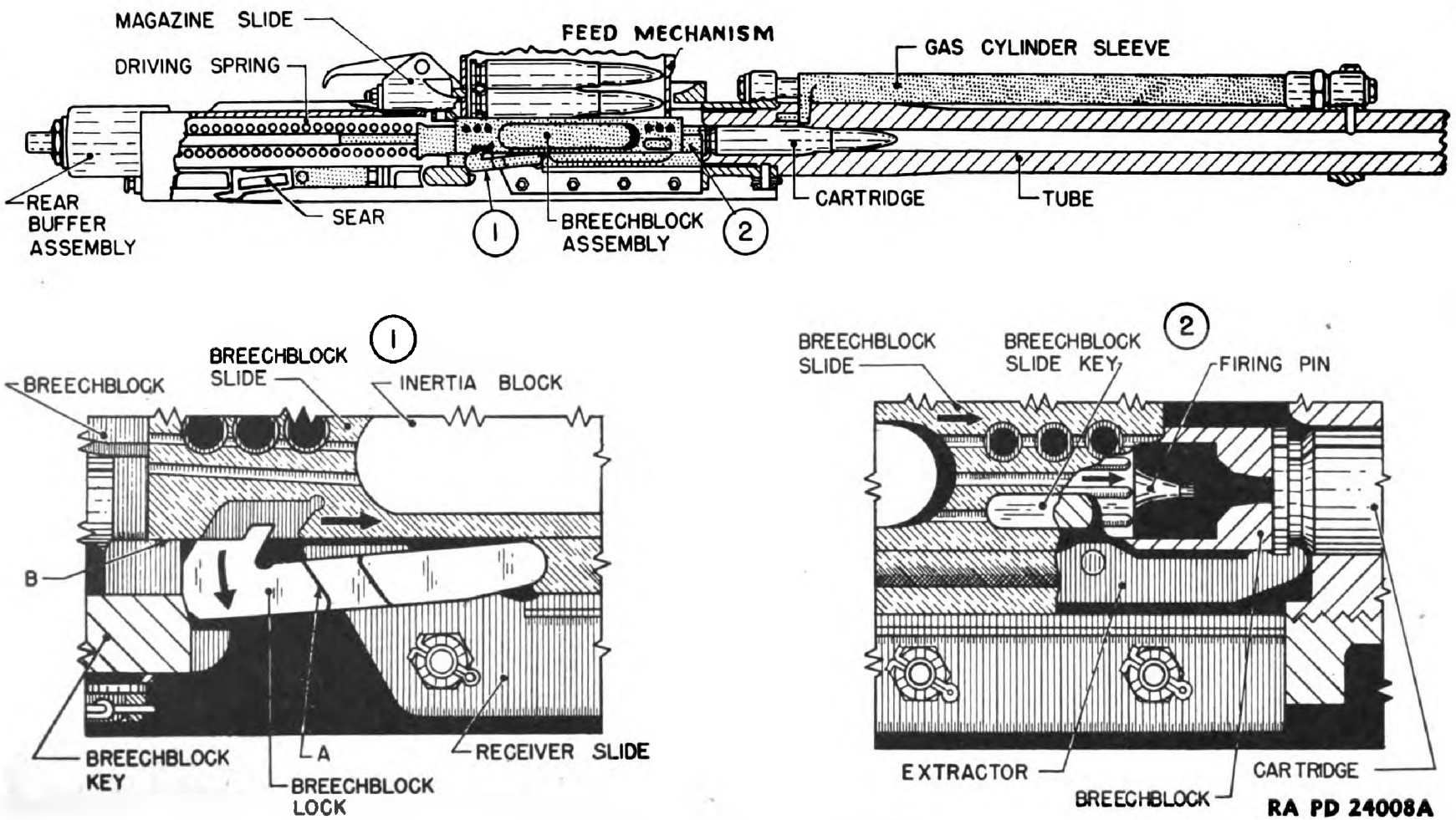

Figure 148. Gun Mechanism Ready to Fire.

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into the chamber of the tube. Cam surfaces on the inside of the mouth of the feed mechanism guide the round downward into the chamber as it is being stripped forward. The rear of the cartridge case slides down the face of the bolt body (due to the pressure of the next round being forced into the mouth of the magazine or feeder, and also the guiding action of the end of the chamber) as the breechblock reaches the battery position. The lower part of the cartridge rim contacts behind the hook part of the extractor. The forward motion of the breechblock and the chambering of the round is stopped by the impact of the bolt face against the rear face of the tube.

Locking. The breechblock lock is now free to pivot into the locked position since it is no longer supported from the bottom by the breechblock locking key. The inclined cam surfaces on the sides of the breechblock lock strike the cam surfaces on the rear of the receiver slides and force the rear of the lock downward. At the same time, the cam surfaces in the recesses in the bottom of the breeckblock slides act against the top rear surfaces of the breechblock lock, also forcing the rear of the lock down. The breechblock slides are being forced forward under the combined forces of the breechblock slide springs, the inertia of the breechblock slides (built up during its forward movement), and the driving spring. The driving spring guide plunger, which contacts the rear of the firing pin, transmits the force of the driving spring to the breechblock slides through the breechblock slide key.

This action forces the rear end of the lock into the locking recess of the breechblock locking key. With the slides all the way forward, they cover the rear top of the lock preventing it from moving upward out of the locked position. The inertia blocks continue forward a short distance within the slides after the slides have reached their foremost position. This action retards the tendency of the slides to rebound and allows the breechblock lock to be forced out of the locked position.

Firing. The breechblock slides, connected by the breechblock slide key and carrying the firing pin, are driven forward until the front of the breechblock slide key strikes the front of the slot in the bolt body. This action carries the firing pin tip through the firing pin hole in the bolt body; the pin then strikes and ignites the primer in the base of the cartridge.

Unlocking. After the explosion of the propelling charge, the breechblock remains locked until the the projectile has traveled along the tube and passed the gas port in the top of the bore. When the projectile clears the gas port, the propellent gases, still at considerable pressure, pass into the interior of the gas cylinder bracket and enter the two holes in the gas cylinder vent plug. They then pass into the gas cylinder.

As the gas expands, the gas cylinder piston moves rearward and pushes the attached gas cylinder sleeve which, through its yoke-shaped rear end, contacts the front ends of the two gas cylinder sleeve push rods. The push rods which extend through the upper front end of the receiver body strike the forward ends of the breechblock slides and move them to the rear.

When the slides move to the rear far enough to allow the breechblock lock to come up out of its locked position, the pressure in the chamber of the gun tube, acting against the bolt face, is transmitted to the rear of the breechblock lock and cams the lock out of the seat in the breechblock locking key into the recess in the bottom of the bolt body. Normally, the cams on the lower edges of the breechblock slides do not contact the upward-projecting lugs of the breechblock lock. During automatic fire, these serve as a safety precaution in case foreign matter or burrs slow the unlocking action of the breechblock lock. Furthermore, they come into action when the gun is being charged.

Extraction. When the breechblock group is unlocked, the remaining pressure in the tube forces the cartridge case and the breechblock group to the rear. During extraction the extractor merely acts as a guide to the cartridge case.

Ejection. The breechblock continues to the rear and the head of the cartridge case strikes the two prongs of the fixed ejector. The lower portion of the cartridge case is held by the claw of the extractor. Therefore, when the rim of the cartridge strikes the ejector, the rear of the case pivots around the claw of the extractor and is ejected out and downward from the bottom of the receiver.

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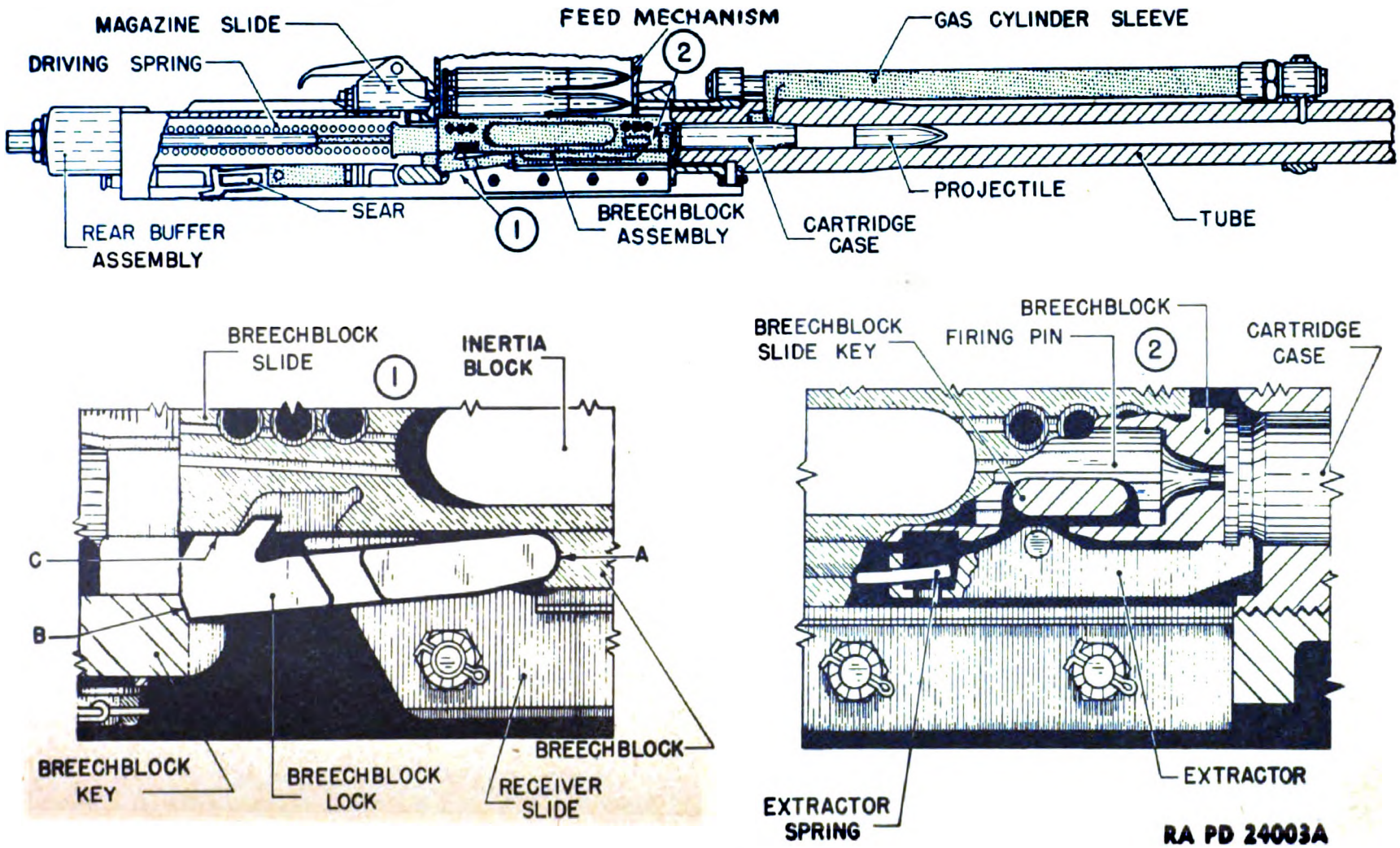

Figure 149. Gun Mechanism Shortly After Firing.

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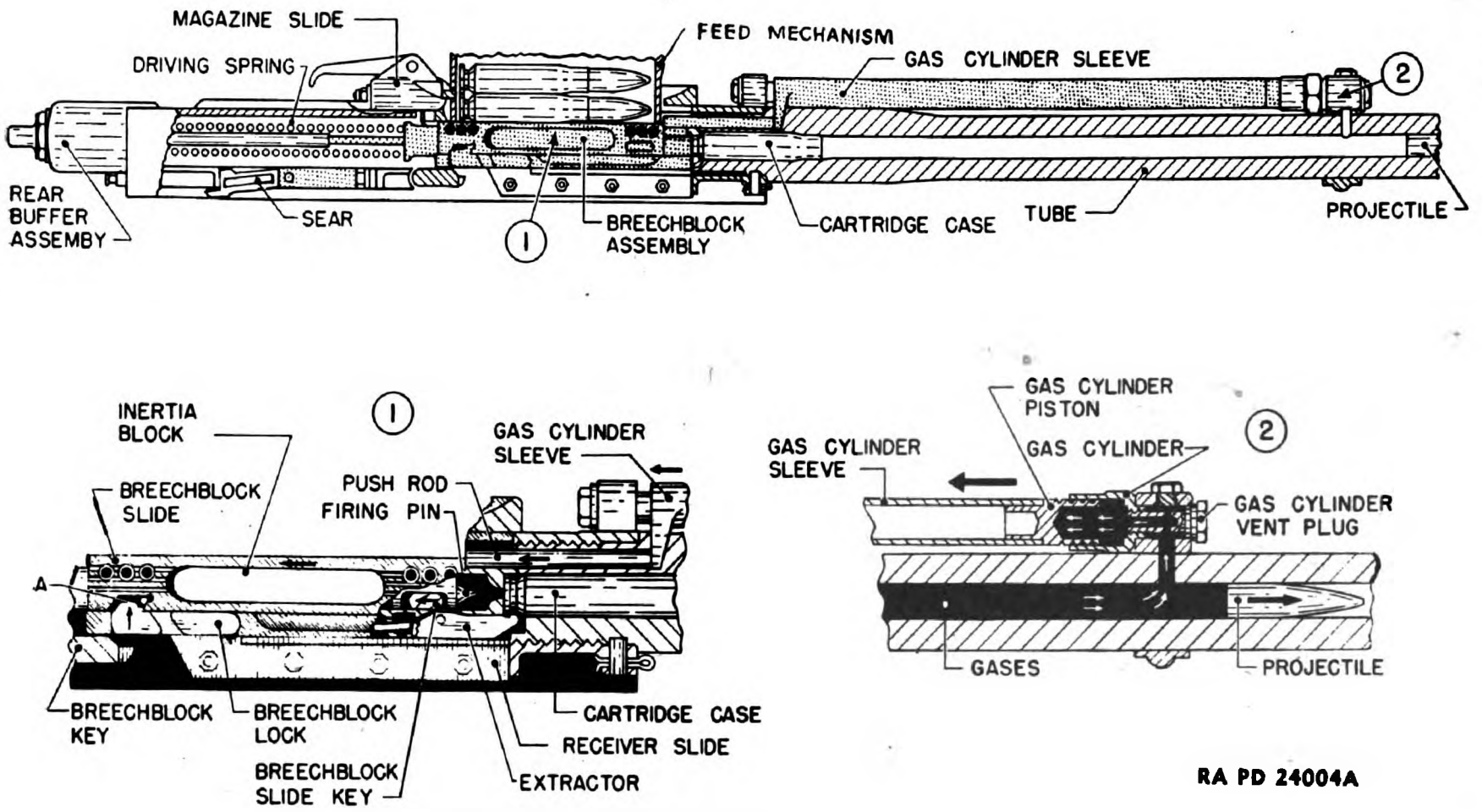

Figure 150. Gun Mechanism During Breechblock Unlocking.

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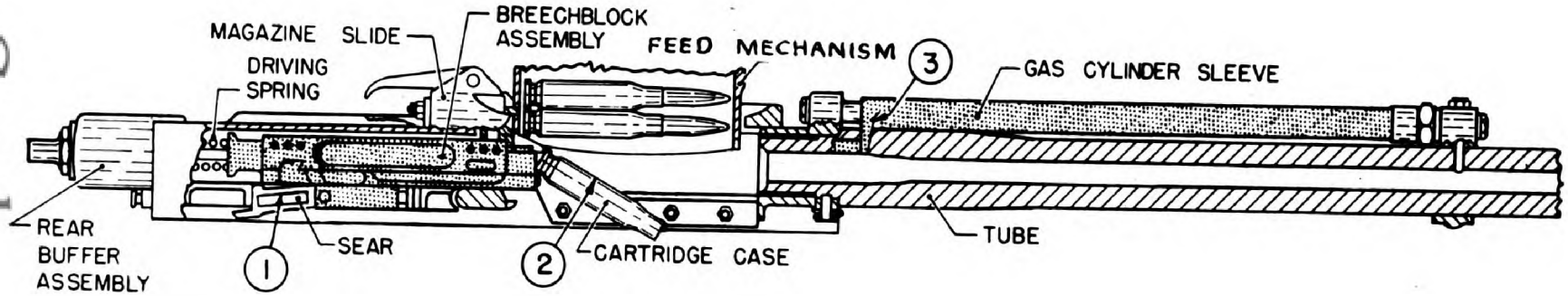

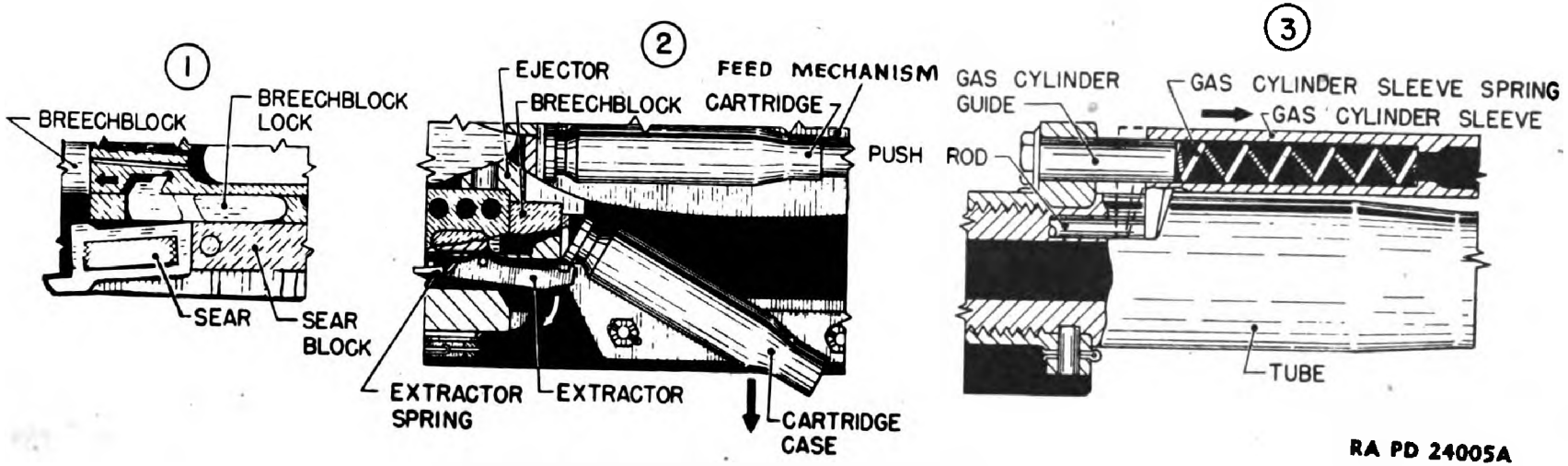

Figure 151. Gun Mechanism. Cartridge Being Ejected.

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Action of Rear Buffer. After traveling to the rear, the rear extension of the bolt body strikes the rear buffer washer and compresses the rear buffer spring, which absorbs the shock of the recoiling breechblock group.

The recovery of the rear buffer spring and the driving spring supply the force for the counterrecoil of the breechblock. This cycle of operation will be repeated until the sear is released or until the ammunition is exhausted.

Operating After Release of Sear. Automatic fire may be stopped by the release of the sear. When the current is cut off from the solenoid, the solenoid shaft moves upward, allowing the sear to move upward by the action of the sear spring and plunger (in M1 sear mechanism the Bowden cable is released, thereby releasing the Bowden connection shaft, allowing the sear to move upward).

After the breechblock is blown to the rear, the lower rear surface of the bolt body contacts the cam surfaces on the top of the sear and cams it down against the sear spring. The breechblock continues to the rear, strikes the rear buffer washer, compressing the rear buffer spring. At the same time, the sear spring forces the sear up into the recess in the bottom of the breechblock lock. After recoil of the breechblock group has been overcome by the rear buffer spring, it recovers and forces the breechblock group forward. On the forward movement of the breechblock group, the sear, if not depressed, will engage the back end of the recess in the bottom of the breechblock lock. This engaging of the sear into the breechblock lock will hold the breechblock group in the rear position.

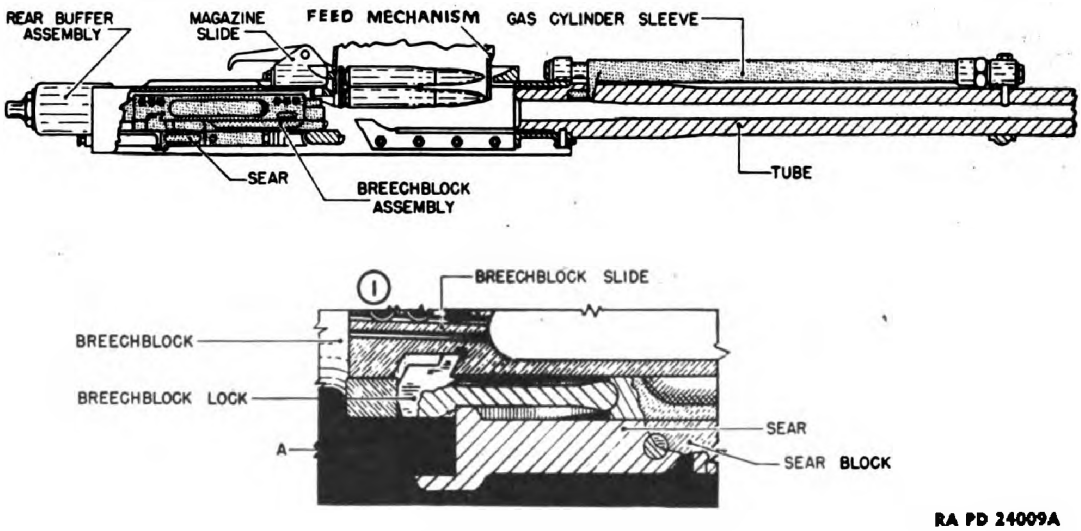

Figure 152. Action of Sear.

If the sear spring is weak and the sear is not entirely engaged in the recess, a cam surface on the sear cover forces the sear into the proper position. This action takes place while the breechblock is moving forward.

Considerable shock must be absorbed by the sear and sear block assembly in order to stop the forward motion of the breechblock. When the sear engages, the sear and sear block move forward and compress the sear buffer spring and plungers which absorb some of the shock; the two sear buffer blocks absorb the rest. The sear and sear block are returned to their original positions by the recovery of the sear buffer springs.

Recoil and Counterrecoil of the Gun. The recoil and counterrecoil of the gun is absorbed by a different manner in each type of 20mm guns.

Type A. This type utilizes the AN-M1 adapter which absorbs the recoil by means of a large recoil spring and a ring-type spring. The ring spring also absorbs the counterrecoil force after the gun has passed the battery position.

Type B. Type B is installed with M6 adapter. The recoil and counterrecoil is absorbed in the same manner as in the type A gun. The M6 adapter is the AN-M1 adapter to which a rear extension has been added in order to increase

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the overall length of the adapter by 8 1/16 inches to suit some mounting requirements.

Type C. This type has the M7 adapter and the thread protector. The M7 adapter consists of the dashpot piston, dashpot washer, recoil spring, recoil spring filler sleeve, recoil spring sleeve, muzzle brake lock, and thread protector. The muzzle brake lock is prevented from rotating by splines on the tube which mate with splines on the inside of the lock. The lock also has serrations on the front end that mate with serrations on the rear end of the thread protector, thereby preventing the thread protector from unscrewing.

A typical installation consists of a cylindrical stationary mounting with an inside shoulder at the front end that serves as an abutment for the rear end of the recoil spring. The dashpot washer and dashpot piston fit inside the mounting in the rear of the shoulder. The mounting has a row of holes around its circumference behind the dashpot piston. When the dashpot piston moves to the rear within the cylindrical mounting during recoil, the piston passes the holes and air is drawn into the cylinder in front of the piston. As the piston moves to the forward position during counterrecoil of the gun, the air is trapped and compressed in the cylindrical mounting. This compression of air, gives a buffing action on counterrecoil. The compressed air escapes around the dashpot piston. The piston at its foremost position strikes the dashpot washer, which prevents metal-to- metal contact of the piston and the shoulder of the cylinder mounting.

The recoil spring takes up the shock of recoil and also acts as the recuperator to bring the gun back into the battery position.

Type D. This recoil and counterrecoil group is the same as Type C, except that the thread protector is replaced by the muzzle brake assembly. The recoil spring and the dashpot piston operate in the same manner.

The muzzle brake assembly, however, absorbs approximately 35 percent of the recoil of the gun. As the projectile leaves the tube, the escaping gases are deflected to the rear on contact with the curved portions of the muzzle brake baffles, which direct the gases against the rearward inclined faces of the slots in the muzzle brake sleeve. This action tends to push the gun forward and partially overcome the recoil of the gun to the rear.

Type E. This type is equipped with the same adapter (AN-M1) as the Type A gun and therefore the operation is the same.

Types F and G. The M7 adapter (with thread protector) is also used on this type; its operation is the same as in the type C gun.

OPERATION—20MM FEED MECHANISM—AN-M1

The An-M1 Feed Mechanism consists of a shaft assembly having on it three sprockets, two feed levers, an ejector assembly, and a tensioning ratchet group, all of which are contained inside of the case assembly. The mechanism is built as either a left hand or right hand feed using a disintegrating metallic link type of belt. Although the mechanism is a spring type of feed, using for its operating energy a clock-type spiral spring, the spring itself is maintained at a constant set tension through the recoil of the gun.

In order to use the AN-M1 Feed Mechanism it is therefore necessary to first remove the muzzle brake group from the gun and replace it with a thread protector.

An AN-M1 or M6 Adapter, commonly called an Edgewater Adapter, is also used on more recent installations.

Also removed from the gun when the AN-M1 feed is used is the gas cylinder guide. It is replaced with a special type of gas cylinder guide and also a rack operating lever assembly.

Operation. First make sure that the belt of ammunition is assembled correctly for the type of feed being used, *i.e.* left or right hand; the leading edge of the belt is then started into the belt guide. The leading double link of the belt must also contain a cartridge. As the cartridge engages the gear-like teeth of the feed sprockets, they will cause the sprockets, shaft, driving spring, driving spring hub, and tensioning ratchet to rotate independently of the rack and actuating segment

After the first two or three cartridges have engaged the teeth of the feed

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sprockets the belt of ammunition will be prevented from backing, or falling out of the mechanism by the driving spring tensioning pawl engaging with the teeth on the circumference of the driving spring tensioning ratchet.

Complete loading of the mechanism is accomplished by turning the tensioning ratchet with a wrench. Rotation of the tensioning ratchet tends to wind the driving spring; but the spring, re-acting on the brake band in the driving spring case, rotates the shaft and feed sprockets pulling the belt into the mechanism. When fully loaded, the mechanism will contain thirteen rounds of ammunition with the remaining portion of the belt strung out on either the left or right hand side, depending upon the feed.

As the cartridges rotate through the mechanism, the nose of each cartridge contacts a camming surface on the front cover and is in turn forced rearward. While the cartridges are being forced rearward by this camming action, the links forming the belt must move through the mechanism in a straight line. The links cannot move rearward because the rear edge of the double loop of each link is pressed tightly against the front face of the center feed sprocket. Thus, the center feed sprocket serves as a link stripper, the links being stripped automatically from the cartridge cases as they move through the mechanism.

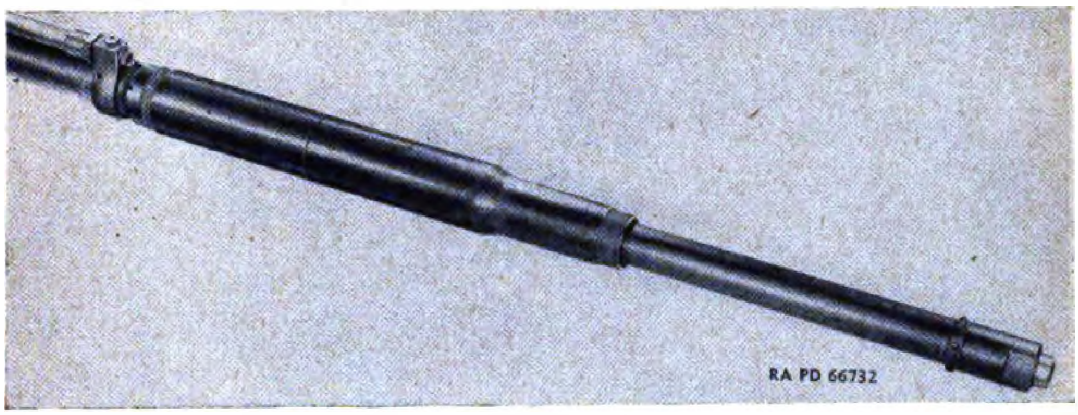

Figure 153. 20mm Adapter M6.

When each cartridge has rotated approximately 2/3 of the distance through the mechanism, it is then stripped entirely free of its link. As each cartridge continues to rotate through the mechanism it engages the link ejector, which is shaped like a four tooth gear, and causes the ejector to rotate. The points on the ejector contact the center of the now free link and force it outward away from the cartridge.

The double loops of the link bear against the link chute cover inner spring causing the single loop of the link to be lifted up and off the cartridge and the next double link. Since the outward movement of the single loop of the link is limited there is a possibility of the single loop re-engaging with the cartridge. This is prevented by the outward movement of the next double loop. The ejected link will then fall out through the link chute.

A plunger under spring tension prevents the ejector from rotating freely and keeps the link ejector in position to be engaged by the next cartridge.

After ejection of the links the cartridges continue to rotate through the mechanism until they contact the ramp of the ejector bracket. The leading two cartridges, no longer being supported by the feed sprockets, are now guided by the ramp down into the mouth of the mechanism. On this downward movement, the leading cartridge forces the two feed levers aside and causes the front feed lever to withdraw the last round retainer, clears the throat portion of the mouth, and allows the leading cartridge free entry.

The two spring loaded feed levers are now partly returned by their springs; and by contacting the second cartridge it in turn holds the first cartridge firmly down in the mouth of the mechanism, ready to be picked up by the breechblock as it comes forward.

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Up to this point, as the leading cartridge is seated firmly down in the mouth, the turning of the tension ratchet has only served to load the mechanism. There has been very little, if any, tension put on the driving spring as yet. In order for the mechanism to function properly, further rotation of the tensioning ratchet is necessary. This will in turn wind the driving spring to its full extent.

Note: Unwinding of the driving spring is prevented by the driving spring tensioning pawl engaging with the teeth on the circumference of the driving spring tensioning ratchet.

Note: Full winding of the driving spring is necessary to insure positive feeding. Lessened tension on the driving spring will cause a failure to feed. In early models of the AN-M1 Feed, the driving spring brake band prevented the driving spring from being broken due to over-winding; however, this allowed the driving spring to lose tension as the brake band sometimes slipped due to the vibration of the gun. This slipping was remedied by welding the brake band to the driving spring case. (See FSMWO A-47-W4)

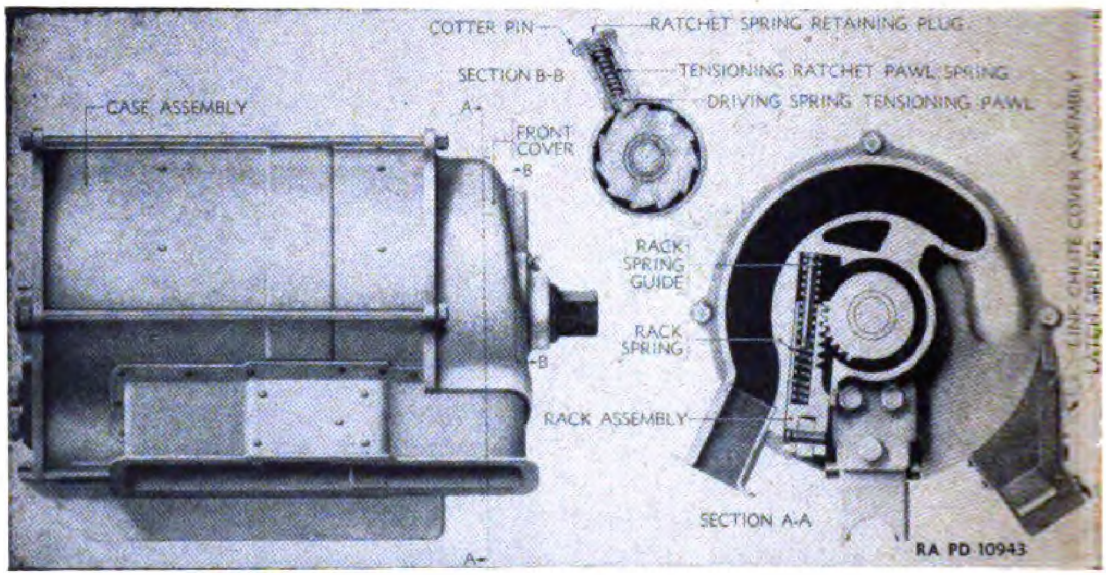

Figure 154. 20mm Feed Mechanism AN-M1. Front Cover Sectional Views.

When the gun is fired, the breechblock, traveling forward, strikes the base of the cartridge case, stripping it out of the mouth of the mechanism and driving it into the chamber. As each cartridge is stripped from the mouth, the fully wound driving spring causes the feed sprockets to rotate and feed another cartridge into the mouth. This feeding action will allow the driving spring to become unwound a slight amount. As the cartridge is fired in the chamber and the gun recoils, the rack operating lever is forced rearward, riding up the slight bevel on the stationary magazine slide. The incline on the rear of the operating lever is now forced underneath the rack, lifting the rack upward. As the rack is forced upward, the teeth on the rack being engaged with the teeth on the ratchet actuating segment will in turn rotate the segment. Rotation of the segment will, in turn, cause the driving spring to be wound back up to its original tension. Thus, through the recoil of the gun, the driving spring is maintained at a constant set tension.

All driving spring tension is released when only two cartridges remain in the mechanism. Release of the tension on the driving spring will allow the two feed levers to return to their normal position. The last round retainer is now forced down into the throat portion of the mouth and restricts the opening. The leading cartridge, of the two remaining, will be picked up and fired by the breechblock on its forward movement, but the last round being chocked off by the last round retainer is never fired from the feed mechanism.

The reason for preventing the last round from seating itself in the firing position in the mouth is as follows: without a round above it, and without the pressure of

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the rear feed lever on the rear of this second round, the first round is likely to pivot on the forward end of the two lips in the mouth. These lips extend along the rear part of the lower edge of the mouth and normally serve to support the round in the path of the breechblock. Without pressure on the rear of the round, the heavy projectile in front will drop down past the mouth. Therefore, the breechblock will not be able to strike against the rear of the cartridge case. Instead, it will hit the projectile and jam it forward, causing a stoppage.

In order to remove the last round safely from the mechanism, insert a screw driver or similar tool through the open belt guide, and push inward on the retainer. This releases the last cartridge which can be removed freely.

Gun, Automatic 20mm (T31)

Comparison of 20mm Automatic Guns AN-M1, AN-M2, and T-31. The T-31 gun is a recently adapted standard weapon representing the latest development in 20mm cannon. Its advantages over the AN-M2 are shown in the following table:

Characteristics	AN-M2	AN-M3
Rate of fire	600-700 rpm	750-850 rpm
Weight less ammo.	138 lbs.	112 pounds
Length	93.7 inches	77.9 inches
Average recoil	1⅛ inches	1-1/16 inches
Trunnion reaction	3500 pounds	3900 pounds (recoil) 1900 pounds (counterrecoil)
Action	Gas operated and blowback	Gas operated and blowback
Muzzle velocity	2850 fps	2870 fps
Sear mechanism	Open bolt	Closed bolt
Charging	Right side of gun; manual charger and hydraulic charger (semi-automatic)	Left or right side with manual charger (semi-automatic) Hydraulic charger (semi-auto.)
Feed	Right or left-hand M1, M1A1, M2, T15 feeds also 60 round drum.	Right or left-hand M1, M1A1, M2, T15 feeds also 60 round drum.
Average belt pull with M2 feed	55 pounds	55 pounds
Types of breechblock	Percussion M2 breechblock	Percussion T31 breechblock Percussion M2 breechblock Electric breechblock
Solenoid	Bottom of cannon only	Right or left side of cannon
Mounting	Complete mounting part of the airplane structure.	Cradle integral with cannon simplifying cannon installation.
Types of ammo.	Percussion primer-ball, HE, HEI, AP, Incendiary.	Percussion primer-ball, HE, HEI, AP, Incendiary.
Application to aircraft	Wing cannon (unsynchronized) Fuselage (unsynchronized).	Wing cannon (synchronized and unsynchronized). Fuselage cannon (synchronized and unsynchronized). Turrets

Construction Changes in the T-31 Gun. Reduction in weight of the T-31 cannon is a result of shortening the tube, reducing the outside diameter of the barrel, and reducing the receiver weight. The coil and ring springs for the recoil system of the T-31 are an integral part of the cannon assembly and by using the M2 feed mechanism the overall height has been reduced approximately 1½ inches. Milling out charging and solenoid lever slots on both sides of the gun has made it possible to charge or fire the gun from either right or left side. Holes are provided on both sides of the receiver for electric contacts with the electric type breechblock. Since the solenoid and charger are mounted to the cradle, which does not recoil, these two pieces are not subjected to the jolting forces of recoil and counterrecoil encountered in the AN-M2 gun. The magazine slide securing arms are also secured to the cradle, eliminating the need for providing a front support on the airplane structure. The shock incident to firing is transmitted to the trunnion at the foreward end of the cradle. Rollers on each side of the cradle support the cannon with a minimum of friction as it moves forward and back in recoil and counterrecoil. A third roller at the bottom of the cradle further aids in friction-free travel and prevents transverse movement.

Malfunctions resulting from variations in mount design to adapt the mount to different planes and positions are eliminated by manufacturing the cradle and gun as an integral item.

Functioning of the Gun. The T-31 Breechblock incorporates a sear and firing pin springs within the assembly, thus permitting the breechblock to remain in a

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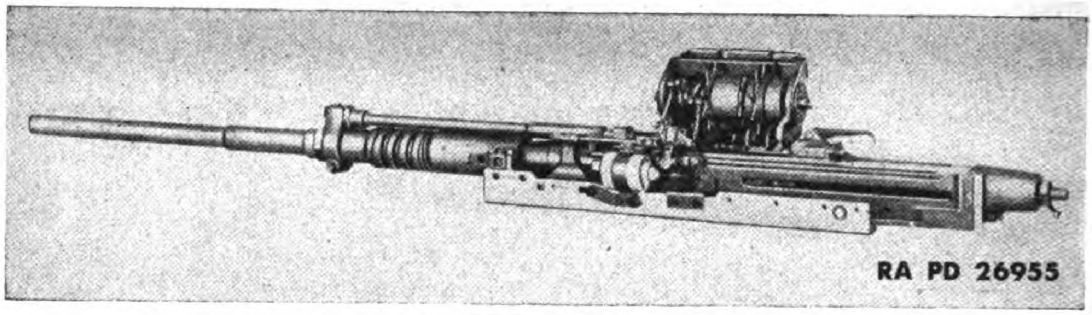

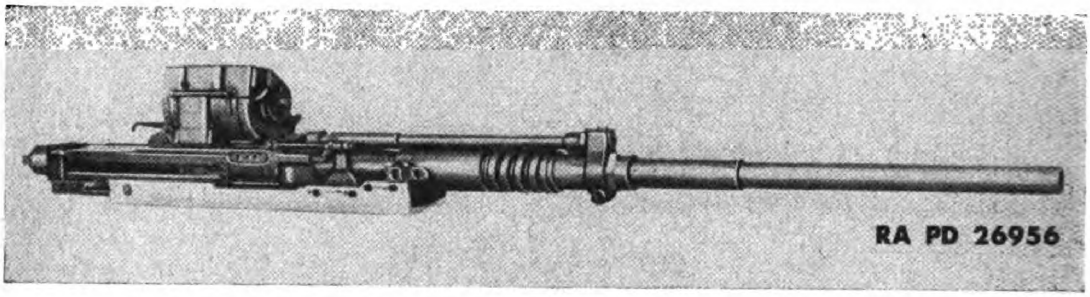

Figure 155. 20mm Automatic Gun T-31 with 20mm Feed Mechanism M2.

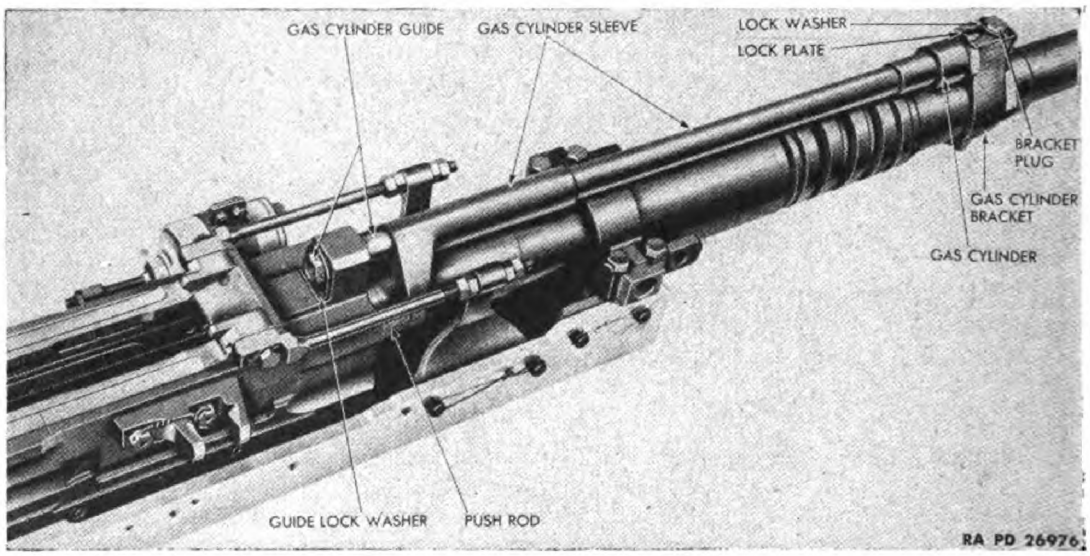

Figure 156. Gas Cylinder and Sleeve Group.

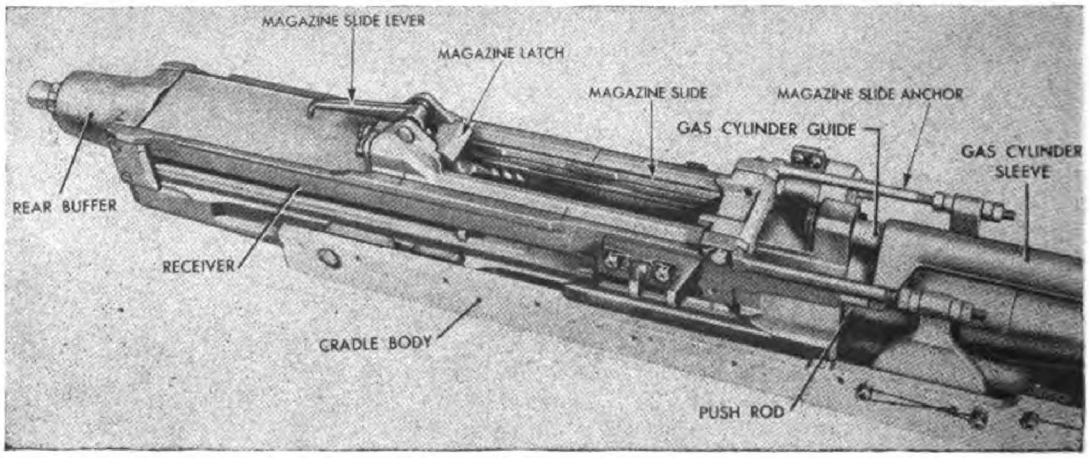

Figure 157. Receiver and Magazine Slide Groups.

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normally closed position comparable to the .50 caliber machine gun. The breechblock slides can move into battery position leaving the firing pin withheld by the sear. This is possible because of the deep cutout of the breechblock slide key. Firing is accomplished on the right hand side by the solenoid lever contacting the sear actuating lever which in turn pushes the sear toward the left, disengaging the firing pin and allowing it to go home. The firing pin is cocked by the breechblock slide key as it moves toward the rear after firing. The breechblock slide key holds the firing pin behind the sear approximately .040 inch during the travel of the breechblock assembly in the unlocked position. During this interval, the sear spring and sear spring plunger force the sear to the right engaging the firing pin as the breechblock slide moves into battery position. Pressure is maintained on the sear spring and sear spring plunger by the sear actuating lever. The sear actuating levers are carried by the breechblock slides to prevent premature release of the firing pin before the breechblock assembly is locked. The firing pin spring retaining plug separates the firing pin springs from the driving spring. To change from right to left-hand firing, the sear is reversed and the sear spring and sear spring plunger are placed on the right hand side. Functioning peculiar to the T-31 gun has been discussed above. For points not covered here the reader is referred to the preceding material on the AN-M1, and AN-M2 guns.

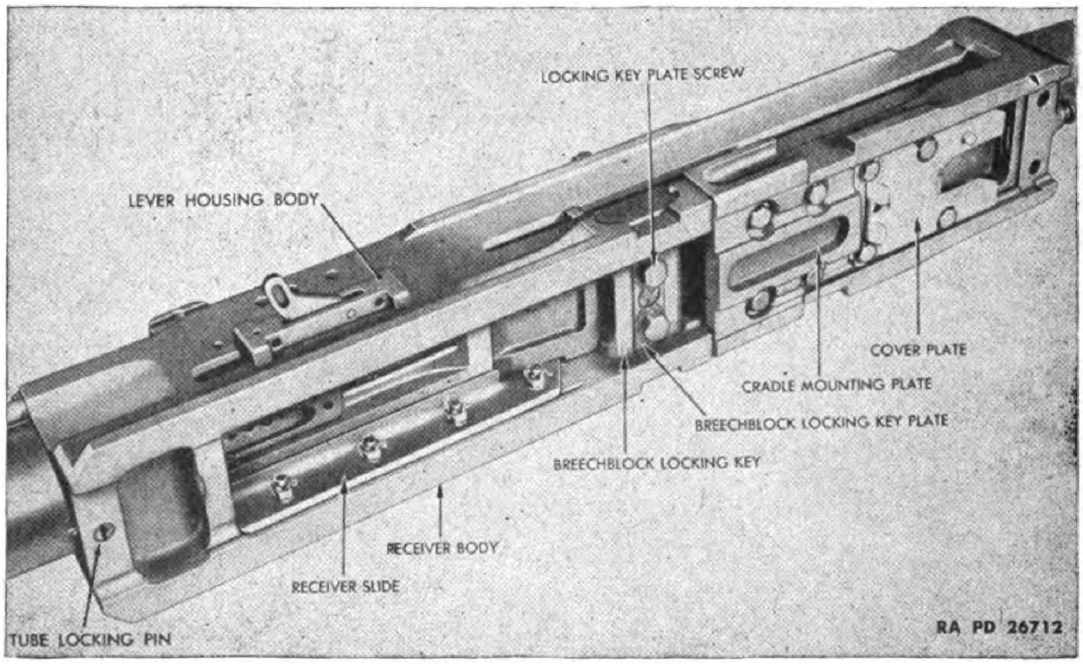

Figure 158 Bottom of Receiver.

20-MM FEED MECHANISM M2

Description. The 20mm Feed Mechanism M2 is a complete unit designed for feeding belted ammunition into the 20-mm Automatic Guns AN-M2 and T-31. There are two distinct M2 Feed Mechanisms—one which feeds ammunition to the gun from the right-hand side and the other which feeds from the left. Ammunition can enter the feed at a wide angle range. The feeder is furnished with a feed chute assembly pivoted about the end bearings and carrying a latch with which it can be secured in the desired angular position either to the feed mechanism directly, or to a cover not furnished with the feeder which is inserted between the feed chute assembly and the feeder frame. In this manner varied angles of entrance to the M2 Feeder can be secured.

The function of the M2 Feed Mechanism is to bring belted ammunition into the gun; separate the rounds from the links; and feed the rounds, one at a time, into the breech of the gun. This mechanism is operated on both recoil and

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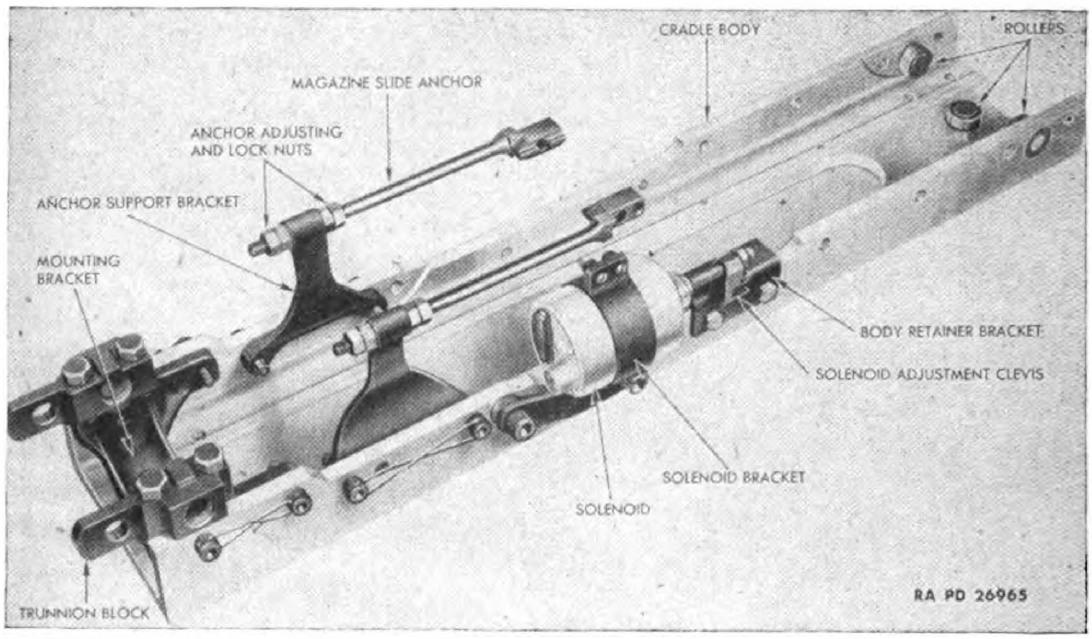
counterrecoil of the gun, which feature allows it to maintain winding with as low as eleven-sixteenths of an inch recoil, and also accommodates maximum gun recoil up to $1\frac{1}{16}$ inches. The drive system will regain full drive spring torque after a dud has been encountered and removed from the gun by recharging. The M2 Feed Mechanism will lift 70 pounds of belted ammunition. This is equivalent to lifting 113 rounds of belted ammunition vertically, or, of pulling a horizontal belt of 575 rounds.



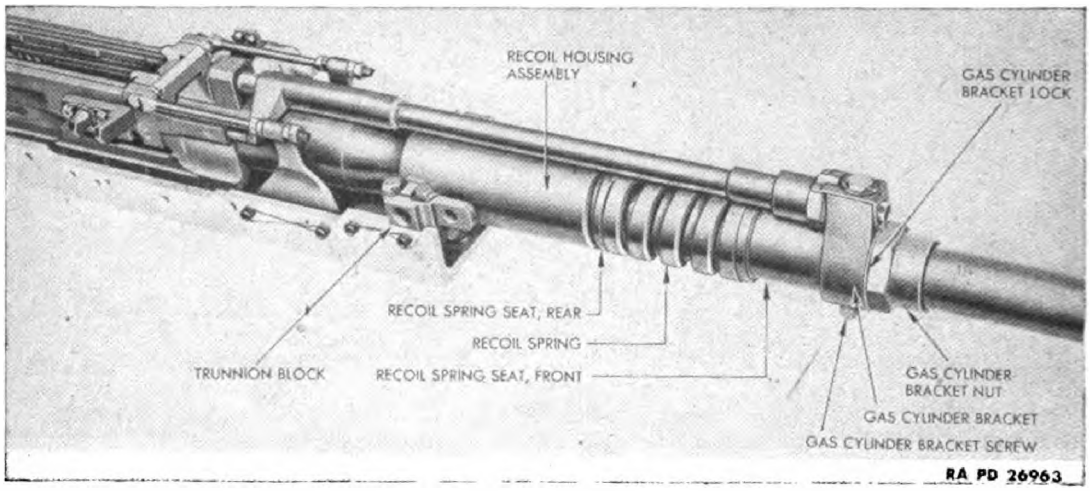


Figure 159. Cradle Body and Attaching Parts. Gas Cylinder and Sleeve Group.

Functioning. The function of the 20mm M2 Feed Mechanism may be broken down into three distinct phases:

(1) Bringing the ammunition from the magazine into the feed.

(2) Stripping the links from the belted ammunition.

(3) Positioning the rounds, one at a time, into the mouth so that they can be carried forward into the chamber by the breech-block bolt.

To simplify the explanation of its functioning, the feed has been divided into three separate groups:

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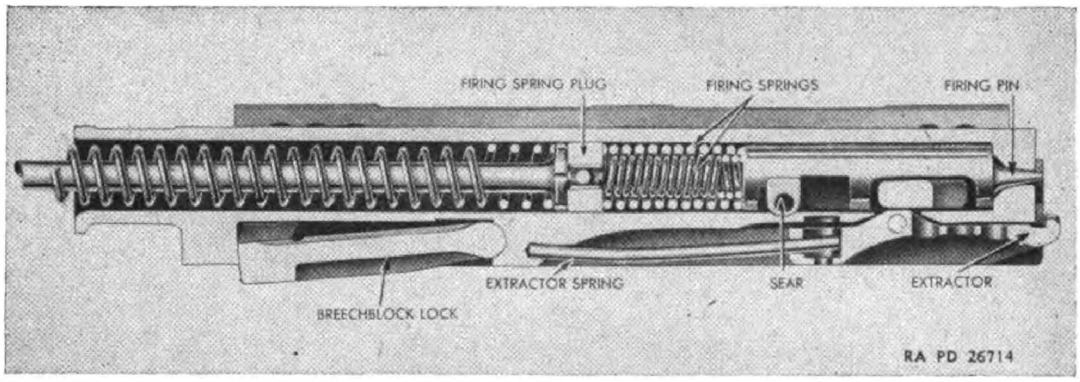
(1) Clutch drive group.
(2) Starwheel housing group.
(3) Frame and mouth group.

The starwheel housing group which brings the ammunition into the feed is



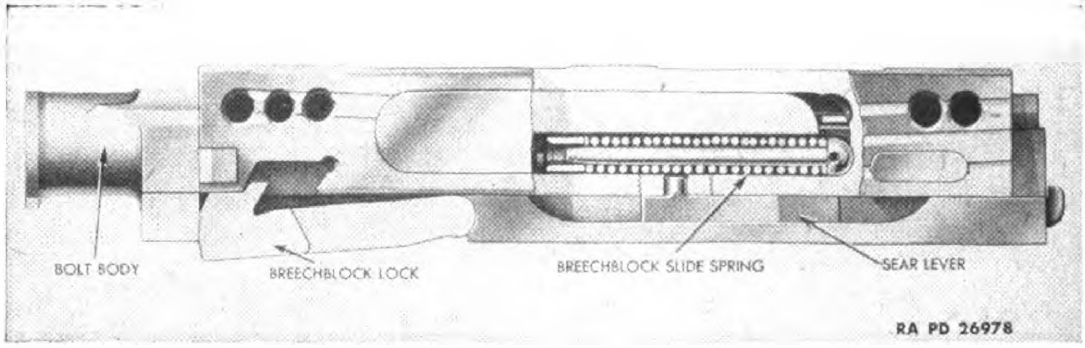


Figure 160. Cross Section of Breechblock.

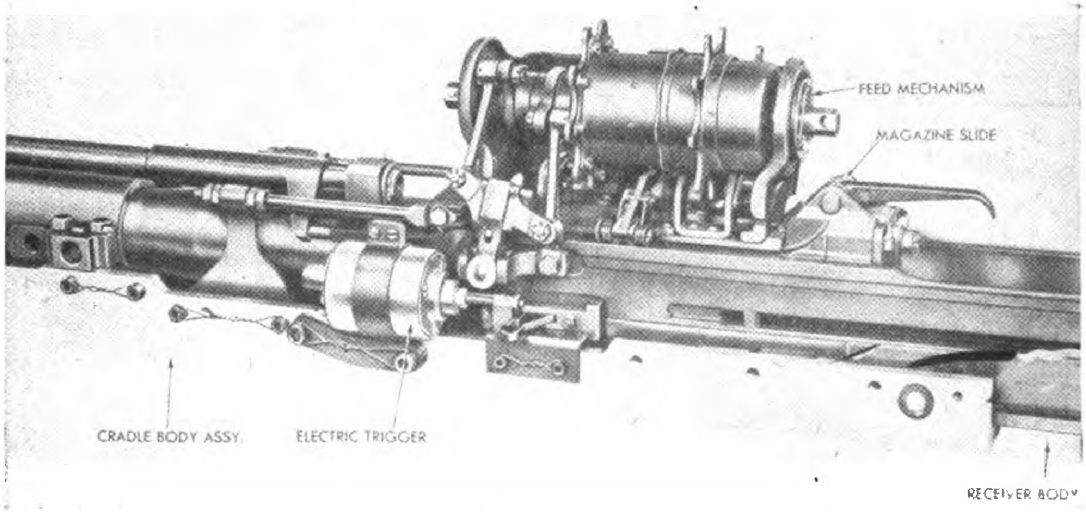


Figure 161. 20mm Feed Mechanism M2 Mounted on M3 Gun.

actuated by a drive spring. The tension of the drive spring is maintained by the recoil and counterrecoil of the gun by means of the clutch drive group. The ammunition belt is engaged by the front and rear starwheels and is carried into the feed past the stripper cams where the links are stripped from the rounds and forced out of the link chute opening in the feed frame. The rounds, freed

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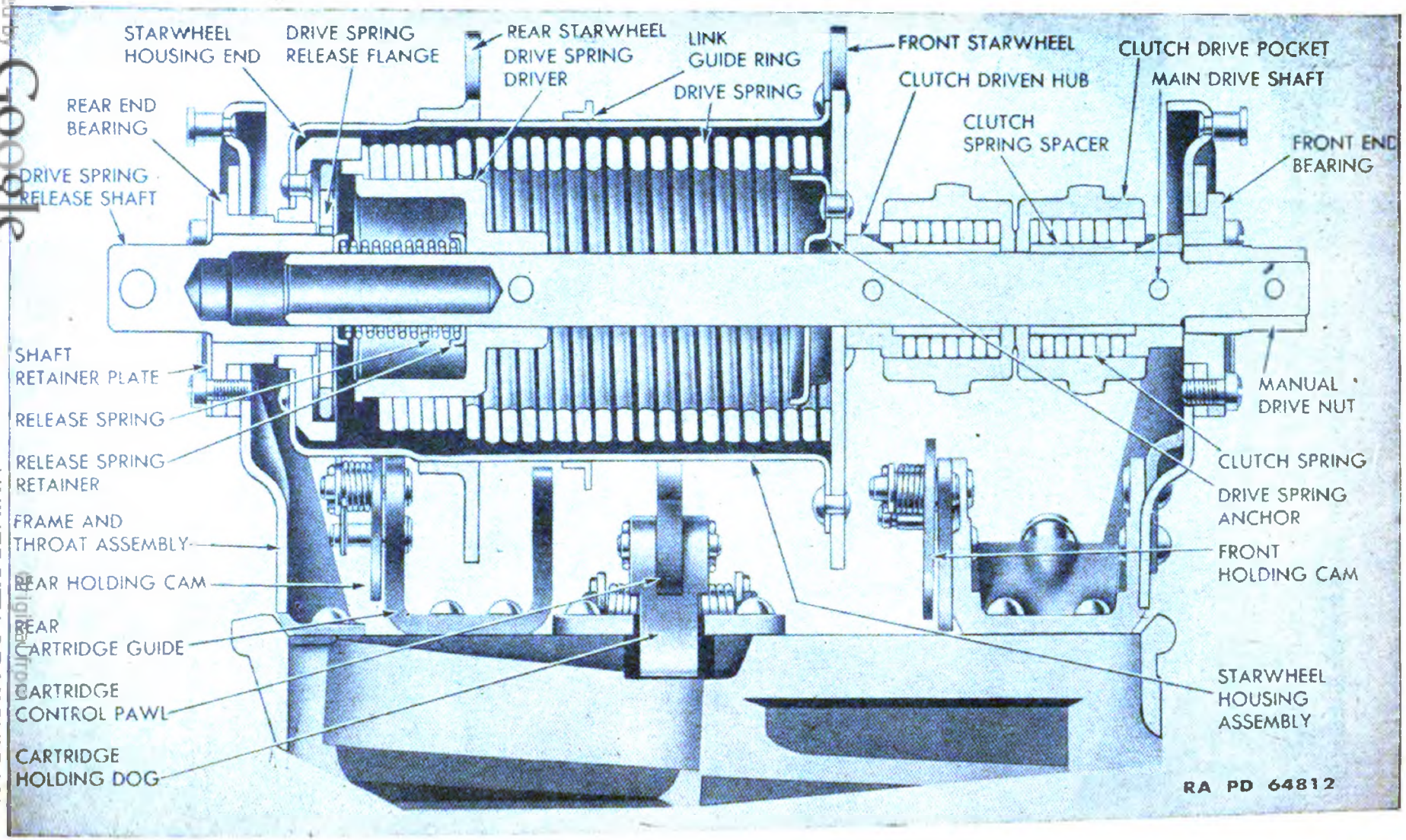

Figure 162. 20mm Feed Mechanism M2. Cross Section View.

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from their links, are carried on past the cartridge holding cams and into the mouth by the force of the drive spring, where they are held in position for chambering. The feed mechanism, mounted on the nonrecoiling magazine slide, remains stationary during recoil of the gun.

A detailed step-by-step description of the functioning of the 20-mm M2 Feed Mechanism is as follows:

A drive bracket attached to the receiver body of the gun actuates the operating lever during recoil and counterrecoil. The operating lever rotates the link operating crank which is pivoted on a bracket secured to the mouth and remains stationary with respect to gun recoil.

As the gun recoils, the link operating crank actuates the two link assemblies which connect the operating crank with the clutch drive pockets. The rear clutch drive pocket transmits motion to the main drive shaft through the clutch spring and hub during recoil, while the front clutch free-wheels. During counterrecoil the action of the front and rear clutches is reversed. Thus, the fore and aft motion of the operating lever is changed into rotary motion to actuate the main shaft assembly.

When the clutch drive pockets rotate in a direction to wind the drive spring, the clutch springs tend to expand within the pockets. The force of this expansion causes the clutch spring to grip and be carried with the pocket as it rotates. The clutch driven hub is pinned to the main drive shaft and is also locked to the clutch spring. Therefore, the clutch assembly rotates as a unit, turning the main drive shaft which winds the drive spring through the drive spring driver (hub). While one clutch assembly is revolving in the winding direction, the other revolves in the opposite direction causing the clutch spring to contract within the pocket, thus relaxing its grip. This permits the pocket to revolve freely in the opposite direction to its clutch driven hub and spring, which always revolve with the main shaft. This action causes the main drive shaft to always be rotated in a direction to wind the drive spring, even though the clutch drive pockets are reversing their direction every half cycle of gun operation.

As the main drive shaft is rotated, the small end of the drive spring grips and revolves with the drive spring driver. This winds the larger portion of the drive spring. The front end of the drive spring is anchored to the front starwheel.

To insure that the drive spring is always fully wound, to provide maximum belt pull, and to protect the spring from becoming overwound, a torque stabilizer action is employed. The torque stabilizer action regulates the drive spring torque from 23 to 27 foot-pounds. The parts which function to produce this stabilizing effect are: the drive spring driver, the small portion of the drive spring, the drive spring lug, and the starwheel housing end. When the gun recoils more than eleven-sixteenths inch, the drive spring driver will revolve through a greater angle every cycle than the starwheel housing is required to revolve to feed one round into the gun. Such a condition would overwind the drive spring if the torque stabilizing action did not function to dissipate excess energy of recoil. The small end of the drive spring terminates as a lug, bent at right angles to the spring coils. The drive spring lug contacts a projection on the starwheel housing end when the spring is fully wound. The projection on the starwheel housing end exerts a force on the small coils of the spring causing them to relax their grip on the driver, until the driver can revolve within the spring and still maintain full drive spring force. This action insures that the spring will always be wound by the driver until the starwheel housing end, which revolves with the starwheel housing, is contacted by the drive spring lug. It also prevents the drive spring from being overwound because the contact of the lug with the starwheel housing end prevents further winding of the spring.

To unwind the drive spring, the drive spring release shaft is pushed forward, carrying the drive spring release flange into contact with the drive spring lug. If the release shaft is revolved in the opposite direction to that of winding, the release flange will exert a force on the drive spring through the lug, causing it to relax its grip on the drive spring driver. This allows the drive spring to be revolved on the driver by the rotation of the drive spring release shaft, thus unwinding the spring. The drive spring release shaft is returned to its non-operating position (rearward) by its release spring.

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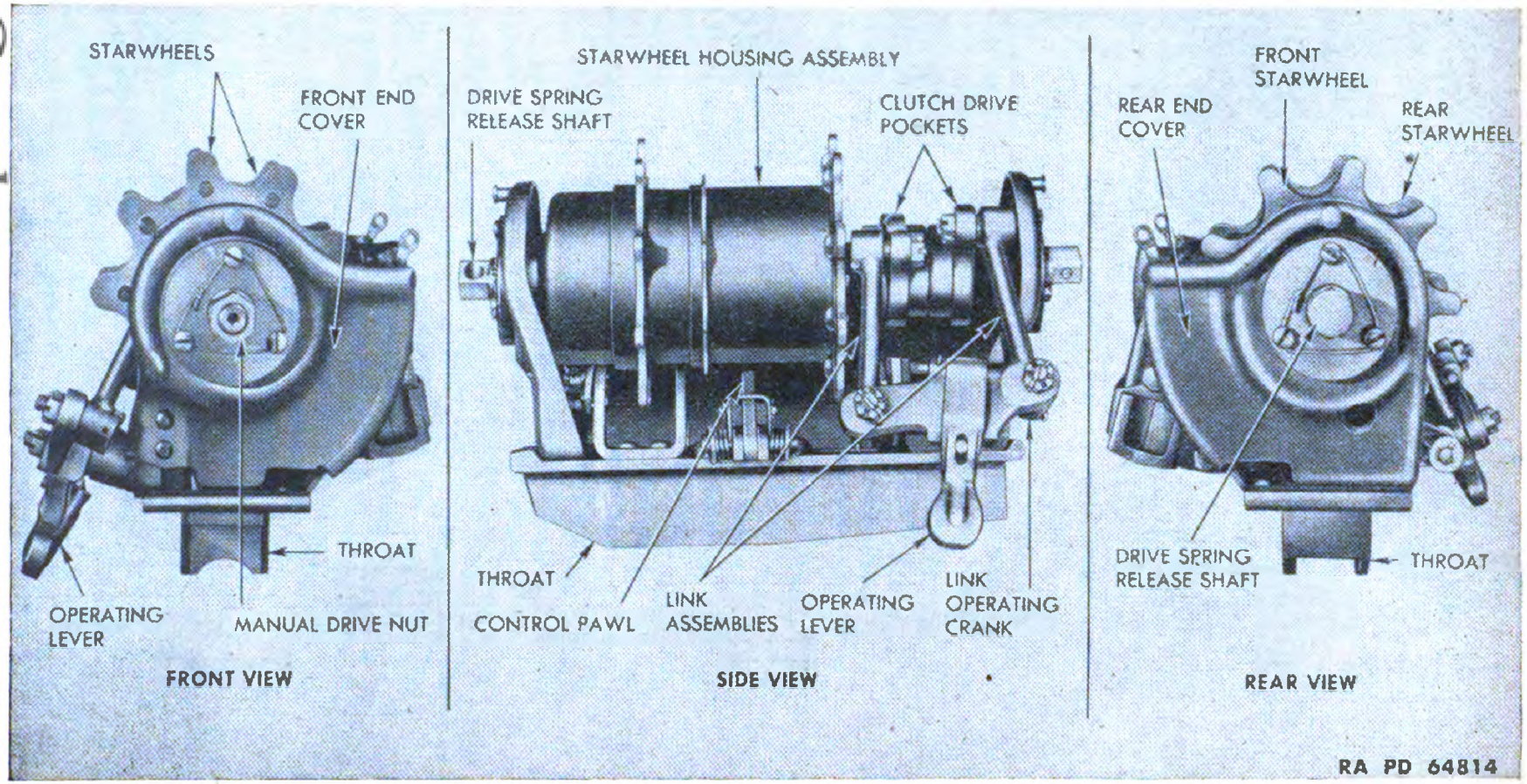

Figure 163. 20mm Feed Mechanism M2. Front, Side and Rear Views.

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As a belt of ammunition is drawn into the feed mechanism by the rotation of the two starwheels which are powered by the drive spring, the rear starwheel engages the cartridge case to the rear of the belt link and the front starwheel engages the round just ahead of the rotating band on the projectile. As the belt rotates with the starwheel housing assembly, the stripper cams wedge between each cartridge case and the ears of the belt links, thus stripping the links from the cartridges. During the stripping action the single end of the link is guided into the link chute by the link deflector, while the double end is being cammed from the round. The link is ejected from the feed mechanism through a link chute extension. After the links have been stripped from them, the rounds are carried on by the starwheel until they are in line with the mouth. At this point they are guided into the mouth by the front and rear cartridge guides. The round is held in position in the bottom of the mouth or on top of the bolt, whichever the case may be, by force exerted by the star wheels through the round following. The guide surfaces on the cartridge guides and the side of the mouth are designed to take approximately 50 percent of the load exerted by the starwheels, thus reducing the force of the round on the top of the bolt or in the mouth. This feature reduces to a minimum the energy required to strip the round from mouth of the feed mechanism as the round is being chambered. It also materially reduces friction of the breechblock bolt, making the gun more reliable under all climatic conditions. The round is positioned in the bottom of the mouth at a 3-degree 20-minute angle. This angle properly directs the round into the chamber as it is being carried forward by the breechblock bolt. The next round to be fired is forced downward on top of the bolt when it is in the forward position. When the bolt is forced rearward and the empty cartridge case is ejected, the next round is forced into position in the mouth where it is carried forward as the bolt contacts the lower portion of the cartridge base during its forward travel.

Just before the incoming rounds enter the feed mouth, they contact the lower side of the spring-loaded cartridge control pawl, raising is slightly. This action lifts the cartridge holding dog, allowing the cartridges to enter the mouth. When the last round has passed under the control pawl and entered the mouth of the feed, the control pawl spring forces the pawl downward so that the holding dog prevents the last round from dropping all the way down into the mouth of the feed mechanism. If the last round should drop into the path of the bolt it would cause the gun to jam. The last round in the belt is held in such a position by the holding dog that the breechblock bolt will not contact it and jam the gun as the bolt closes on the empty chamber. This round is also positioned so that it clears the starwheels, permitting them to spin and automatically unwind the drive spring when the last two rounds have entered the mouth. The last round, held by the holding dog, is released and forced into the feeding position in the mouth by the action of the first round of a new belt on the cartridge control pawl and dog. As the incoming rounds enter the mouth, they contact the front and rear spring-loaded cartridge holding cams, forcing them aside. When the last round leaves the starwheels and enters the feed mouth, the cartridge holding cams are forced over the top of the cartridge by the cartridge holding cam springs. The holding cams prevent the last two rounds in the mouth from reentering the feed and, in so doing, position the lower round in the mouth so it can be stripped out by the breechblock bolt.

20-MM FEED MECHANISM T15

Description. The 20mm Feed Mechanism T15 is a small lightweight unit that drives electrically to supply ammunition from a belt to the 20-mm Automatic T31 Gun as well as to the M1 and AN-M2 Guns. It may serve both for left and right feed, requiring only the reversal of various parts.

The rounds are separated from the belt links by the T15 Feed Mechanism and are moved to the feed mouth by feed wheels on a shaft rotated by an electric motor. As the successive rounds move beyond the control of the feed wheels in the feed mouth, spring-driven loading levers and a retaining finger continue the down feed and hold each round in the position from which it is picked up by the breech bolt. The loading lever and retaining finger springs are energized by the

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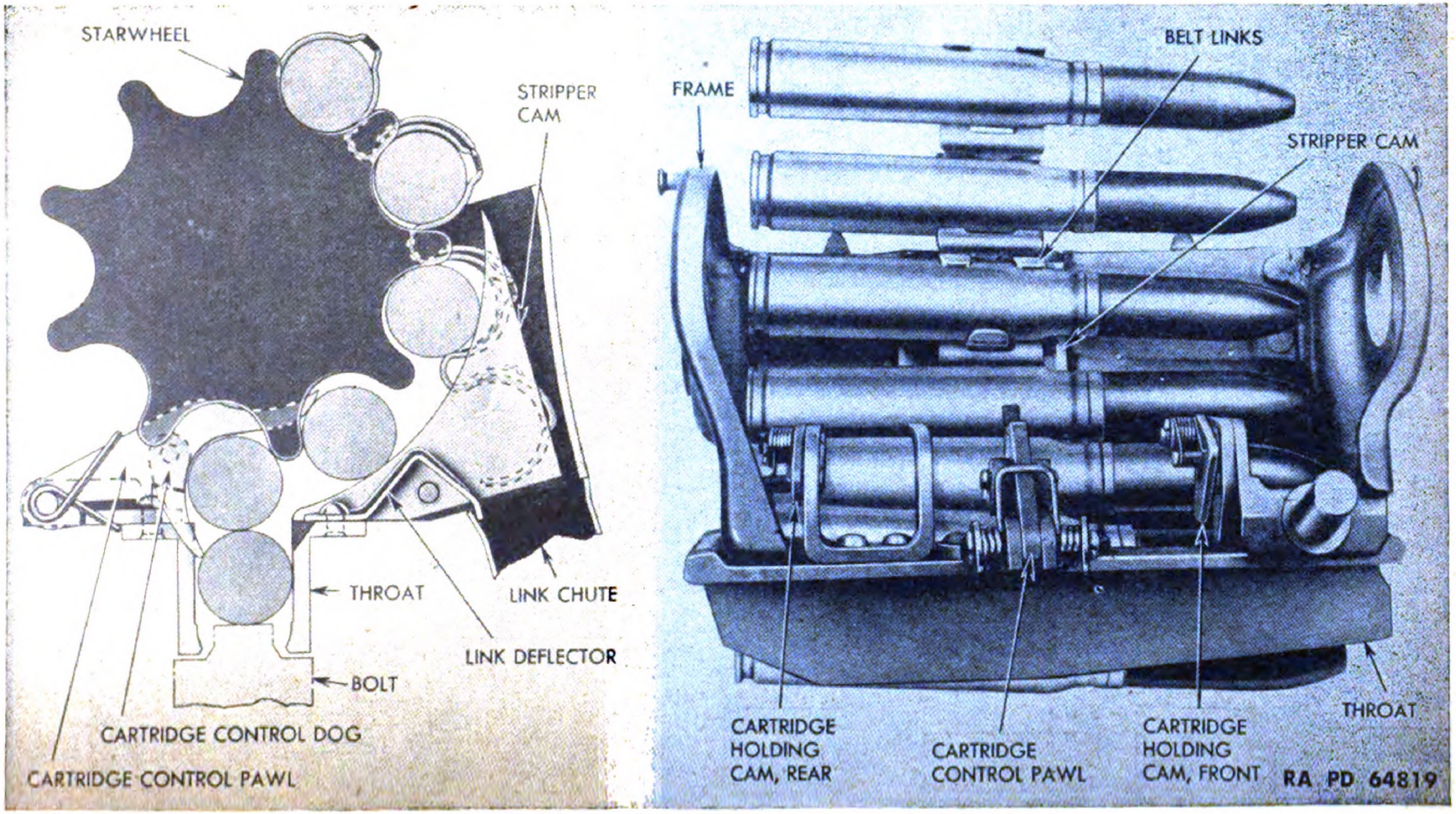

Figure 164. Stripper Cam Action Right-Hand Feed.

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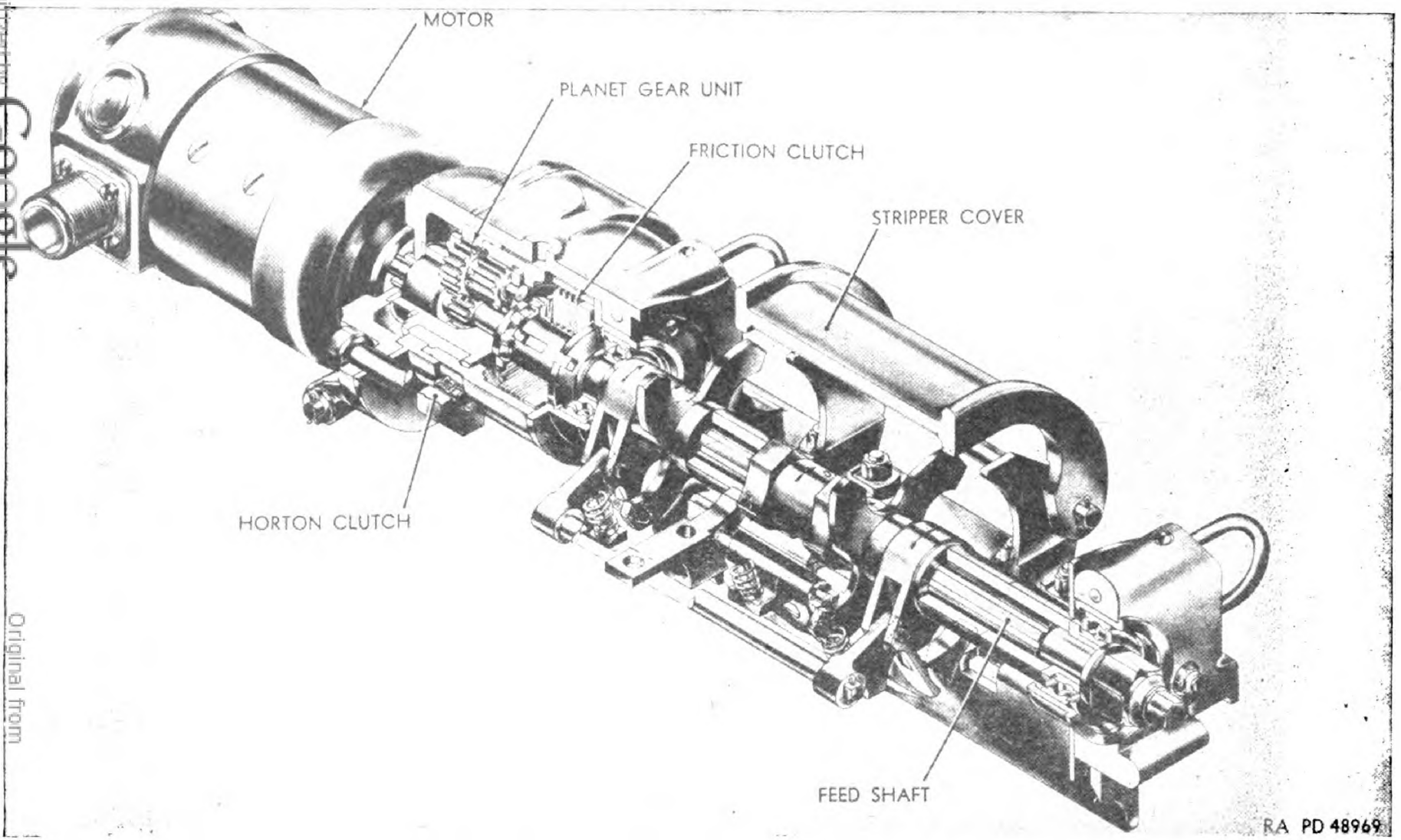

Figure 165. 20mm Feed Mechanism T15. Right-Hand Feed, Etc.

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yielding movement of the levers and the finger as the rounds enter the feed mouth under the control of the feed wheels. Since the feed shaft cannot feed faster than required by the rate of fire, a friction clutch, through which the motor force is transmtted to the drive shaft, slips a little before each round is rammed from the feed mouth. Normally the clutch is set to transmit a force of 155 to 165 inch-pounds at motor speed before slipping. The T15 Feed Mechanism will exert a pull of 80 pounds on the ammunition belt.

In removing successive links from the rounds, a stripper applies pressure on the single end of the link forcing it off the belt in cooperation with a stripper cover as the feed wheels, acting on the primer end of the round, continue to feed the round. Thus, no force is applied to the projectile end or nose of the round, obviating any possibility of a loosening or damaging of this sensitive round portion.

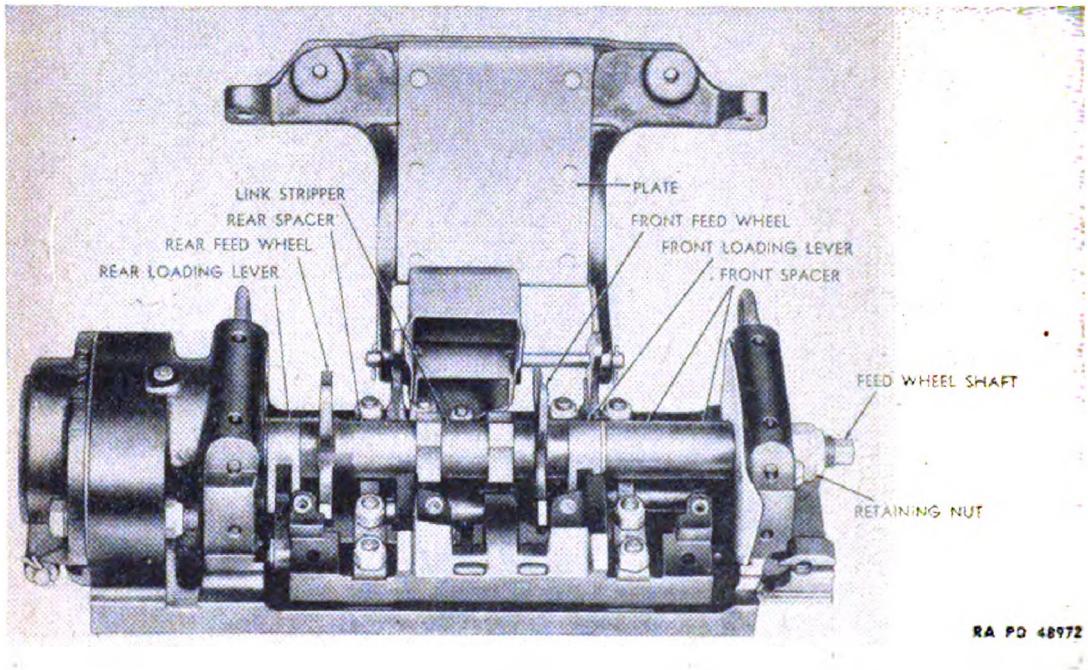

Figure 166. 20mm Right-Hand Feed Mechanism T15 Without Motor.

M3 or M3E1 Links are used in making up the ammunition belt for supplying ammunition to the feeder. The double end of the link leads. With these links, a high degree of belt flexibility is obtained.

The feed motor for the load and duty cycle of the feed mechanism has splined shafts at both ends. When not in use, these shafts are protected by removable caps. A plate on the motor indicates which cap is to be removed when applying the motor to a right or to a left-hand feed mechanism. The motor has a single prong AN connector and has the other common wire grounded to the motor frame. The following pertains to the fire control system for a single gun, the instructions beginning with the power turned off, the switches in open position, and the relay coil deenergized. (The gun is not charged at this time and no ammunition is in the feed mechanism.) The sequence of operation of the fire control system is as follows:

1. The power circuit breaker is first closed, thereby connecting the feed mechanism to the power supply. The closing of this circuit breaker does not operate the firing solenoid or the motor.

2. The ammunition loading switch is held in load position. This energizes the motor and operates the feed mechanism until the loading switch is released.

3. Upon indication that the feed mechanism functions properly, the gun can be loaded and charged. After loading and charging, the firing mechanism is actuated to fire the gun. The gun will continue to fire until the ammunition belt is exhausted or the firing mechanism is no longer actuated.

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4. Closing of the trigger switch energizes the motor time delay relay coil, thereby closing the relay contacts and starting the motor which then accelerates and runs at a speed sufficient to feed ammunition faster than the gun needs to maintain its rate of fire.

5. Upon release of the trigger switch the feed motor time delay relay maintains power on the motor for a sufficient length of time to position a round in a position to be picked up by the breech bolt for the next burst of fire.

The wiring diagram shows the electric circuit and a proposed firing mechanism.

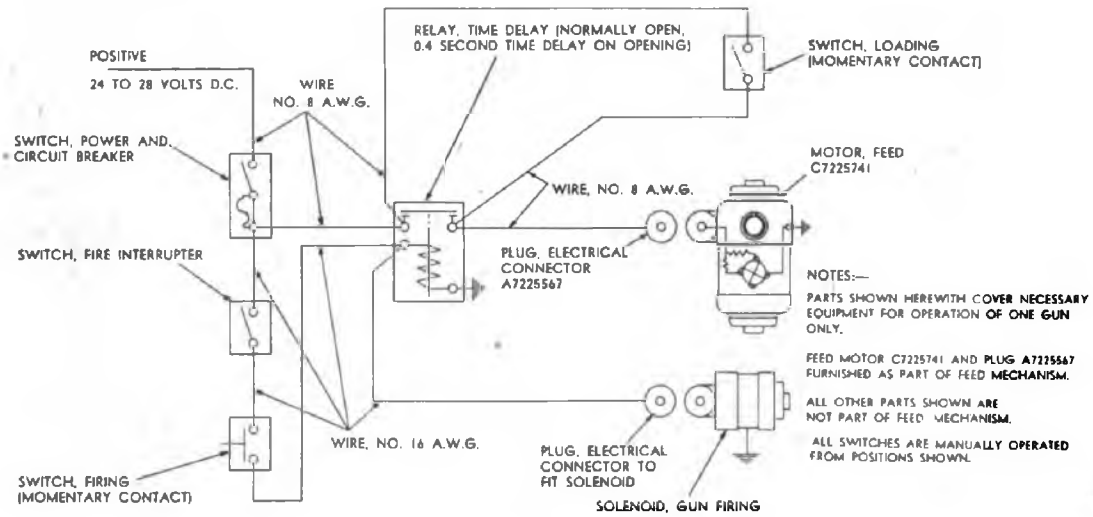

Figure 167. Wiring Diagram for 20mm Feed Mechanism T15.

The motor is secured to the inside of a housing cap by means of motor screws prevented from loosening by lockwire. The cap is secured to the feed frame by housing cap screws and nuts and forms an enclosure for the open gear housing end of the feed frame. The feed wheel shaft is driven by the motor through a planet gear unit and a friction clutch mounted in the gear housing. The planet gear unit functions as a reduction gear, transmitting one rotation to the feed wheel shaft for each 35.7 rotations of the motor. The motor rotates a gear shaft which turns in bearings in a planet pinion cage as well as in a needle bearing in the end of the feed wheel shaft. The gear shaft rotates planet pinions about planet pinion pins mounted in the planet pinion cage. Each planet pinion comprises two large and two small pinions. The large pinions mesh with an internal gear secured to the gear housing of the frame by means of the housing cap screws. The small pinions rotate a clutch gear to which friction washers, comprising the driving members of the disk or friction clutch, are joined. The driven members of the clutch consist of friction disks which are mounted to rotate with the feed wheel shaft. The setting of the clutch is determined by a lock nut threaded onto the end of the shaft and held in position by a lock washer. Three spring washers, carried by an outer spacer interposed between the lock washer and the outer clutch disk, equalize the pressure applied to the friction clutch by the lock nut. The clutch is normally set to transmit a slipping torque of 155 to 165 inch-pounds at motor speed.

If the reverse torque is less than the friction clutch setting, reverse movement of the rounds when the gun is not being fired is prevented by a Horton clutch which consists of two clutch plates, mounted in the feed frame, and four spring-loaded rolls, two in each plate. The rolls are wedged between the clutch plates and the periphery of the clutch gear by the pull of the belt when the gun is not being fired and prevent reverse movement of the feed wheel shaft at this time.

Functioning. The function can more readily be understood by reference to figure 168. The feed mechanism fulfills the following broad functions:

(1) To draw the linked rounds into the feed mechanism.

(2) To strip the rounds from the links.

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(3) To position the rounds, one at a time, in a position in the feed mouth from which they are picked up by the breech bolt. For simplification, the movement of the first, or leading round, of the belt is described. It is understood that in describing the function, the motor is running and the proper switches have been closed to insure continuous feed of the belt and firing of the gun.

Successive rounds pass over the guide faces on the operating lever bracket and are engaged by the feed wheels.

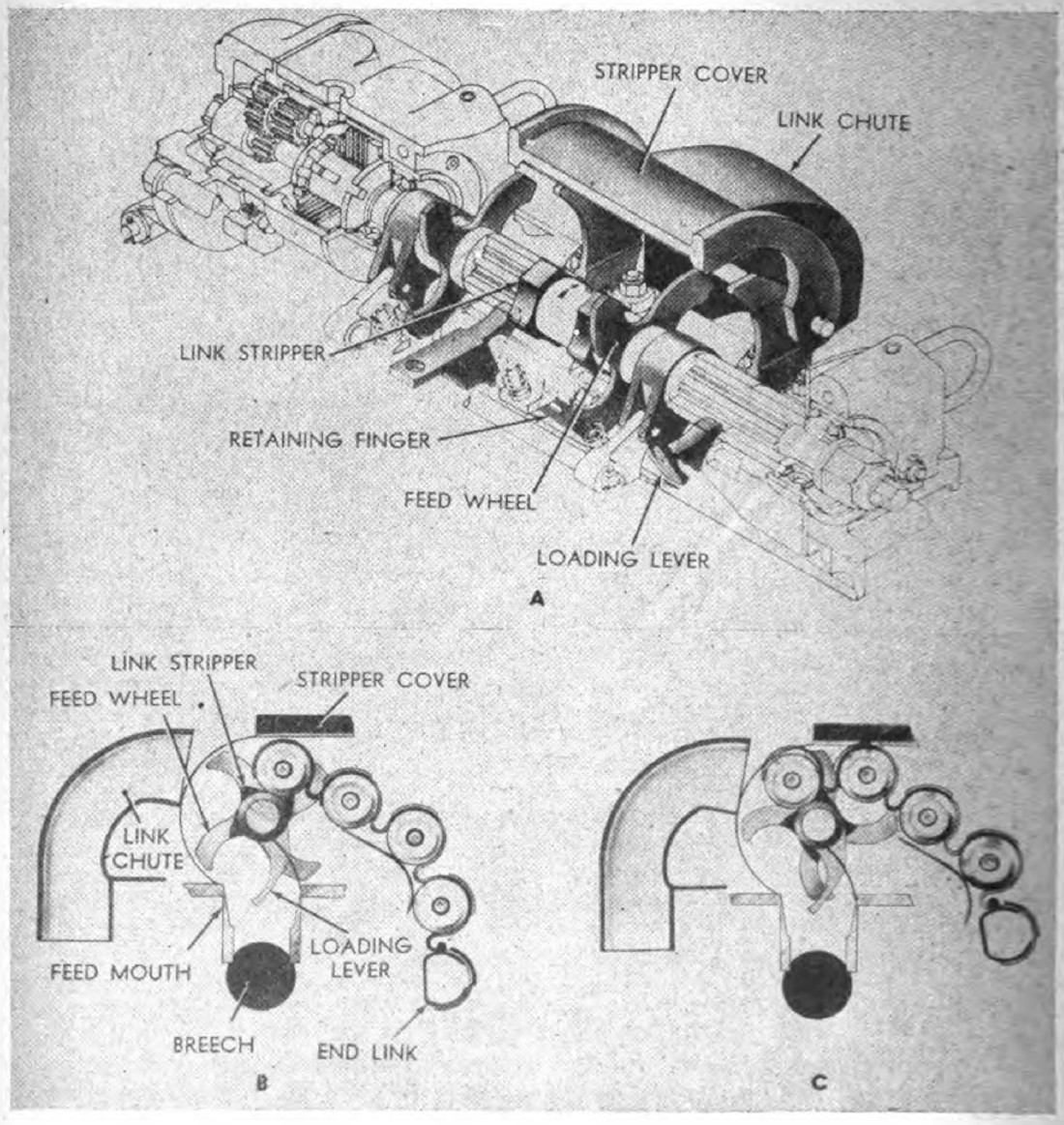

Figure 168. 20mm Feed Mechanism T15. Travel of Rounds Through Feed Mechanism.

The leading round moves beyond its highest position and the second round in the belt approaches its highest position in the feed mechanism. At this time the single end of the link, joining these two rounds, is forced against the adjacent face of the stripper cover by the link stripper, which presses against the crimped portion of the link between the rounds. The link stripper thus provides a fulcrum about which the double end of the link is controlled to cause the stripper cover to force the link off of the leading round as the feed wheels continue to move the round downward.

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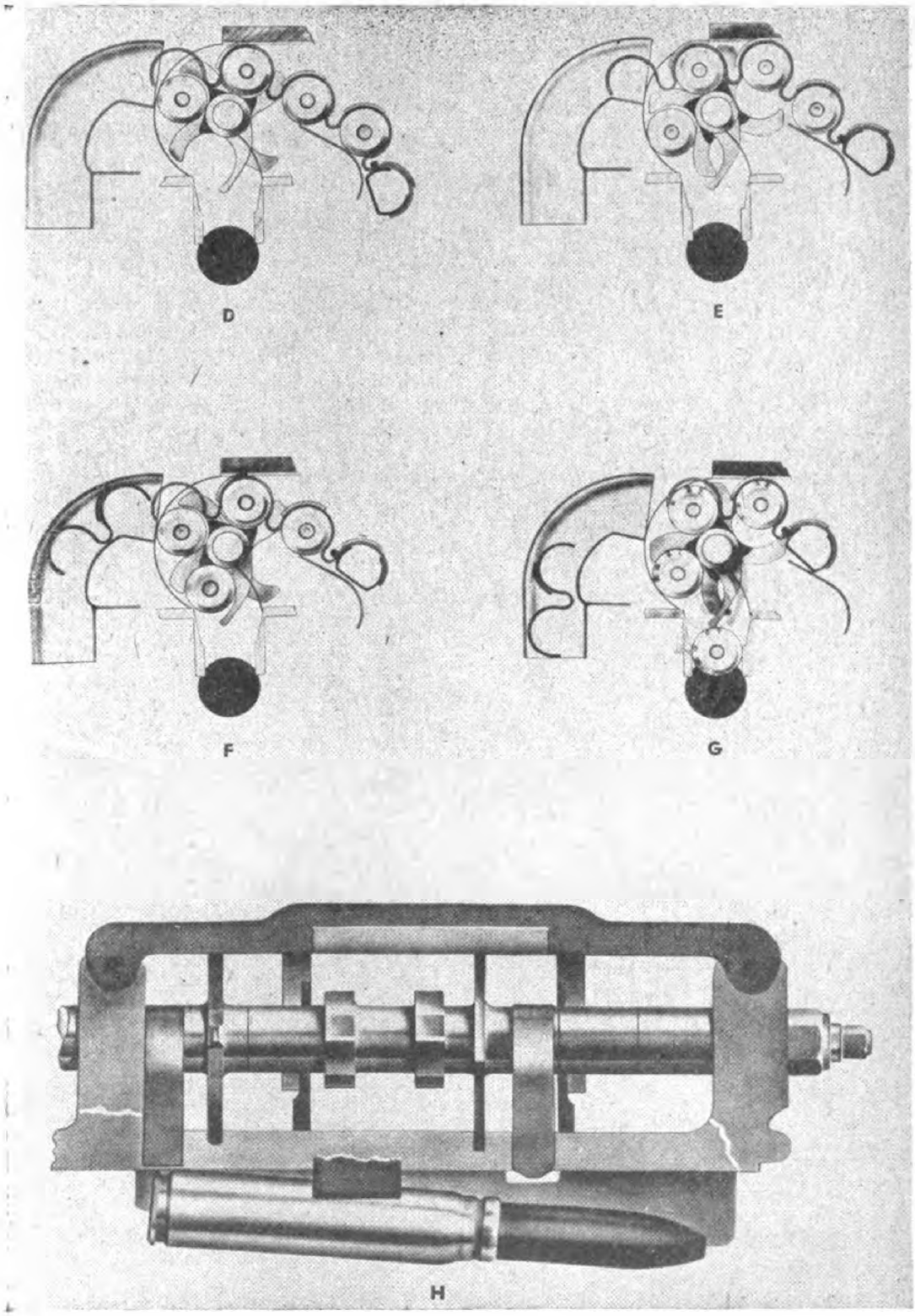

Figure 169. 20mm Feed Mechanism T15. Travel of Rounds Through Feed Mechanism.

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The freed link is guided into the link chute by the pressure of the following link and is disposed of by sliding out of the link chute and the link chuting.

The freed leading round continues to move about the feed shaft, the inner faces of the chute supports controlling the round until it reaches the leading guides on the operating lever bracket.

The feed wheels force the round downward in the feed mouth along the loading guides and past the loading levers and the retaining finger held by their springs in position to be engaged by the round.

As the round moves downward, the loading levers and the retaining finger are forced outward by the round; the springs, acting on the loading levers and on the retaining finger, being energized by the yielding movement of these parts.

When the round reaches a position in the feed mouth in which it is beyond the control of the feed wheels, that is, in which it has moved beyond the periphery of the feed wheels, the loading levers are free to return to their initial position in the feed mouth and, in so doing, snap the round downward by the action of their springs as soon as the breech bolt is sufficiently recoiled.

While the round is held in the feed mouth in preparation to being moved downward by the loading levers, the friction clutch slips to safeguard the motor against excessive pressure, thus temporarily interrupting the rotation of the feed wheel shaft until sufficient room is provided by the final downfeed movement of the leading round to resume the functioning of the feeder.

The round is held in final position on the ways of the feed mouth at the proper angle for ramming by the retaining finger and the rear loading lever.

Each round is released from its link and fed to final position in the manner described above.

The last round may be fed from the feed mechanism, since the retaining finger and the loading levers are capable of bringing it to the position from which it is picked up by the breech bolt.

INSPECTION AND CORRECTIVE ACTION PROCEDURE FOR 20MM GUN

The purpose of inspection is to determine whether a weapon is in serviceable condition, and to insure safety in firing. The complete weapon is inspected for proper adjustment, proper clearances, and completeness, as well as to repair or replace all defective parts. Before inspection can be conducted the weapon must be free of any grease, dirt, rust, or foreign matter which may interefere with proper inspection. Inspection is done either visually or by the use of special tools and gages.

Gage Inspection. Gage inspection is that which is done with the use of various special tools and gages for that particular type of gun. Gages used on the 20mm are: (1) feeler gages (2) depth micrometers; (3) assorted drills (used as substitutes for plug gages); and (4) steel rules.

Visual Inspection. Visual inspection is that which is done without the use of any special tools or gages.

Special points to observe on visual inspection:

Check to see that the gun is complete and properly assembled.

Check for burred, broken, rusty, or damaged parts. All sharp edges should be removed.

Make sure the gun has been cleaned thoroughly and properly lubricated with the correct type of lubricant.

Check function of the gun by manual operation using dummy ammunition.

Test fire the gun.

MALFUNCTIONS

Malfunction. Failure to charge when using hydraulic charger M1.

Caused by: Lack of pressure in hydraulic system.

Preventive Maintenance: Inspect for loose connections, and repair all damaged parts. Check level of hydraulic fluid periodically, and add fluid when necessary.

Malfunction. Failure to charge when using hydraulic charger M1, or manual charger, M2.

Caused by: Broken charger lug on right breechblock slide.

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Preventive Maintenance: Check for possible cracking of charger lug and burrs either on charger lug or charger lug slot in receiver.

Malfunction. Failure to charge when using hydraulic charger M1.

Caused by: Hydraulic fluid leaking around head of piston.

Preventive Maintenance: Check for improper assembly of piston packing. Make sure that no sand or grit gets into cylinder which may chew up sealing edge of piston packing and scratch inside wall of cylinder. Inspect regularly.

Malfunction. Failure to load.

Caused by: Burrs causing binding, on moving parts of breechblock or in receiver.

Preventive Maintenance: Inspect breechblock and receiver after each firing of gun. Clean thoroughly, check for worn or damaged parts and lubricate with correct lubricant.

Malfunction. Failure to load.

Caused by: Insufficient recoil of breechblock. The breechblock, not coming back far enough to clear the end of the new round, will dig into the side of the solid brass cartridge case and buckle the case.

Preventive Maintenance: Keep breechblock and receiver free of burrs and foreign matter. Make sure that gas cylinder vent plug is not lubricated. Make sure that vent and bracket plugs are tight and securely locked. Check driving spring guide plunger and tube for straightness. Oil all cartridge cases lightly. (Make sure no oil gets on primer.)

Malfunction. Failure to fire.

Caused by: Broken or worn firing pin.

Preventive Maintenance: Inspect on regular inspection for cracks, burrs, and pitting of firing pin. Check tip of firing pin for erosion caused by primer of cartridge being pierced.

Malfunction. Failure to fire.

Caused by: Defective primer or cartridge causing misfire.

Preventive Maintenance: Inspect cartridges before loading in magazine. Check for loose projectile or bad crimping. Also check to see that, on oiling the round, the oil has not seeped in around crimping or into primer.

Malfunction. Failure to unlock.

Caused by: Metering holes of gas cylinder vent plug or gas port in tube clogged up.

Preventive Maintenance: Inspect gas port and vent plug for carbon deposits. Keep vent plug clean and dry at all times. Never lubricate vent plug.

Malfunction. Failure to unlock.

Caused by: Worn gas cylinder or piston allowing excessive escape of gases.

Preventive Maintenance: Keep gas cylinder and piston well lubricated and free of foreign matter. Polish off all burrs that may cause binding.

Malfunction. Failure to unlock.

Caused by: Loose gas cylinder vent or bracket plug or both.

Preventive Maintenance: Check plugs to see if loose. Insure that both plugs will stay tight by locking them with lock plate and lock washers. *Note:* Gas cylinder vent plug will always loosen up due to heat expansion and subsequent cooling unless properly locked.

Malfunction. Failure to eject.

Caused by: Partly clogged metering holes in vent plug causing slow unlocking and insufficient recoil of breechblock.

Preventive Maintenance: Keep vent plug clean and dry at all times. Never oil as this causes carbon deposits to form on plug and clog up metering holes.

Malfunction. Failure to eject.

Caused by: Broken extractor. Cartridge has no pivoting support on lower side of case.

Preventive Maintenance: Inspect for possible cracks developing on extractor. Remove all burrs by stoning. Check to see if there is binding of extractor pin or bolt body.

Malfunction. Runaway gun.

Caused by: Broken sear.

Preventive Maintenance: Check sear closely on regular inspection. Keep properly lubricated. Check sear buffer springs for weakness. Remove all burrs.

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Malfunction. Failure to extract.
Caused by: Any failure to unlock.
Preventive Maintenance: Same as in failure to unlock.

Malfunction. Failure to extract (on charging only).
Caused by: Broken extractor.
Preventive Maintenance: Check on regular inspection for possible cracks on extractor. Check to see if there is binding of pin in bolt body. Remove all burrs.

Malfunction. Failure to eject.
Caused by: Broken prongs on ejector.
Preventive Maintenance: Inspect ejector closely for possible cracks. Check to see that clearance between bottom of prongs and stop of bolt body is at least .005 inch. Check diameter of metering holes in vent plug. Large holes will cause fast unlocking with excessive blowback pressure. Cartridge case will strike ejector with too much force, thereby causing greater fatigue.

Malfunction. Runaway gun.
Caused by: Jammed trigger mechanism, or defective solenoid.
Preventive Maintenance: Check solenoid before installation on gun. Remove all foreign matter. Keep dry and free of rust. Make sure solenoid is properly adjusted.

CLEANING AND LUBRICATION

The most important single point regarding maintenance of the 20mm aircraft gun is correct procedure of cleaning and lubrication. These procedures are especially important in aircraft weapons because it is normally impractical to work on the guns during flight.

Cleaning Guns Received from Storage. Guns which are covered with Compound, rust preventive, 'heavy' must be cleaned very thoroughly. It is essential that all traces of the compound be removed, even from those points where it would seem that no moving parts would be working. (This is necessary since operating conditions may later be such that any compound left in would be melted and would drop down on moving parts.) Extreme care must be taken that all springs, holes, and recesses are thoroughly cleaned.

Commercial Degreasers are sometimes available for use in degreasing large numbers of guns. Generally these degreasers use live steam. Immediately after being so cleaned, the gun should be lubricated and should not be touched by bare hands while so doing.

Dry Cleaning Solvent can be used to remove rust preventive compound. The parts are taken from the gun, and parts and casing immersed in a tank of the solvent. Stiff floor brushes can be used on certain surfaces while paint brushes, tooth brushes, and test tube brushes will be required for the quick removal of the compound from the various recesses. In an emergency, carbon tetrachloride, kerosene, or even gasoline (white preferred) can be used in place of the solvent which is recommended. After using a solvent, make sure it is thoroughly removed from the parts by wiping. Lubricate all parts which are not painted immediately after cleaning. Precautions should be taken for proper ventilation and fire prevention when using toxic or inflammable solvent.

Hot Water Containing Soap, Soda Ash, etc. Disassemble the gun completely, place all the small components in a wire basket, completely immerse the basket in a vat containing boiling water. Where the vat is not large enough to receive the assembled receiver and tube group, wash with above solution by using clean rags or brushes. When using vat, skim the rust preventive from the top of the water. Leave parts in the bath for approximately half an hour, dry thoroughly, and lubricate. Never use water and lye, or any caustic to clean gun components.

In the event that no vats or tanks are available, an oil-drum can be cut lengthwise and will provide two tanks approximately 14 inches deep.

Lubrication. If a gun is to be used immediately or within 20 days, all parts are given a thorough but light coat of special preservative lubrication oil. (For use below 0° F, all parts should be wiped dry and be free of all lubricant.) The oil is best applied with a brush, but clean lintless cloths may be used.

The gas cylinder vent plug should never be lubricated except when it is to be

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put in storage. When preparing the gun for firing, oil all sliding surfaces with a light film of oil (except for the gas cylinder vent plug).

Cleaning. The gun should be cleaned as often and as thoroughly as possible. It will not always be possible to pull the gun from the plane for cleaning the entire weapon. In such cases, it will be impossible to clean the gun thoroughly, but the bore of the gun must be cleaned after each firing.

The bore is cleaned by thoroughly wiping it with patches wet with rifle bore cleaner, until several successive patches go through the bore without being soiled. (A brass brush may be run through the bore to aid in the removal of foreign matter) If rifle bore cleaner is not available, hot water and soap, or hot water and soda ash, hot water alone, or even cold water can be used. The use of rifle bore cleaner is definitely desirable, but any water solution can be used. Dry the bore with dry patches after it is clean, then apply a light coat of special, preservative oil. This procedure should be followed for at least three days.

All parts of the gun should be cleaned daily or as often as practicable. This can be done by wiping with a clean cloth, swabbing or dipping parts in solvent, etc.

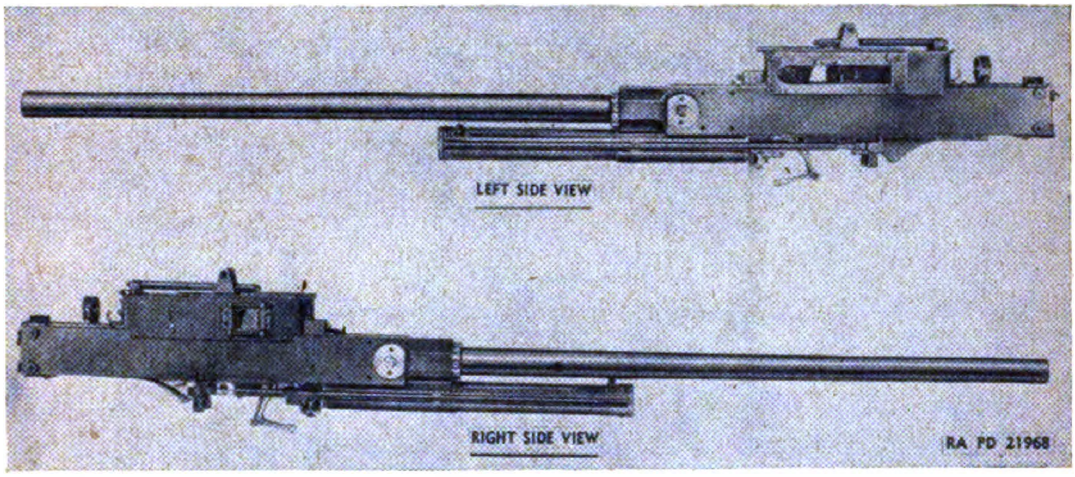

Figure 170. 37mm Automatic Gun M4.

Preparing Gun for Storage and Shipping. *Short Periods.* At all temperatures, use light, preservative, lubricating oil as a rust-preventive for short periods not to exceed two to six weeks, depending on climatic conditions. If this is not available, use engine oil, SAE 10, or sperm oil.

Short-Term Storage: At all temperatures, use light, rust-preventive compound as a rust-preventive for short-term protection. This should not be used on weapons put in indefinite storage. Light rust-preventive compound is a sluggish liquid and may be applied with a brush or by dipping. In applying, heating is not necessary except in very cold temperatures.

Long-Term Storage: At all temperatures, use heavy, rust-preventive compound as a rust-preventive for long-term or indefinite storage. Heavy rust-preventive compound is a heavy, dark-colored, sticky grease and must be made fluid prior to use. A practical method to obtain fluidity is to place container in a vessel of water, heating it to a temperature of not over 180°F, and then air-cooling it to the desired consistency before using. The best method of applying the compound is by dipping, as there is much less chance that air bubbles will be included in the grease film.

37MM AUTOMATIC GUN, M4

The 37mm M4 automatic gun was the first weapon of artillery caliber to be mounted as standard equipment in a modern war plane. Research and tests had been conducted on the 37mm gun as early as 1927. In the late 30's and early 40's, the 37mm gun was perfected. The Ordnance Department working with the Army Air Force decided that the Bell Aircraft Company should design and actually build a plane around this new aircraft weapon. Hence, the P-39, or as it is more

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widely known, the 'Aircobra,' made its debut. It is one of the first modern war planes to mount a fully automatic weapon firing a projectile larger than .6 inch in diameter and one containing a bursting charge and a point-detonating fuze. This was our first glimpse at flying artillery. Quite a few wrinkles had to be ironed out. Changes and improvements were made and are still being made. Finally all was set. The Air Force and the Ordnance Department were satisfied with the Aircobra, and soon the 'sting' of one of our more heavily armed planes was felt. Results have proved that the larger aircraft weapons have a definite place in modern aerial warfare.

Description. The 37mm M4 gun is a fully automatic weapon, aircooled, and fed from the left-hand side by an endless articulated belt. It is either mounted as a fixed gun firing through the hollow propeller hub or is mounted to fire somewhere outside the arc of propeller rotation. The gun uses the long recoil principle of operation.

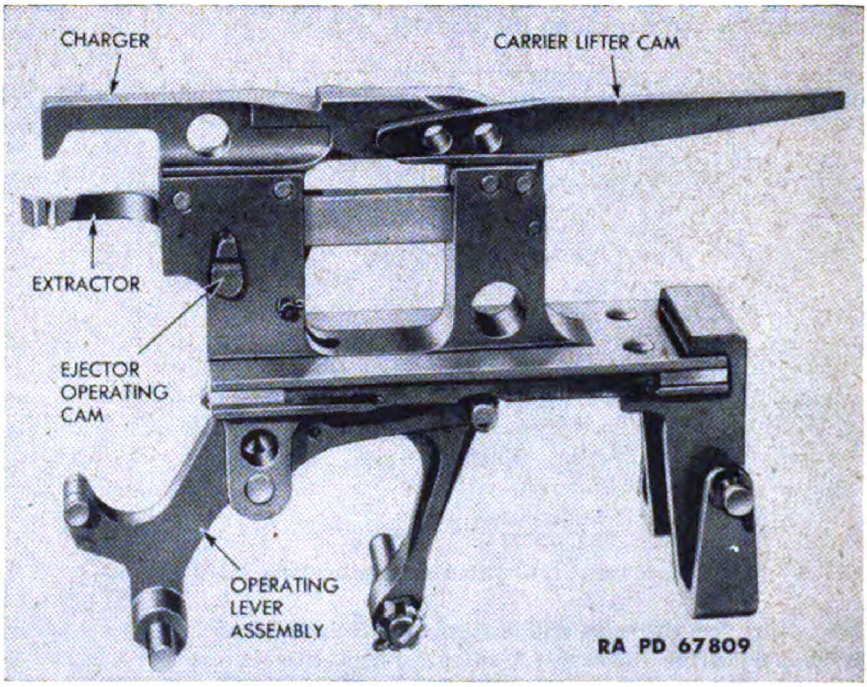

Figure 171. Lock Frame Assembly (Operating Lever Retracted).

The 37mm M4 gun has a muzzle velocity of 2,000 feet per second, and fires at the rate of 150 rounds per minute. It weighs 215 pounds without the magazine, and has an over-all length of approximately 89 inches.

The weapon is so constructed that it will fire in any position, all parts functioning independently of gravity. It may be fired manually or by remote control through a solenoid mounted at the rear of the gun.

As a fixed gun, the plane must be aimed rather than the gun. The typical armament installation in the P-39 calls for two cal. .50 machine guns in the nose as well as two cal. .50 guns in each wing, in addition to the 37mm M4 automatic gun mounted in the nose. So the forward firing fire power of this plane is really terrific.

This weapon is fired in air-to-air combat at ranges of 200 to 400 yards, and at this range its accuracy is deadly. The effective range is, of course, much greater, but for accurate shooting it is usually employed within the above ranges. The air-to-ground range will vary, and the accuracy of the gun is very effective from 200 to 1,500 yards in this type of firing. The tracers from the cal .50 machine guns and the 37mm guns are used to correct the sighting line, and many an accurate and well-placed shot can be delivered by a skilled pilot at ranges even greater than those mentioned.

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The gun is composed of eight major groups or parts; namely, the tube, tube extension, lock frame, feed box, recuperator, two driving springs, breechblock, and back plate. All of these parts are either mounted or assembled to the receiver and trunnion block group. The purpose and function of these major parts or groups will be covered in a general manner, followed by a discussion of the complete cycle of operation of the weapon.

The receiver and trunnion block groups form the main support and housing for the moving parts and groups of the gun in the plane. Therefore, this group serves as a support for the working parts, and controls and directs the movement of these parts.

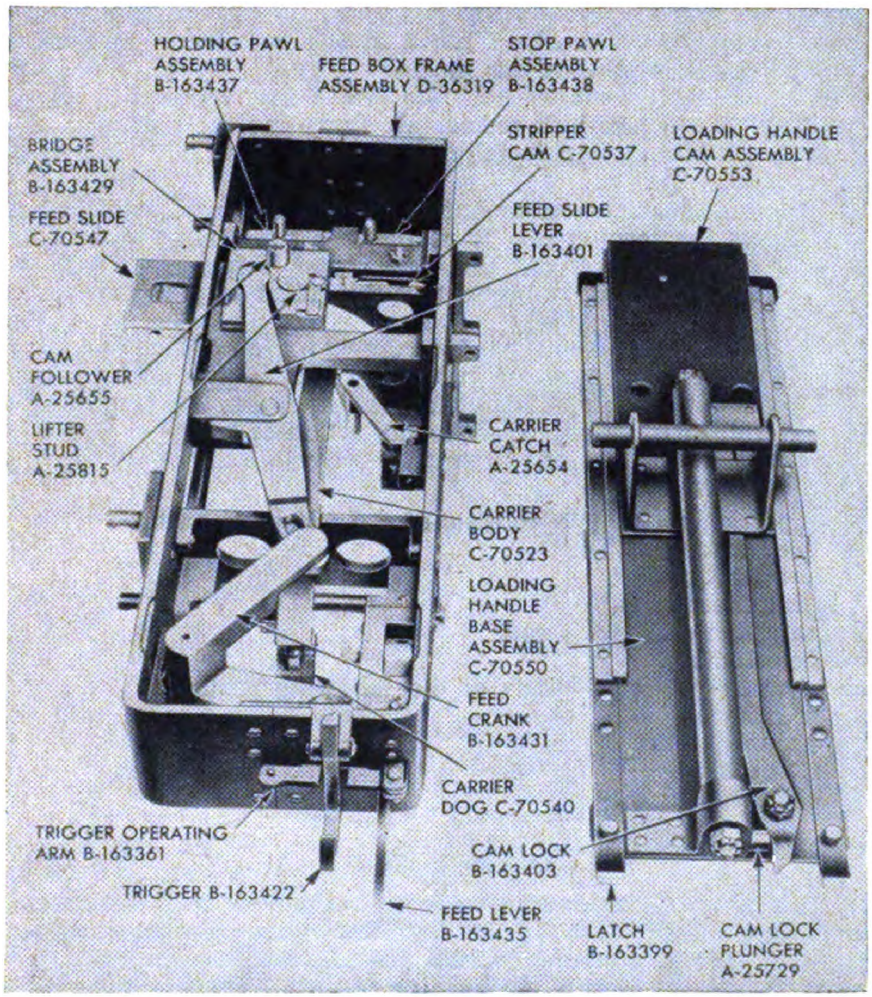

Figure 172. Feed Box and Feeding Mechanism.

In the gun tube we have the firing chamber whose principal function is to direct the discharged projectile. The lands and grooves (rifling) cause the projectile to rotate, thus maintaining the direction and the stability of the projectile in flight and preventing it from tumbling.

The tube extension guides the rear end of the tube and provides a means of connecting the tube and tube extension to the recuperator as well as providing a means of mounting a few of the other working parts of the weapon.

The recuperator is principally a housing or cylinder containing a piston, piston rod, a recuperator recoil spring, recuperator bushing with throttling slots, and appropriate end caps with the necessary oil seals. It is known as the 'recoil brake.' The action of this type of a brake is known as the 'hydro spring type.' By means of a hydraulic or throttling action and the compression of the recupera-

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tor spring, the force of recoil is absorbed and the recoiling tube and tube extension are returned to battery position. This action is so smooth and gradual that the explosive force is absorbed and does not materially affect the flight of the plane.

The lock frame assembly is actually the timing device used to time the movement of all of the recoiling parts so that the parts or groups do their respective jobs at the proper time and in the proper places. The many functions of the lock frame include loading the cartridge into the chamber, actuating the breechblock, firing the round by means of a hammer striking the firing pin, and performing the initial and final extraction. It also aids in ejection.

The breechblock assists in the final loading of the round, locks and closes the breech end of the gun tube, and actuates the trigger trip. It also provides a mounting for the firing pin.

The back plate absorbs the shock of recoil of the lock frame and reduces its tendency to rebound against the carrier pin.

The two driving spring assemblies hold the lock frame against the carrier dog during the counterrecoil of the lock frame. At that time the driving springs are compressed. Hence, these springs supply the force to drive the lock frame into the battery position.

The feed box provides a means of mounting the M6, 30-round, endless belt type magazine. It controls the feeding of one round at a time into the feed box and positions the new round for loading. The new round, being positioned, also acts as a means of releasing the lock frame so that the round may be carried forward into the chamber.

We can break down the action of the M4 gun into two distinct groups: the recoiling and the non-recoiling parts or groups. Recoil is produced by using the force of the explosion of the propelling charge which forces the recoiling portions rearward. Counterrecoil is accomplished by the action of springs. The recuperator recoil spring returns the tube and tube extension while the two driving springs return the lock frame assembly.

The recoiling portion of the gun consists of the following parts:

Tube and tube extension.
Lock frame assembly.
Driving spring assemblies.
Recuperator piston and piston rod.
Breechblock assembly.

The non-recoiling portion consists of the following parts:

Trunnion block group.
Feed box group.
Recuperator housing.
Back plate assembly.

OPERATION

Charging. This is a full automatic weapon, but before it is ready to fire it must be manually charged. With the M6 30-round magazine correctly assembled to the gun and filled with ammunition, the procedure of charging the gun is as follows: first, retract the lock frame to the rear until it is held by the carrier dog; second, pull the loading handle to the rear twice. The first pull places the first round in position inside the feed box, and the second pull strips the round from the belt. The action of the lock frame then chambers the round and the gun is ready for firing.

In discussing the operation of this weapon, the general aspect will first be considered, and then each phase will be discussed separately.

General. The 37mm M4 aircraft cannon is a long recoil-operated weapon. The force of the explosion drives the tube, tube extension, and lock frame to the rear. After approximately 6 inches of recoil from battery position, the operating lever has lowered the breechblock sufficiently so that the extractor no longer engages the breechblock. Thus the lock frame is free to move to the rear independently of the tube and tube extension. The lock frame does not separate from the tube and tube extension, however, until the recoiling parts have moved 7¼ inches in recoil. At this point, the movement of the tube and tube extension is appreciably

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slowed by action of the recuperator mechanism, while the inertia of the lock frame causes it to continue rearward at its original rate. Since the cartridge case is held between the lips of the extractor and the extractor is attached to the lock frame, initial extraction occurs as the recoiling parts separate.

The lock frame continues to the rear and strikes the buffer plunger, compressing the springs and forcing the friction pieces against the side of the buffer housing. The buffer mechanism throws the lock frame forward. After going forward almost 1 inch the lock frame is caught and held by the carrier dog.

During separation of the recoiling parts, and while the lock frame is going to the rear, the tube and tube extension also continue their rearward movement. When the tube and tube extension have recoiled 9⅝ inch, the recuperator mechanism stops further motion to the rear. At this point the recuperator recoil spring will cause the tube and tube extension to go forward in counterrecoil. It should be noted that the lock frame has been caught by the carrier dog even before the tube and tube extension have reached the full distance of their recoil.

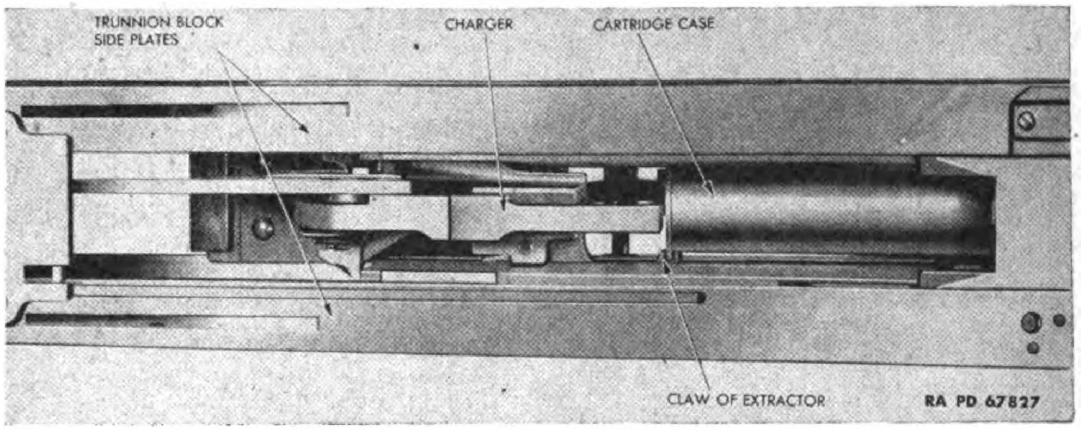

Figure 173. Lock Frame Assembly Moving Forward. Round Held in Claw of Extractor.

During recoil three important functions are performed: unlocking, the initial phase of cocking, and initial extraction of the cartridge case.

As the lock frame is held to the rear, the tube and tube extension are driven forward by the recuperator recoil spring, extraction is completed, the ejector knocks the round from the receiver, the driving springs are compressed since the driving spring tubes are carried forward with the tube and tube extension while the driving spring rods are held stationary by the lock frame, and the feed lever is rotated forward causing a round to be fed into the receiver. As the round is fed into the receiver, the lock frame is released and pulled forward by the compressed driving springs, chambering the round. As the lock frame moves into battery position, the breechblock is raised behind the round. When the breechblock is in its battery position, the gun may be fired.

Firing. This is the process of igniting the propelling charge of the round in the chamber. When this charge is ignited it forces the projectile through the tube and toward the object at which the gun is directed.

When firing the first shot after the gun has been manually charged, the trigger operating arm is pulled to the rear by a solenoid. The trigger operating arm forces the trigger to the rear. As the trigger rotates to the rear, it draws with it the trigger bar located in a recess in the right side of the receiver. A projection on the forward end off the trigger bar is engaged with the top of the trigger lever, which is located with the trigger lever connector on the right side of the tube extension. As the trigger bar is pulled to the rear, the trigger lever is rotated to the rear about the trigger lever pin.

If the front end of the trigger lever connector is held down by the trigger trip, the trigger lever connector will be drawn to the rear as the trigger lever is rotated to the rear. (The breechblock when fully in battery position will force the

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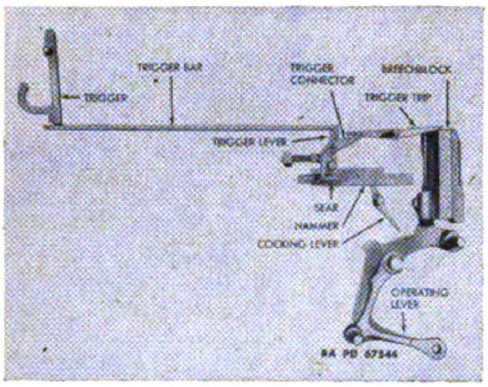
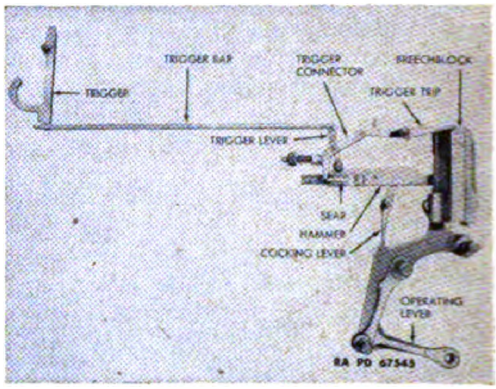
forward end of the trigger trip up. The trigger trip is located in a recess near the front of the tube extension and is pinned at its mid-point. Therefore, as the breechblock lifts the forward end of the trigger trip, the rear end of the trigger trip will rotate downward and will thus force the front end of the trigger lever connector down, and the trigger lever connector will be drawn to the rear as the trigger lever is rotated to the rear.)

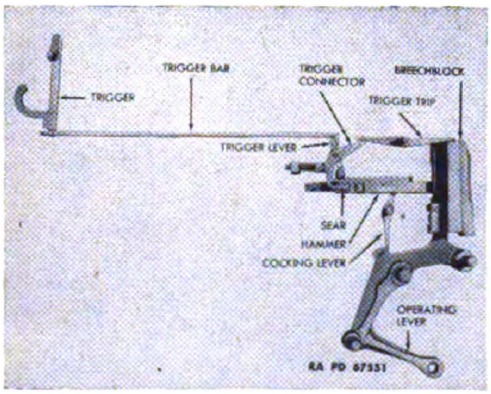
As the trigger lever connector moves to the rear it contacts the sear on the lock frame and causes the sear to rotate out of engagement with the sear notch of the hammer. The hammer is driven forward by the compressed hammer spring and strikes the firing pin which is set in the center of the breechblock.



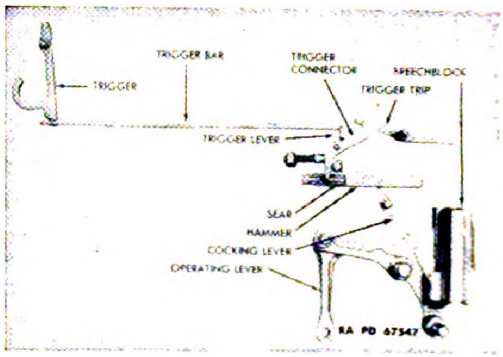
Ready to Fire.



Firing Position.



Beginning of Recoil.



Breech Open.

Figure 174. Trigger Mechanism Functioning—Manual Fire.

When firing a burst, constant pressure is exerted on the trigger, and the trigger bar will be held to the rear at all times. As the tube and tube extension move into battery position, the trigger lever contacts the trigger bar. This causes the top of the trigger lever to be rotated and held to the rear. When the breechblock is raised to its battery position at the end of counterrecoil, the front end of the trigger trip will be raised, the rear end will be forced down and will bear upon the front end of the trigger lever connector. The trigger lever connector will thus be rotated about its pivot on the trigger lever and will cause the sear to be rotated out of engagement with the hammer. The hammer will be forced forward and will strike the firing pin causing the round to be fired.

Unlocking. When a round is fired, the breech end of the tube must be tightly closed until the high pressure of the powder gases has subsided. The process of opening the breech end of the tube is known as unlocking. This process occurs as the recoiling parts move rearward.

The firing pin when hit by the hammer will strike the primer unit of the round

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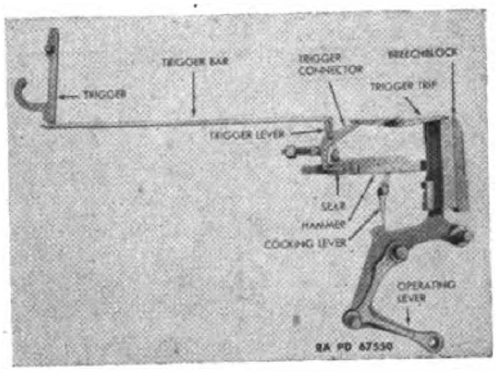
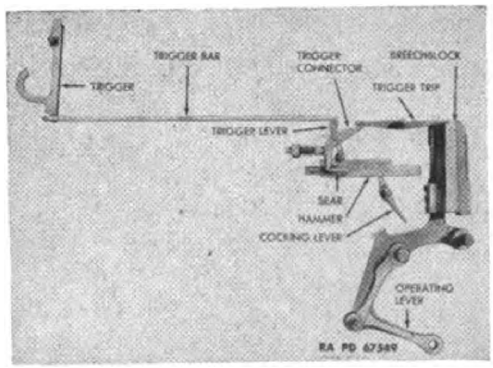
and cause the round to be fired. The expanding powder gases drive the projectile forward through the tube. At the same time the powder gases act against the rear end of the cartridge case. This force on the cartridge case is transmitted to the face of the breechblock, and the recoiling parts—the tube, the tube extension, the lock frame, and the driving spring groups—are driven to the rear.

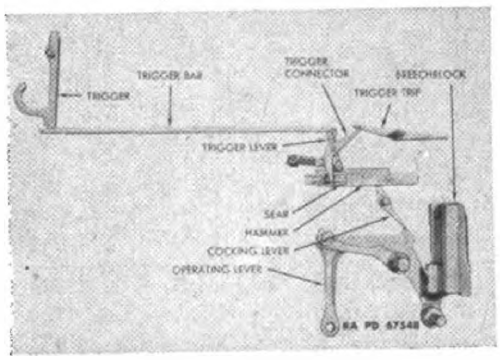
The recoiling parts move together during the first portion of recoil due to the fact that the tube is screwed into the tube extension, the breechblock is engaged in the grooves at the forward end of the tube extension, and the extractor is hooked around the breechblock.



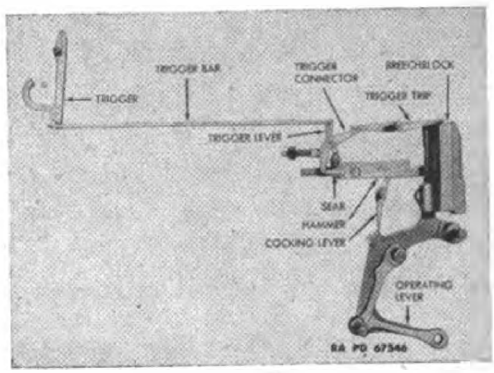
Breech Open.



Ready to Fire.



Firing Automatically.



Beginning of Recoil.

Figure 175. Trigger Mechanism Functioning—Automatic Fire.

As the lock frame travels to the rear, the operating lever guide pins follow the operating lever cams and cause the front end of the operating lever to be rotated downwards. This action brings the breechblock down from its battery position, since the breechblock lifting guide pin of the operating lever mates with the T-slot of the breechblock. The breech end of the tube is thus opened after the high pressure of the powder gases has subsided, and the process of unlocking is completed.

Extraction. Extraction is the process of withdrawing the fired cartridge case from the chamber. Initial extraction is accomplished on recoil, while the final extraction occurs on counterrecoil as the lock frame is held to the rear and the tube and tube extension move forward.

When the gun is fired, the tube, tube extension, and lock frame move to the rear together. The cartridge is in the chamber, and the rim is held in the extractor, which is attached to the lock frame. When the recoiling parts have moved 7¼ inches together, the lock frame separates from the tube and tube extension, though all recoiling parts are still moving to the rear. Since the rim of the cartridge is held by the extractor the process of extraction begins at this point.

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The lock frame continues to the rear, strikes the buffer, and comes forward a very short distance before it is caught and held by the carrier dog. The tube and tube extension recoil a maximum distance of 9⅝ inches before the recuperator recoil spring carries the tube and tube extension forward in counterrecoil. As mentioned before, the empty cartridge case is held securely by the extractor; and as the tube and tube extension go forward in counterrecoil, the chamber slides forward and away from the cartridge case.

Cocking. This is the process of retracting the hammer until it is caught and held by the sear so that it may later be released to fire a new round. The process is begun as the operating lever starts to rotate during the rearward movement of the recoiling parts. The process is completed as the operating lever is rotated back to its battery position on counterrecoil.

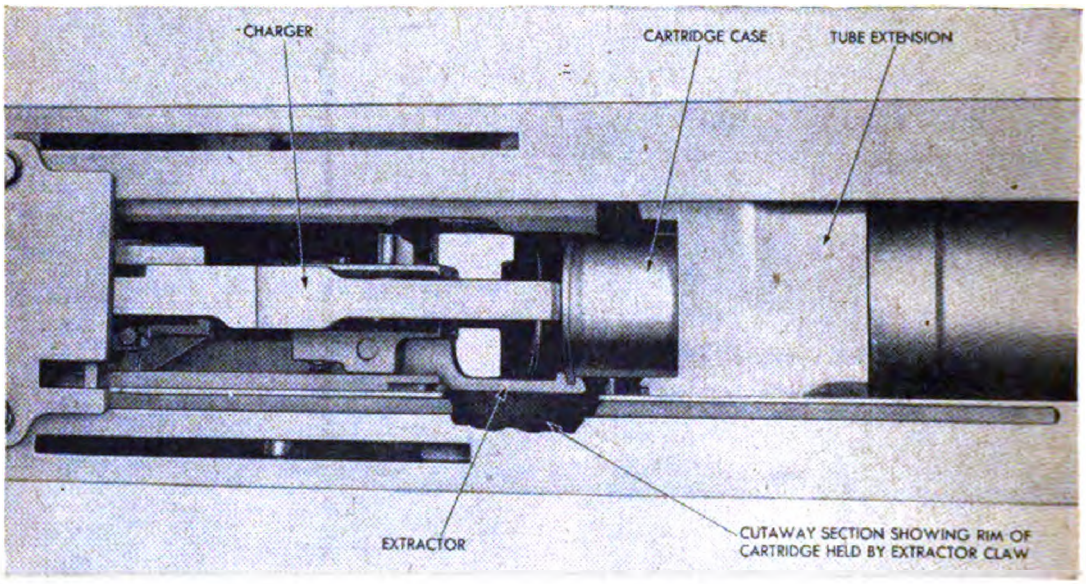

Figure 176. Initial Extraction Taking Place During Separation of Lock Frame from Tube Extension.

As the operating lever is rotated in recoil, the cocking lever cam on the operating lever (the lobe on top of the operating lever) contacts the cocking lever and rotates the bottom of the cocking lever forward. The top part of the cocking lever is engaged in a longitudinal slot in the hammer, and, as it is rotated to the rear, the cocking lever cams the hammer to the rear. As the hammer is drawn to the rear, it cams the sear outward and the sear (which is no longer held back by the trigger lever connector) snaps forward so that it will retain the hammer when the operating lever rotates forward in counterrecoil and no longer exerts pressure on the cocking lever.

It should be clearly understood that the operating lever and cocking lever hold the hammer to the rear and out of engagement with the sear until the operating lever is rotated forward in counterrecoil. When this occurs, the hammer is allowed to go forward and is caught by the sear. Cocking is then completed.

Ejection. Ejection is the action of expelling the empty cartridge case from the receiver after the case has been withdrawn from the chamber by the extractor. The entire ejection process occurs on counterrecoil as the tube and tube extension move forward and the lock frame is held to the rear by the carrier dog.

As the tube and tube extension move forward in counterrecoil, the ejector, which is on the inner left side of the tube extension, is in such a position that its forward end is above the rim of the cartridge case. (The ejector has been placed in this position by the action of the ejector operating stud on the lock frame as the lock frame moves forward in loading the round now being ejected. Having been so positioned, the ejector remains with its forward end elevated throughout recoil. As the tube and tube extension move forward in counterrecoil, the under

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edge of the carrier lifter cam bears on the rear portion of the ejector and insures that the forward end of the ejector remains elevated. The carrier lifter cam acts on the ejector in this manner until shortly before the ejector strikes the empty case.) When the tube and tube extension have gone forward in counterrecoil sufficiently so that the empty case is entirely extracted from the chamber, the rim of the case is contacted by the underside of the ejector. At this time the empty cartridge case is held between the lips of the extractor. As the tube and tube extension continue to move forward, the contact between the underside of the ejector and the round will cause the cartridge case to be cammed partially from between the lips of the extractor. Further movement of the tube and tube extension in counterrecoil causes the ejector to strike the ejector operating stud on the forward part of the lock frame. Upon striking this stud, the forward end of the ejector rotates downward rapidly and strikes the extracted case from the top, knocking it through the bottom of the receiver.

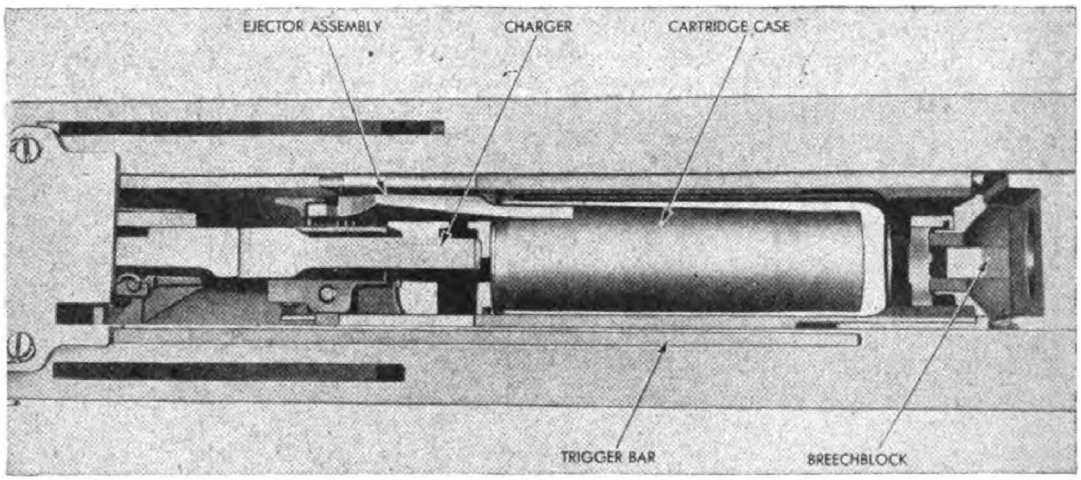

Figure 177. Ejection of Empty Cartridge Case. Lock Frame Held to the Rear, Tube Extension Moving Forward.

Feeding. This is the action of placing a round in such a position that it can be pushed forward into the chamber. The entire feeding process occurs on counterrecoil while the lock frame is held to the rear and the tube extension moves forward.

In automatic feeding, the phase may be considered to begin at the time when the feed lever operating stud on the right side of the tube extension engages the feed lever. This occurs in counterrecoil while the tube and tube extension move forward into battery position. The feed lever operating stud is behind the feed lever and causes the lower end of the feed lever to rotate forward, pivoting about the feed lever pin.

This forward movement of the feed lever is transmitted through the feed lever swivel and the feed crank to the feed slide lever, forcing the rear end of the feed slide lever to the left. The feed slide lever is pivoted near its midpoint, then its forward end moves to the right as the rear end is forced to the left. The forward end of the feed slide lever engages the feed slide bridge in such a manner that the feed slide bridge and the feed slide move to the right under the impulsion of the feed slide lever. It should be noted that as the feed slide moves to the right, the cartridge feeder stop pawl is cammed forward out of engagement with the belt and so allows the articulated link belt to move, as will be described below.

The feed pawls are pinned to the underside of the feed slide. These pawls engage in slots cut in the top plates of the articulated link belt and they pull the belt to the right as the feed slide moves to the right. When the feed slide moves from left to right, the round to be fired is cammed downward out of engagement with the articulated link belt by the stripper cams on the right side of the feed box.

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As the round moves down and to the right, it contacts the carrier catch lug and rotates the carrier catch to the right. The carrier catch, under impulsion of the round, finally slips from engagement with the carrier and is released. When the front end of the carrier is no longer held up by the carrier catch, the carrier spring forces the front end of the carrier downward. The carrier in rotating downward strikes the round that contacted the carrier catch and aids in positioning the round for loading. This position is with the base end supported on the ejector and with the nose of the round supported on the tube extension bridge. It is in this position that loading begins.

Feeding of more than one round at a time is prevented by the cartridge feeder stop pawl, which will engage in a notch in the edge of the toe plate of the articulated link belt if the belt should be drawn too far to the right.

The feed lever operating stud slips beneath the feed lever when the tube and tube extension are almost in battery position. When this occurs, the round has already been positioned for loading. The feed slide and feed slide bridge are then carried to the left by the feed slide lever spring acting on the feed slide lever. The feed pawls will now engage the slots cut in the toe plate of the clip holding the next round of ammunition.

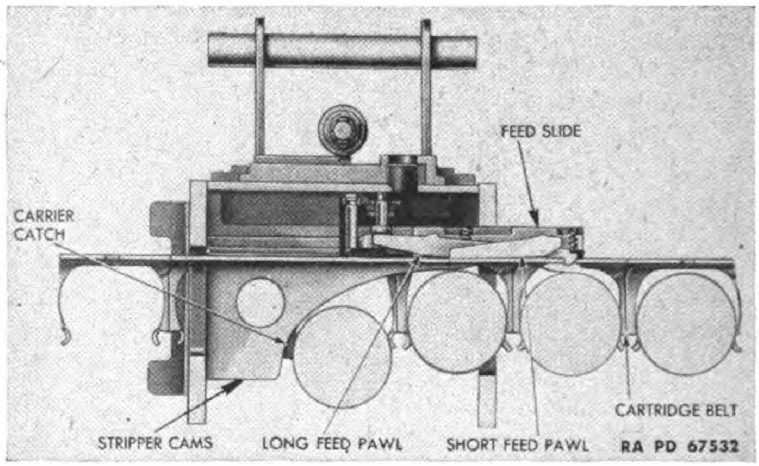

Figure 178. Action of Stripper Cam.

The articulated link belt is held from moving to the left with the feed slide by the cartridge feeder holding pawl, which engages with a notch in the edge of the toe plate of the articulated link belt. Camming surfaces of the feed pawls enable the feed slide to move to the left even though the belt is held in position by the cartridge feeder holding pawl.

The force of the feed slide lever spring is transmitted through the feed slide lever, feed crank, and feed lever swivel to the feed lever, causing the feed lever to rotate to the rear and assume its normal position.

When charging by hand, the loading handle cam is pulled to the rear by the loading handle. The loading handle cam switch acts on the loading handle cam follower, which is an integral part of the feed slide bridge, and forces the feed slide bridge and feed slide to the right. This movement of the feed slide accomplishes the same phases of feeding as were outlined above. It should be noted, however, that when charging by hand it may be necessary to operate the loading handle twice before the round is cammed downward by the stripper cams.

During recoil, the feed lever operating stud on the outer right side of the barrel extension contacts the lower part of the feed lever, pivoting it slightly. The feed lever will then snap back into position in front of the stud. This is not a feeding operation.

Loading. Loading is the process of positioning the round in the chamber of the gun after the round has been fed into the receiver. This process occurs entirely on counterrecoil of the lock frame.

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The lock frame is released from the carrier dog when the round, which is being fed into the receiver, pushes the carrier catch out of engagement with the carrier. The compressed driving springs pull the lock frame forward, and the charger strikes the round. At this moment, the base of the round is supported by the ejector and the nose by the tube extension bridge. Loading may be considered to begin at the time when the charger strikes the round.

The charger pushes the round forward for approximately 4 inches. At this point the base of the round drops over the forward end of the ejector and between the lips of the extractor. The extractor carries the round forward almost to its final position as the lock frame continues its forward movement. When the lock frame is approximately ¼ inch from battery position, the breechblock, in coming into battery, forces the extractor to the right and away from the round and accomplishes the final seating of the round. The front face of the breechblock acts as a camming surface upon the base of the round and forces the round fully into the chamber.

Locking. Locking is the process of closing the breech end of the tube when the round is fired; this occurs as the lock frame moves forward into battery position.

After the breechblock has been lowered by the action of the operating lever during the rearward movement of the recoiling parts, it is held in the retracted position by the breechblock stop. Thus, when the lock frame comes forward in counterrecoil, the breechblock lifting guide pin of the operating lever mates with the T-slot of the breechblock.

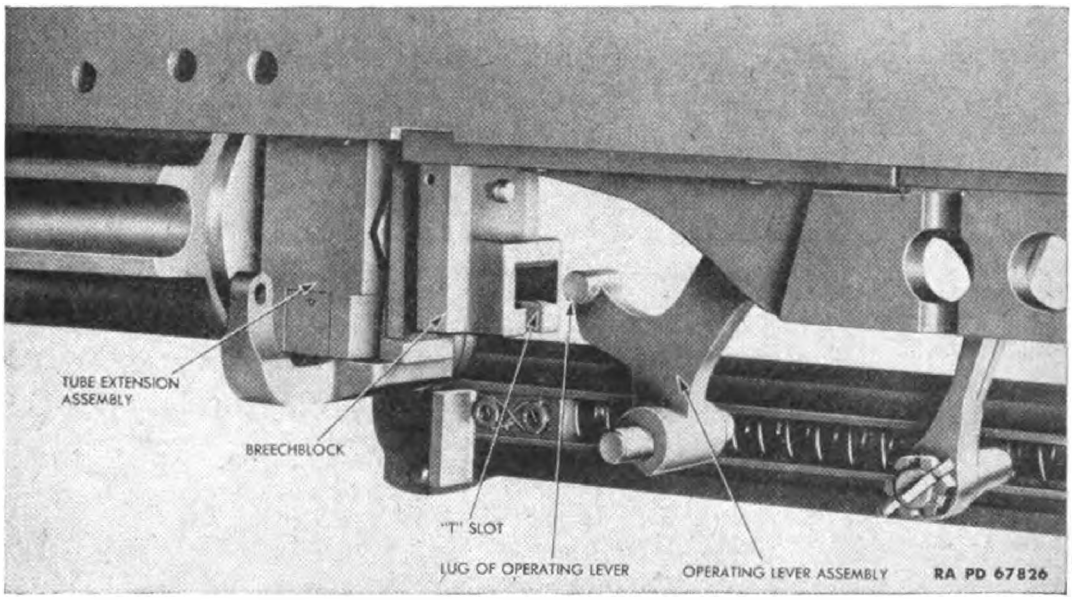

Figure 179. Breechblock Down Resting Against Stop.

As the lock frame continues forward, the front end of the operating lever is moved upwards by the action of the operating lever guide pins in the raceways of the operating lever cams, and by the action of the operating lever springs acting through the operating lever strut. Since the breechblock lifting guide pin is on the forward end of the operating lever, the breechblock is forced up into battery position as the front end of the operating lever is rotated upward. As the breechblock goes into battery position, the extractor is forced to the right and away from the round. This movement of the breechblock also lifts the forward end of the trigger trip. The breech end of the tube is thus closed and the process of locking is completed.

Recuperator Action. Recoil is absorbed by the recuperator spring and the throttling of the recoil oil between the recuperator bushing and the recuperator piston. The recuperator piston rod is attached to the tube extension; and as the

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tube and tube extension go to the rear in recoil, the recuperator piston is also drawn to the rear. The recuperator is filled with oil, and the movement of the piston to the rear forces the oil to flow from one side of the piston to the other. Opportunity for the oil to flow from one side of the piston to the other is provided by the longitudinal slots cut in the recuperator bushing.

The oil in flowing through the small opening provided by the bushing acts to oppose rearward movement of the piston. Also opposing recoil is the recuperator recoil spring, which is compressed as the piston moves to the rear. The size of the bushing slots is gradually reduced toward the rear end, which increases the resistance offered to movement of the piston and serves to cushion recoil. When the recuperator piston has traveled 9⅝ inches in recoil, the rear face of the piston passes the slots in the bushing. Since the oil can no longer flow past the piston through the slots and since oil is incompressible, further movement of the piston to the rear becomes impossible.

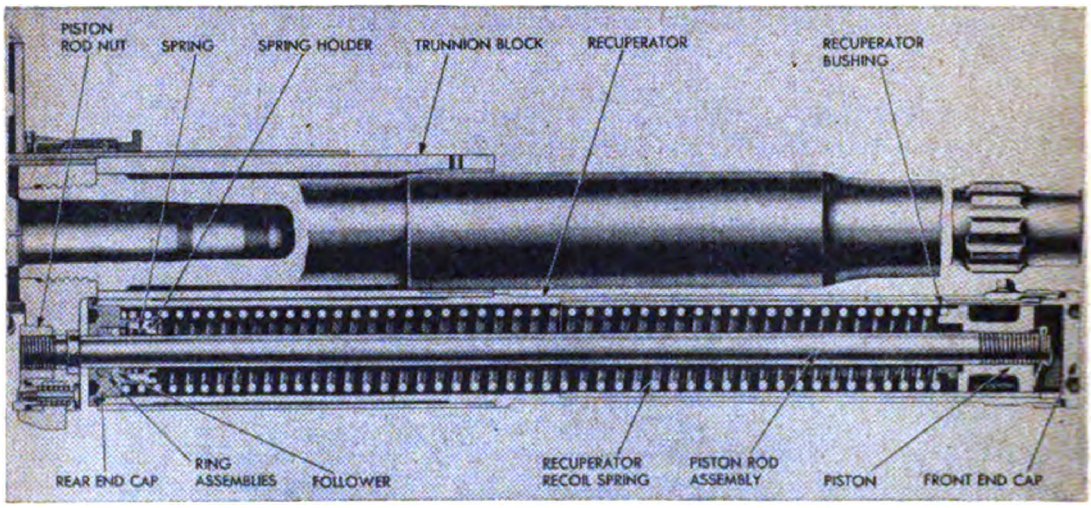

Figure 180. Cross-Section of Recuperator.

Counterrecoil is effected by the compressed recuperator recoil spring, which pushes against the recuperator piston. As the recuperator piston is attached to the tube and tube extension, this pressure on the piston forces the tube and tube extension into battery position. Counterrecoil is cushioned at the extreme end of the stroke since the longitudinal slots in the recuperator bushing are sharply reduced in size at the extreme forward end.

SAFETY FEATURES

Location of the Firing Pin. The firing pin is located within the breechblock. This arrangement provides a positive safety since the breechblock must be fully in battery before the firing pin is aligned with the hammer and the primer of the round. This safety feature is made even more positive by the mating bevels on top of the firing pin and on the bottom of the hammer. Such an arrangement necessitates the center of the hammer striking the center of the firing pin.

Trigger Trip. Before the gun can be fired, the front end of the trigger trip must be raised. This can only occur when the breechblock is completely in battery position. (It should be noted that the trigger performs other essential functions in addition to acting as a safety.)

Loading Handle Cam Lock. This prevents the gun from being charged when the trigger is to the rear. The 37mm M4 is generally charged when the plane is on the ground. If the trigger was to the rear when the gun was charged, the round would be fired immediately after it was chambered. Such firing would be very hazardous to surrounding planes, personnel, and buildings. (In addition to its function as a safety, the loading handle cam lock provides interference in movement of the trigger if the loading handle cam is not entirely forward. There

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are two dangers in firing with the loading handle cam to the rear of its normal position: first, the feed slide may be prevented from moving far enough to the left to engage the slots in the articulated link belt and thus be prevented from feeding the next round into the receiver. This would be caused by interference of the loading handle cam follower and the loading handle cam switch. Second, the tube and tube extension are prevented from going into battery position if the loading handle cam is to the rear of its normal position. This is true since free movement of the loading handle cam follower is not possible with the loading handle cam to the rear of its normal position.)

INSPECTION

Inspection is for the purpose of determining by critical examination the condition of the piece, whether repairs or adjustments are required, and what remedies are necessary to insure serviceability and proper functioning. Its immediate aim is trouble prevention. A few of the purposes of an inspection are:

To detect faulty or careless preventive maintenance; especially inadequate lubrication.

To determine when replacement of parts is necessary due to ordinary wear or defects in parts.

To verify that all modifications authorized by Modification Work Orders have been made.

A thorough knowledge of the disassembly, assembly, functioning, operation, and adjustments of the gun is necessary for ordnance personnel engaged in inspection work. Inspections should not be made just for the purpose of making them, but should be made to discover deficiencies or defects calling for corrective action. When properly carried out, inspections and corrective maintenance will insure the maximum performance of the weapon.

Before any inspection is begun, the gun should be properly cleaned to remove any grease, dirt, or other foreign matter, which might interfere with its proper functioning.

There are two types of inspection; namely, visual and gage. Visual inspection is of vital importance. It consists generally of making a check of the entire gun as a unit for its appearance and general condition. Check for completeness, with emphasis on cotter pins, locking wire, springs, and plungers. Check for proper assembly and cleaning. Observe the general appearance of the bore and chamber of the tube. The tube should be cleaned thoroughly to prevent bulges, erosion, corrosion, and pits, which affect the accuracy of the weapon. All moving parts must be free from traces of foreign matter, particular care being taken that all recesses in which springs or plungers work are thoroughly cleaned.

Check for proper lubrication. Proper lubrication prevents wear, scoring, corrosion, burrs, pitting, and rust. Oil is a vital necessity, but should be used sparingly. Only prescribed lubricants will be used.

Check for proper action of parts when the gun is hand operated and dummy rounds are used. Check for broken, rusty, burred, worn parts. Check for sharp edges. Check for proper action of the gun when it is test fired.

For more detailed information on inspection and gaging see TM 9-1240.

Malfunctions. A malfunction is the improper or incomplete action of some parts of the gun or its ammunition or accessories, usually resulting in a stoppage.

A stoppage is a cessation of fire resulting from a malfunction. A thorough knowledge of operation is most important in determining the causes of malfunctions.

When attempting to determine the cause of a stoppage, it is first necessary to remove all loaded ammunition. Then examine the position of the recoiling parts. Examine all rounds and empty cases. Defective cartridges cause many malfunctions. Note the outward condition of the round. Often burrs, scratches, or wear made by the extractor or by the ejector may reveal the cause of the malfunction.

Preventative Maintenance. The following rules of preventive maintenance should aid in eliminating stoppages.

Clean and lubricate the gun properly.

Be sure the gun is properly assembled and that all adjustment are correct, especially in the recuperator.

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Whenever a cotter pin is removed, it should be replaced with a new one.

Check all springs frequently.

Check the fitting of tube, tube extension, and lock frame, and breechblock.

Correct loading of ammunition in the belt, of the belt to the magazine, and the magazine to the gun.

A complete list of the more common malfunctions will be found in TM's 9-241 and 9-240.

Certain precautions must be taken when a stoppage occurs either while the gun is in the plane during flight or while the gun is on the ground. The first precaution to observe is to be sure that after any stoppage the bore is cleared before continuing firing. If the bore is not cleared and another round is fired, the gun will be seriously damaged. The construction of the gun and its location in the plane makes it practically impossible to apply immediate action in order to remedy stoppages in flight. The gunner should not attempt to remedy a stoppage while in the air by recocking the gun and attempting to fire. The live defective round might explode during the process of being extracted and ejected and cause serious damage.

After flight the corrective action will consist of removing the ammunition from the magazine. To do this, pull the manual charger far enough to the rear to cock the hammer. Pull the trigger. If the round does not fire, make several more attempts to fire it. Wait sufficiently long after the last attempt to fire to prevent the danger of a 'hang fire' or a 'cocked off' round exploding when the breechblock is not fully closed. Pull the manual charger all the way to the rear, and extract the defective round, handling it with extreme care. Then the cause of the malfunction can be determined and the necessary corrective action taken.

Care and Lubrication. It is a known fact that wear does not depend entirely upon the number of rounds fired. Much depends upon the care given the bore, such as cooling the gun between rounds, (i.e., firing short bursts rather than long sustained bursts), and cleaning and lubricating the weapon. The bore and chamber of the gun must be kept in perfect condition for accurate shooting and the entire gun must be kept properly cleaned and lubricated for effective functioning.

37MM AUTOMATIC GUN, M9

Development of the Gun. With the increased use of the 37mm in air to ground combat, it was found that the 37mm M4 and M10 did not possess the necessary muzzle velocity to be too effective against armored vehicles. Hence, it was decided by the AAF and the Ordnance Department to develop a new 37mm with an increased muzzle velocity and a gun that would be effective against all types of armored or otherwise protected targets. As a test model or basic, the 37mm M1A2 anti-tank and anti-aircraft weapon was selected. This weapon did have the firepower and the muzzle velocity. Although it was a basic ground weapon, immediate steps were taken to modify this gun for aircraft use. Numerous problems were encountered but after many exacting and exhausting tests the gun was ready for service. At first glance it looked like a big brother to the M4 and that's exactly how it turned out. The new gun was a larger version of the 37mm M4. It was standardized as the Gun, Automatic, 37mm M9 Aircraft.

This 37mm M9 is a fully automatic, high velocity weapon of the long recoil type. It may be mounted to fire through the propeller hub or at some point outside the plane of propeller rotation. The gun is not used as a syncronized gun but it is fired by remote control through means of a solenoid mounted at the rear of the gun.

From the above information it can readily be seen that in many ways there was little or no difference between the M4 and the M9 gun other than the larger size and greater weight of the M9. Generally speaking, this is true. But with a larger and heavier gun and with a weapon using metal disintegrating links a number of changes were incorporated in this gun. As far as the operation and function of the gun, the 3-37mm (M4, M10, and M9) are all alike. We will discuss only those points that are different and the reason for having the different parts. Also the results of such differences. The disassembly, care, lubrication, inspection, repair, adjustment, and assembly procedures are very much alike in all guns. Their

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operation is the same and therefore it can safely be said that a thorough knowledge of one gun will and can be applied to the other two weapons.

Differences Between the M9 and the M4 Guns. The tube is larger, heavier, and has splines on the front end for ease in assembly and disassembly the same as the 37mm M10. A tube support assembly is placed on the recuperator for removal and replacement of the tube. The tube in the M9 weighs approximately 120 pounds and has an overall length of .78 inches. The rifling of 12 evenly spaced lands and grooves makes 1.56 turns in the tube and has a uniform R.H. twist.

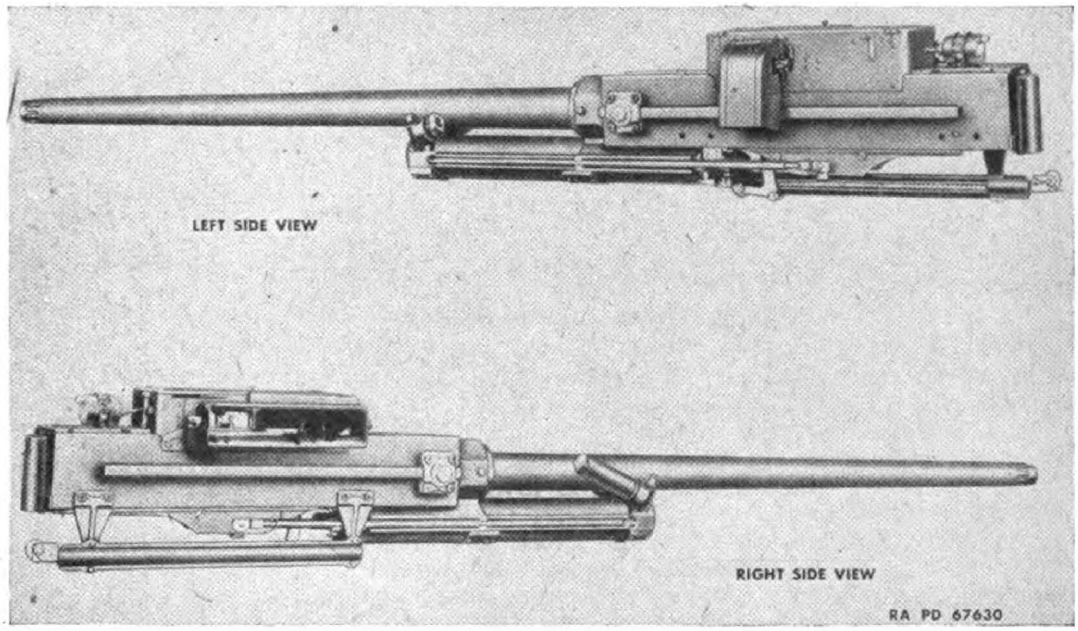

Figure 181. 37mm Automatic Gun M9. Right and Left Side Views.

The disassembly and assembly procedure for the M9 is the same as the M4 with the exception of the removal of the parts or assemblies that are different. They are, however, in the minority; therefore, after working on the M4 and M10 it would be a rather easy matter to disassemble the 37mm M9. If additional information should be needed for disassembly see TM 9-241 on the 37mm M9.

COMPARISON DATA FOR M4, M10 AND M9 37MM AIRCRAFT GUNS

	M4	M10	M9
Rate of fire (Avg.) RPM	150	165	140
Muzzle velocity (HE Shell) ft. per sec.	2000	2000	2600
Muzzle velocity (AP Shell) ft. per sec.	1825	1825	2800 to 3050
Wt. of gun without mount and accessories (lbs.)	213	231	405
Wt. of tube only (lbs.)	55	57.5	120
Length of tube (inches)	65	65	78
Overall length of gun (inches)	89.5	89.57	104
Recuperator oil capacity (ozs.)	42	42	72
Length of recoil (T&T Ext.) inches	9⅝	9¾	10¾

Trunnion block assembly. A heavy rib runs the full length of each side plate on the outside. These ribs provide a means of securing the gun in the mounting and also strengthen the side plates.

The trunnion block bushing is of one piece construction. It is secured in the trunnion block by two retaining screws. Grooves are cast in the bore of the bushing and are filled with graphite for lubrication.

A groove in the under side of the top flange of the right side plate and two guides are provided for mounting the trigger bar.

A rear operating lever cam is assembled to each of the two side plates. Each assembly has a spring loaded switch mounted on a pivot that is screwed to the cam. These switches guide the movement of the operating lever guide pins.

The front operating lever cams have bronze inserts riveted to the front and the

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rear of the front operating lever cams. These inserts provide a bearing surface for the guide pins on the operating lever. A key hole is slotted or machined into the rear left side of the receiver to receive the accelerator cam stud.

A spring loaded latch slide on the rear end of the right side plate bottom flange extends under the backplate to lock the back plate in place.

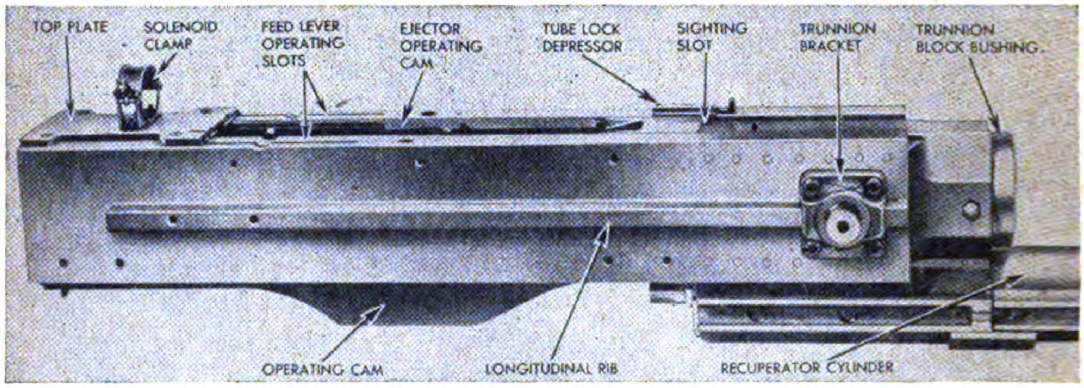

Figure 182. Trunnion Block Group. Side View.

The upper flange of each side plate is slotted to receive and accommodate the feed lever so that a right or a left hand side feed box may be used. A carrier bearing brace is mounted to the top flange. This carrier bearing brace is not interchangeable with the other when the feed is changed from right to left. However, the top of each side plate is drilled and tapped to accommodate the two brace attaching screws and locating dowl pin for either the right or left hand brace. This brace enables the shock of engagement of the lock frame to the carrier dog to be transmitted to the carrier pin and then to the brace and feed box.

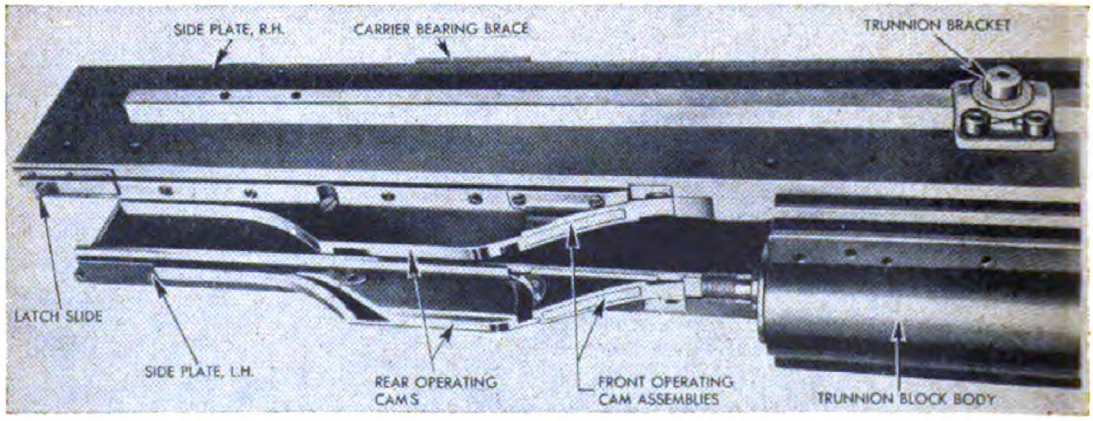

Figure 183. Trunnion Block Group Showing Operating Cams.

The ejector operating cam is mounted in the under side flange of the left side plate. This cam causes the ejector to pivot downward on counterrecoil of the tube extension.

A trunnion bracket assembly is attached to each side plate by four cap screws. A key fits into a tapered slot in the longitudinal rib and is held by a set screw to securely position it in the trunnion. Each bracket is machined so as to fit securely in the airplane mounting bracket.

Tube Extension. The ejector stud is sweated into the ejector. A spring forces the rear end of the ejector upward and the action of the ejector is controlled by the ejector cam which is riveted to the top flange of the left side plate.

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The breech block stop hinges on the driving spring front bracket and is held in place by a spring loaded lock pin.

An accelerator assembly (not used in the M4 gun) is mounted on the left rear end of the tube extension. Its function and operation will be explained later.

A piston rod screw is mounted in the front of the driving spring front bracket and is used to lock the piston rod and tube extension. The screw fits into a notch in the collar in the rear of the recuperator piston rod. The piston rod nut and this screw lock the piston rod to the tube extension.

In addition to the bronze shoes on the top and bottom of the tube extension a round auxiliary bronze shoe is located on the left side of the tube extension. These shoes provide a bearing surface between the tube extension and the side plates.

Two feed lever operating studs, one on each side of the tube extension allow the tube extension assembly to be used with either a left or right hand feed.

Recuperator Group. The recuperator recoil spring is in two equal sections with a bronze separator between the springs. The separator pilots in the recuperator cylinder and keeps the ends of the springs in line.

The piston is shorter than the M4 piston, has one land only, and has four steel seats riveted to the rear side to form a seat and guide for the front end of the front recuperator spring.

The recuperator bushing is larger in diameter and slightly shorter than the M4. The elongated slots are longer in length and are tapered, instead of rounded, at the front end. Three shallow grooves, approximately .030 of an inch deep extend from the front end of the slots to the front end of the bushing to by-pass oil after the piston passes the front end of the slots on counterrecoil.

The shoulder on the rear of the recuperator piston rod is notched to engage a piston rod screw mounted in the tube extension.

A recuperator expansion tube (not used in the M4) is mounted in a bracket at the front end of the recuperator housing. A drilled passage from the expansion tube enters the recuperator at the front end of the elongated slots in the bushing. Air trapped in this expansion tube acts as a cushion to stop the tube and tube extension without shock at the end of counter recoil. The oil filler hole is located in the recuperator expansion tube at the front end of the recuperator.

The recuperator socket is provided with a threaded opening for the expansion tube on both sides of the recuperator; the hole not being used is fitted with a closing plug.

The socket also contains a relief screw on each side, which act as vents when removed during filling. The filler screw on the expansion tube side is fitted with an oil level indicator, used to check oil level.

The stuffing box in the recuperator rear end cap is the same as in the modified M4; that is, with the four chevron type packings, a gland, spring and spring holder.

Breechblock Assembly. The breechblock is larger and heavier than the M4 breechblock. Two large recesses are milled in the rear surface to reduce weight.

It has two grooves that engage lands in the tube extension. These grooves are inclined forward one degree and thirty minutes (1° 30′) from vertical.

The breechblock stop is hinged, as previously explained; the breechblock may be removed by pulling outward on the stop retaining knob, which releases the stop so it can swing downward and allow the breechblock to slide out of the tube extension.

A hardened steel bushing, drilled for movement of the small end of the firing pin, is pressed flush in the front face of the breechblock.

The assembly otherwise is the same as the M4.

Back Plate Assembly. The back plate assembly is a little different in construction and outward appearance then the M4 back plate. It consists of a housing, buffer plunger, plunger stop screw, two "V" shaped friction pieces, a ring spring (consisting of 13 rings), an adjusting screw, and an adjusting screw-set screw. The set screw is assembled to the inner side of the back plate and soldered into place.

The back plate will be disassembled by base shop or arsenal personnel only.

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In first, second, and third echelon the entire back plate will be replaced. No repairs or replacement of parts will be attempted by 1st, 2nd or 3rd echelon men.

There is only one cross tie for mounting the back plate assembly to the side plates on the M9, instead of the two cross ties on the M4.

The assembly is vertically located in the grooves in the side plates by the top flanges of the side plates and a spring loaded latch slide mounted on the lower flange of the right side plate. The latch slide extends rearward under the back plate housing.

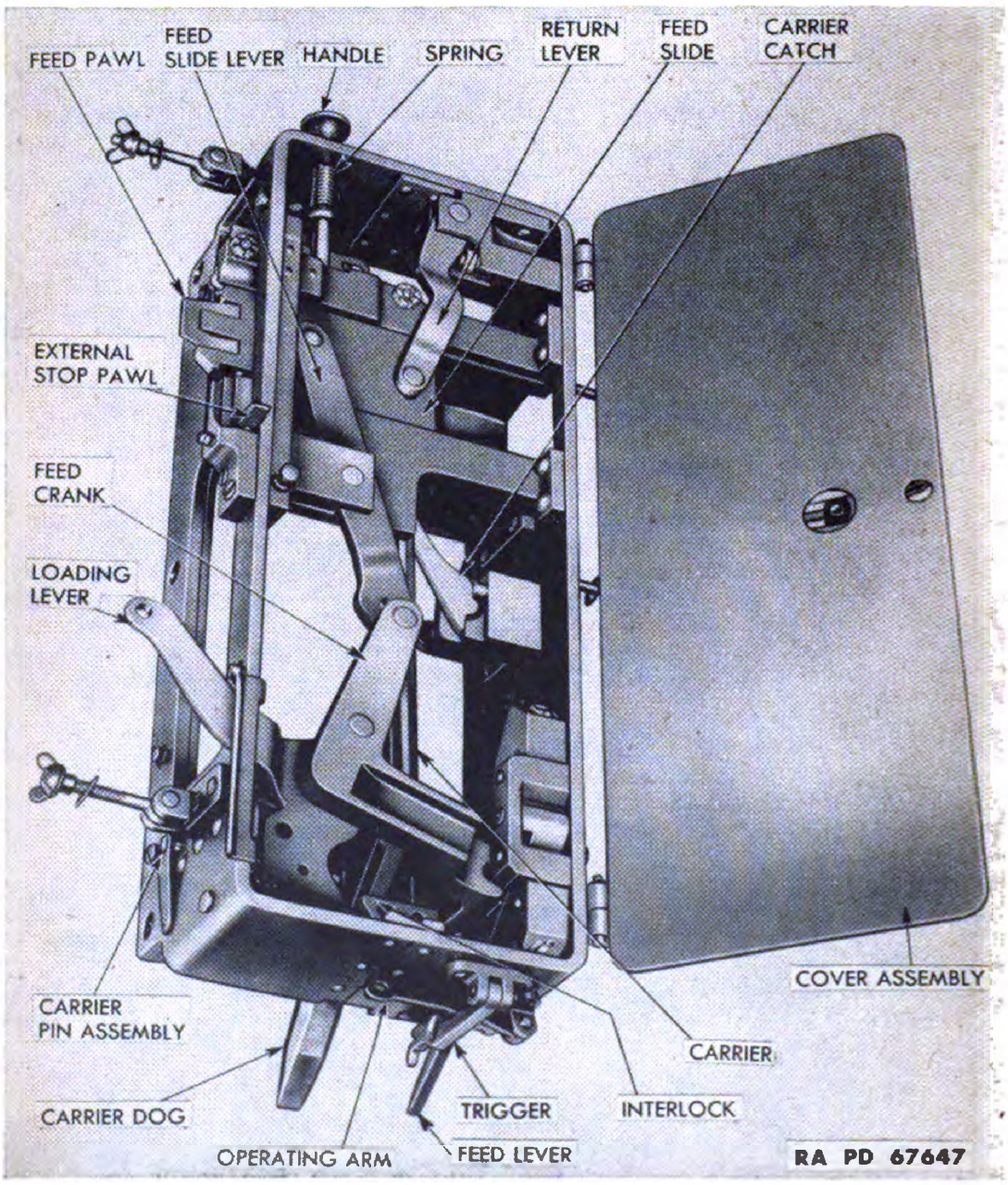

Figure 184. Feed Box and Feeding Mechanism. Left Hand Feed.

Feed Box and Feeding Mechanism. The big difference between the feed box for the M9 in comparison to the M4 is that in the M9 a metal disintegrating link bolt is used while in the M4 an endless articulating link belt is used.

The principle difference between the 37mm M9 left hand feed and right hand

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feed guns is in the feed box. In the left hand feed box the rounds enter from the left and the links are ejected through an opening in the right hand side of the feed box. The right hand feed box is just the reverse, therefore many of the corresponding parts of the feed box are not interchangeable, but differ only in that they are mirror images of each other. Therefore, we will describe the mechanism in a left hand feed gun only; the R. H. feed would be just the reverse.

The cartridge feeder holding pawl and stop pawl are pivoted to the front feed slide track on shouldered studs which are riveted to the pawls and secured by castellated nuts and cotter pins. Stops on the under side of the track enter large holes in the pawls to limit their travel.

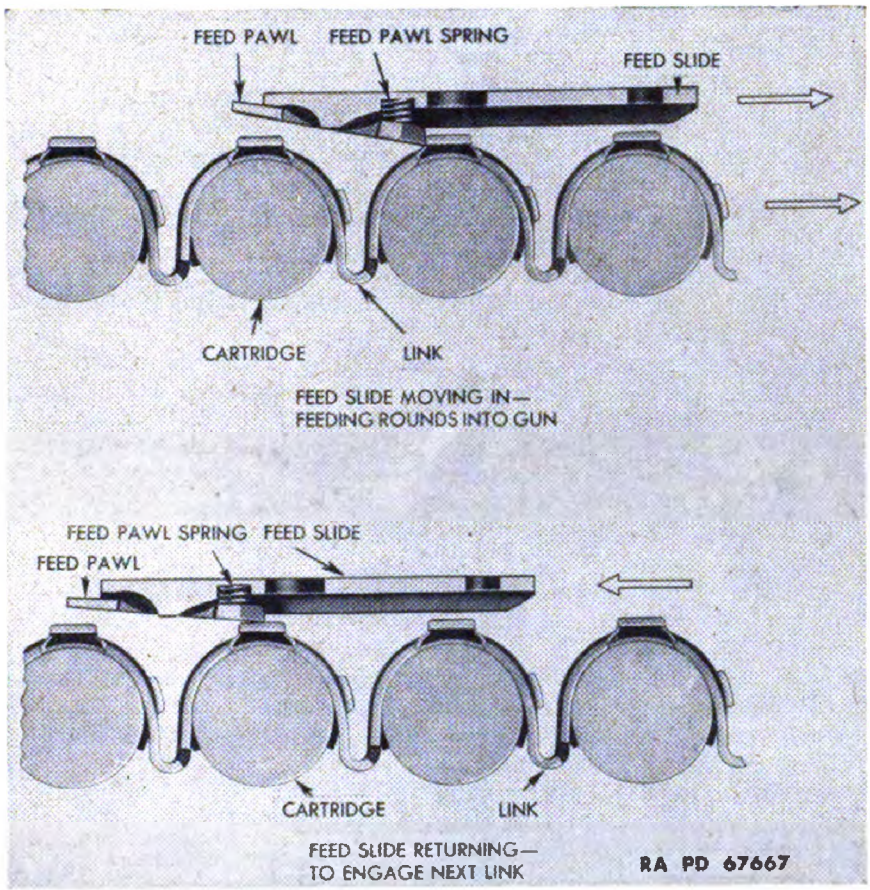

Figure 185. Feed Slide and Feed Pawl Action.

The pawls are held in engagement with the links by a connector (attached to both pawls) to which a spring loaded connector shaft is attached at its middle. This connector shaft extends through the front of the feed box frame and is provided with a handle (button type). Pulling outward on the handle retracts both pawls, and the spring on the shaft pushes both pawls into engagement with the links.

The feed slide assembly has one spring actuated feed pawl only. This pawl can be disengaged from the links by depressing the finger release tab that extends beyond the feed slide. A bridge is not used with the feed slide in the M9 gun.

The feed lever is pivoted on a pin and lock assembly similar to the pin used for the carrier assembly in both guns. The swivel in the M9 is a flat steel stud riveted to the feed lever and it is free to turn.

A feed slide return lever (not used in the M4) is pivoted in a bracket in the right hand front corner of the feed box frame. A spring and plunger in the bracket pushes the rear end of the lever to the left. A stud on this rear end

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of the lever engages the left end of the feed slide, causing it to move to the left also. This mechanism replaces the feed slide lever spring and plunger that worked against the tang on the feed lever slide in the M4 to return the feed slide to its initial feeding position.

The feed slide lever is lighter than the M4, is forked at the rear end to engage the feed crank stud, and has a stud on the front end to engage a slot in the top surface of the feed slide.

The carrier assembly has two projections on the under side for engagement with the carrier lifter cam on the lock frame. These projections are contoured on top to receive the rear end of the incoming round and to hold it in the path of the charger. There is a rib on the top of the carrier body.

The feed box cover is a flat steel plate hinged on removable pins on the right side. A slide latch and knob assembly operates in a housing riveted to the cover and when latched engages a stud on the feed box, which locks the cover in the closed position.

The loading handle cam assembly is not used on the M9 gun. A loading lever and return spring are located near the rear of the feed box, the lever pivoting about the bearing of the feed crank and operating through a slot in the side of the feed box. This lever engages a pin in the feed crank to accuate the feeding mechanism during manual loading.

An interlock mechanism consisting of an interlock body, plate, and spring positioned at the rear of the feed box prevents operation of the loading lever unless the lock frame is locked to the rear.

A feed and link chute is attached to the right or left side of the feed box by means of swinging eye bolts and wing nuts. This chute is used to support and guide the rounds into the feed box. A link ejection chute is attached to the opposite side of the feed box by eye bolts and wing nuts and is used to carry the links out of the feed box after the round has been stripped out of the link.

An external stop pawl assembly composed of a stop pawl bracket, and a stop pawl, spring, and pin. The bracket is mounted to the outside of the feed box by two screws, on the top side of the feed box just above the opening where the rounds enter the feed box. The external stop pawl supplements or aids the stop pawl inside the feed box in preventing double feeding, that is, feeding of more than one round at a time.

Initial loading is accomplished by pulling the manual charger cable to the rear, retracting the lock frame. With the lock frame locked to the rear the loading lever is pulled, feeding a round into the feed box far enough to trip the carrier by pushing the carrier catch to the right.

The carrier catch is a little different in construction and in the manner in which it is mounted in the feed box, but the function is the same in both the M4 and the M9.

Accelerator. This feature is not incorporated in the M4 gun. Because of the greater weight of the M9 tube and tube extension, the recoil of these parts must be stopped more slowly than in the M4 gun. Therefore, the rear ends of the slots in the recuperator bushing have a longer taper to accomplish this action.

Since the lock frame is held to the tube extension by the driving springs, the lock frame is more gradually slowed down also. Under some firing conditions, the lock frame may not have sufficient inertia left, after separation, to move back far enough to be held by the carrier dog. Therefore an accelerator has been incorporated in this gun.

As previously described, the accelerator assembly is pivoted on the left rear end of the tube extension, while the accelerator cam is located on the rear end of the left side plate.

At approximately the point of separation, the roller on the rear arm of the accelerator contacts and rides upward on the inclined surface of the cam. The front arm of the accelerator therefore pushes rearward against a square lug on the lock frame, thus giving the lock frame sufficient rearward travel to be engaged and retained by the carrier dog.

Lock Frame Assembly. The general appearance of the lock frame assembly is similar in both guns, with a few exceptions: on the M9 there is no ejector oper-

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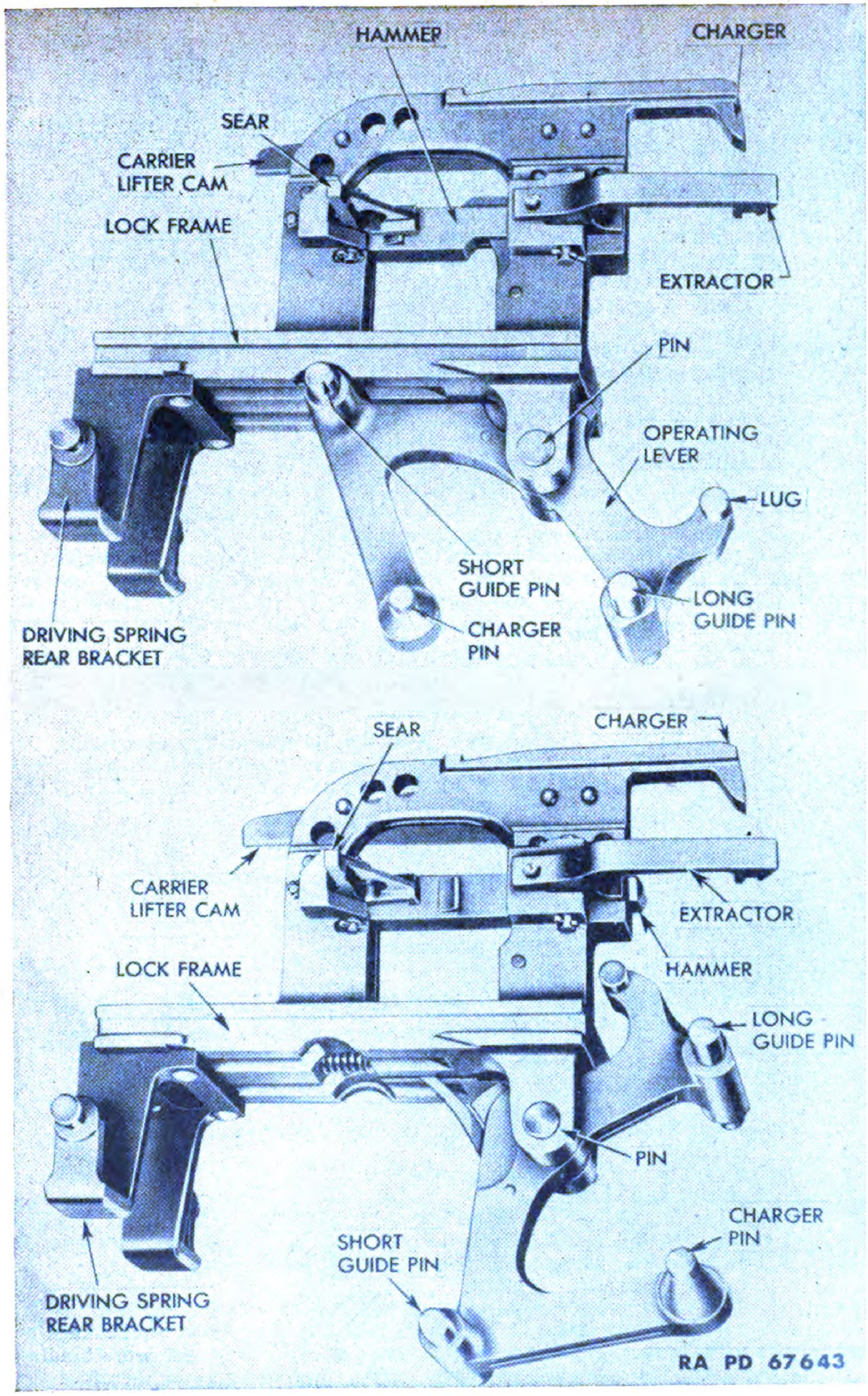

Figure 186. Lock Frame Assembly.

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ating stud. (A cam is on side plate.) The carrier lifter cam is very much shorter; it extends only a little over an inch beyond the rear of the charger.

There is a manual charger pin sweated into the operating lever body instead of the hole as in the M4. This pin is contacted by the shoe of the manual charger M3 and is used to manually charge the gun.

The extractor is mounted to a removable extractor pin.

On the left rear, just above the grooves of the base of the lock frame that slide in the side plate flanges, is a square lug. This is the lug the accelerator contacts during recoil insuring positive rearward movement of the lock frame.

There are fewer clearance cuts and lightening holes in the M9 lock frame and it is a little lighter in weight than the M4.

Driving Spring Assemblies. The driving spring assemblies in both guns are duplicates with the exception of size. The driving spring assemblies on the M9 are a little larger and a little longer. All of the other parts of the assemblies are of the same general design and appearance; the function of the assemblies and their respective parts are the same in both guns.

Manual Charging Assembly. This assembly is attached to the lower right side plate by four cap screws. The assembly consists mainly of a longitudinally slotted tube fitted with two mounting brackets and inclosing a coil spring and plunger. The plunger is fitted with a projecting shoe which contacts a pin attached to the operating lever. A flexible charging cable is engaged in a plunger plug and the plug is assembled to the plunger. The plunger moves rearward in the tube when the cable is pulled, thus manually charging the gun. The plunger is returned to its forward position by the coil spring when the cable is released. The charger is known as the 37mm charger M3. The charger provides a means of retracting the lock frame to cock the gun by remote control or to manually extract a round from the chamber.

The manual charger M3 is for either right or left hand feed and is not interchangeable.

OPERATION

The firing cycle in the M9 is the same as in the M4 with a few exceptions; the action of the accelerator aiding the rearward movement of the lock frame, the feeding action is slightly different as the disintegrating link belt is used in the

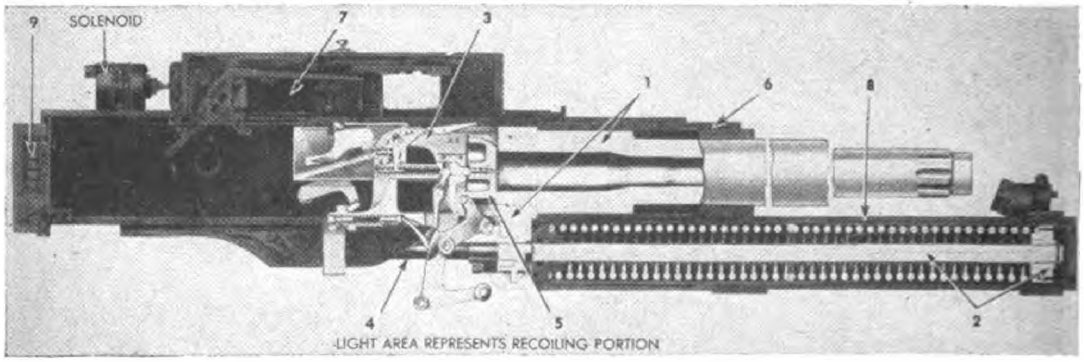

Figure 187. 37mm Automatic Gun M9. Recoiling and Non-Recoiling Parts.

M9. Counterrecoil action is slightly different due to the buffer action of the expansion chamber and the rounded slot in the front of the recuperator bushing. The length of recoil of the moving parts is a little longer in the M9. The tube and tube extension recoil 10¾ inches and the lock frame a little over 12 inches. All of the phases of operation are the same in both guns.

MALFUNCTIONS

Malfunctions will be the same in both guns with the exceptions of breakage or wear of the parts that are different. For example, if the accelerator were binding it would not assist the rearward movement of the lock frame and therefore the lock frame would not move far enough to the rear to be caught and held by the carrier dog. This principle is applicable to any weapon; a mulfunction can be

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traced to its cause through the knowledge of the firing cycle. Using this knowledge we can trace any malfunction and decide where, how, and when the stoppage occurred.

Inspection, care, cleaning, lubrication and repair is, generally speaking, the same in both guns.

The one difference in the method of checking the oil level in the recuperator is that in the M9 we have an oil level indicator instead of the filler screw. This method provides a more accurate check of the oil level. With the recuperator elevated to a five degree angle, the oil level indicator should show the amount of oil. If necessary oil will be added at the indicator opening until the oil runs out the relief screw hole. Oil recoil light U. S. A. specification 2-36D will be used at all times.

AMMUNITION

The same types of ammunition are used with both guns, but the ammunition for the M4 can not be used in the M9 because the cartridge case used with the M9 is much larger, has a more distinct shoulder and has an extractor groove instead of a rim. Furthermore, the propelling charge is heavier in the M9 ammunition. The projectiles are the same in both guns; the M56 nose fuse is used with HE ammunition for both guns, and the M80 armor piercing projectile is used in both guns. All precautions for storage, handling and issuing ammunition will be observed, as covered in chapters 8 and 9, Ammunition and Ammunition Supply, respectively.

37MM AUTOMATIC GUN, M10

One of the big problems that was encountered with the use of a 37mm gun in a plane was the amount of ammunition that would be fired in any one mission. With the M6 30-round magazine the supply of ammunition was limited to 30 rounds. For some missions this would be sufficient; for others it was not. Therefore, the need for either a new type of magazine or a new method of carrying ammunition was required. After numerous experiments the final decision was for the 37mm gun to use a metal disintergrating link belt with the ammunition loaded

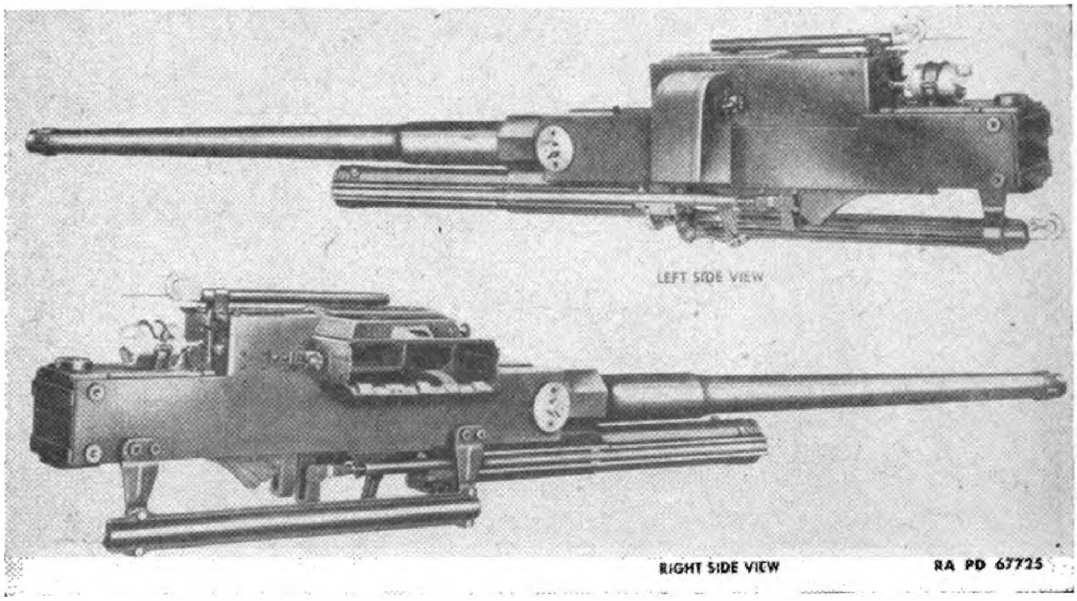

Figure 188. 37mm Automatic Gun M10. Right and Left Side Views.

the same as M.G. ammunition in ammunition boxes. This was a definite improvement through which the amount of ammunition that was carried on a mission was limited only to the amount of space available in the plane at the gun installation for storage of ammunition boxes.

We now have the standard 37mm M10. The M10 through its test period was

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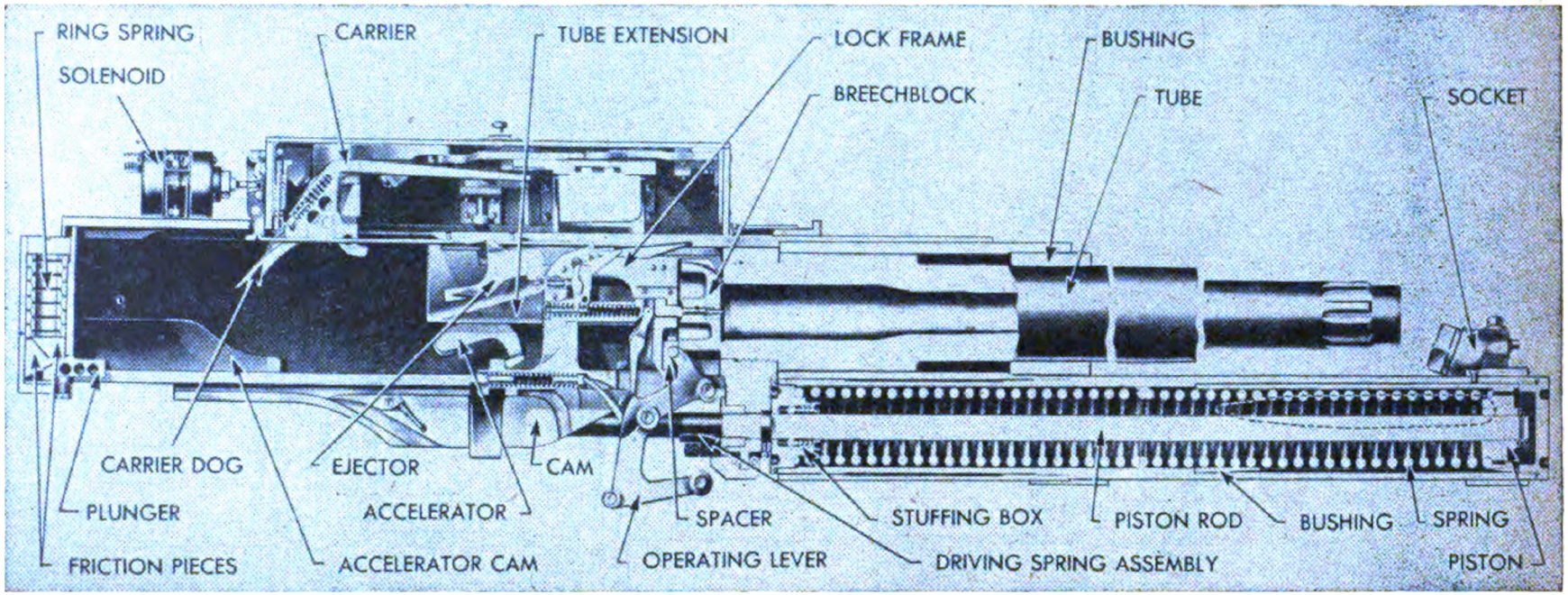

Figure 189. Cross-Section of M9 Gun.

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known as the M4E3 and M4E4. In addition to the changes in the feed box so that distintergrating metal links could be used instead of the endless belt, a few other changes and modifications were made. The M10 will replace the M4 in most plane installations. Since the M4 is the basic 37mm aircraft gun, it has

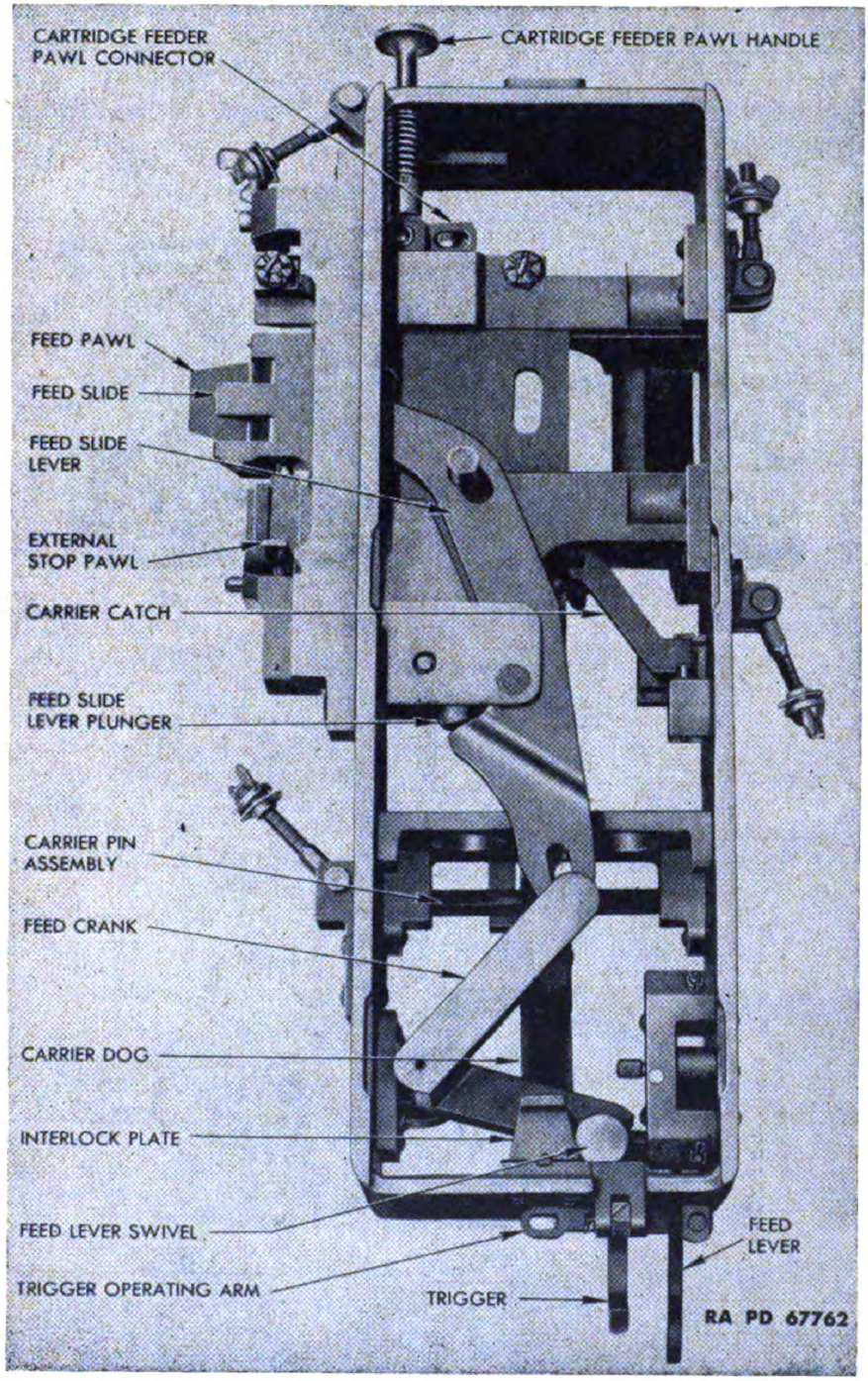

Figure 190. Feed Box and Feeding Mechanism M10 Gun.

been covered thoroughly in this manual. The M10 is so similar to the M4 that only the differences between these two models will be discussed.

Differences Between M4 and M10 Guns. Remember that in general appearance the two guns are identical. In construction they are the same. The operation,

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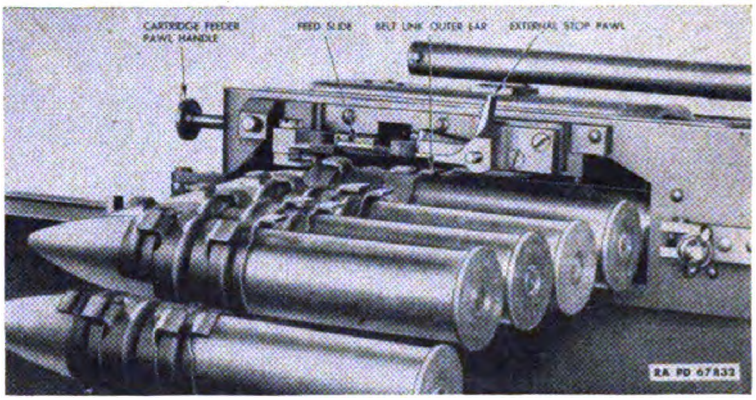
care, lubrication, and inspection procedures are the same in both guns. The main differences between the M4 and M10 are:

The feed box and feeding mechanism of the M10 gun is designed to feed ammunition from a disintegrating link belt. By changing the feed box and feeding mechanism the gun can be made to feed from left to right or from right to left, the belt link being ejected through a link chute. An interlock lever and a trigger lock function the same as the loading handle cam lock in the M4. It prevents the manual charger from feeding a round when the trigger is depressed by locking the loading slide assembly. When slide assembly is charged or hand feeding accomplished the trigger can not be pulled.



Cartridge Feed Using Metallic Link Belt.

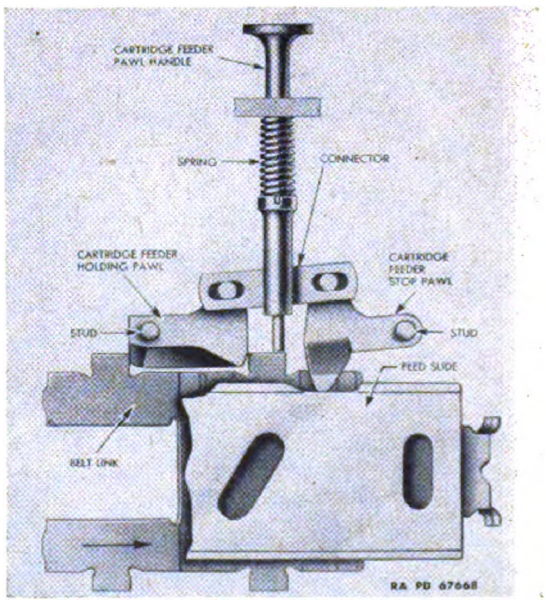


Figure 191. Cartridge Feeder Stop and Holding Pawls.

The loading handle cam assembly has been replaced with a loading slide assembly which has only a cable connection for manual feeding. The recuperator system is the same as the M4.

Four tapped holes are provided on each side plate for attachment of the lock frame manual charger.

The back plate assembly is similar in appearance and operation except for the adjusting screw being recessed and the buffer plunger being a little longer. Newest adjusting screws are not recessed but are identical with the M4 adjusting screw.

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The trunnion block bushing is pressed in slightly more than flush with the front end of the trunnion block body.

Splines are provided in the muzzle end of the tube for easier disassembly and assembly.

Back plate. The M10 back plate, instead of having a coil spring, has a ring spring in segments. The more recent models have the same back plate as the M4 back plate assembly.

The disassembly and assembly procedure on the M10 gun is the same as the M4 which has been covered in detail. Therefore there should be very little difficulty encountered when called upon to service the M10 gun. One must remember that the M10 uses a metal link belt. Otherwise the two guns are identical and that which applies to one weapon will also apply to the other.

75MM GUN M4 AND MOUNT M6

In 1943 when the War Department first released the information that the Army Air Forces were using a plane that mounted a 75mm gun in its nose, the public, the armed forces, and quite a few Ordnance men were astounded. The fact that the 75mm was mounted in a plane was at first breathtaking. Quite a few Japs already had felt the sting of the newest and largest weapon to be mounted in an airplane. At last the Ordnance Department and the Army Air Forces had succeeded in mounting the prototype of all "flying Artillery"—the 75mm gun. This was the same caliber piece that was used as a ground weapon so effectively by the Allies in World War I. Since the gun fires from the nose of the plane, it was easy to understand why, in enemy reports, natives of some of the Pacific Islands stated that the Yanks were using a plane that "spat fire" and was comparable to the "Dragon", only this was a "flying dragon." Another miraculous achievement of the Ordnance Department and the Army Air Forces had been attained which would play its part in the fight to drive the enemy to complete and overpowering defeat.

This marvel of modern aircraft armament caused considerable comment not only among the general public but also among the members of the armed forces. When will this flying artillery reach its ultimate goal? That was their question. We can't answer that now because as long as American ingenuity, thought and ability are still active, we of the Ordnance Department, in cooperation with the air forces will continue to produce the world's best and finest aircraft armament.

Lets break down the 75mm and see just how the Ordnance Department and the Army Air Forces, succeeded in mounting it in a plane.

Few people realize that in World War I the French experimented with an aircraft mounted 75mm gun and with some degree of success. Of course it can truthfully be said that it was not really a 75mm gun that was mounted in the plane. Rather it was a tube that was muzzle loaded with a 75mm projectile with breech end sealed with a load of buck shot. On priming this weapon, the projectile was blown out of the muzzle end of the tube and the shot out of the rear. This was rather a clumsy contraption and not very effective but the idea was good. Later models of this type of aircraft armament had a solid block of wood in the breech end rather than the buck shot. Reports are not available as to how effective this latter weapon was but it does have its place in the development and history of aircraft armament.

Even before 1941 and 1942 the Ordnance Department was conducting tests at Army Air Force's request that a 75mm gun be mounted in a plane. Our weapon was complete, that is, a gun and mount, the latter to incorporate some kind of a recoil brake that would absorb both the shock of recoil and, cushion and control the counter-recoil of the gun. This was accomplished through the use of the same type of a recoil brake as was used in the M3 tank that mounted the 75mm gun. With this gun and mount as a basis, tests were conducted with a number of different types of mounts. The 75mm gun M3 was adopted and while the now standard M4 gun is similar in construction and design, there are a few minor differences between the M3 tank gun and the M4, 75mm aircraft gun.

The big problem was how and by what means the recoil of the gun could be

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controlled. The recoil brake had to be smooth, completely effective and so arranged that the flight of the plane would not materially be affected when the weapon was fired. The mount and system that was finally accepted is known as the hydro-spring type of recoil brake. (See chapter 2 Artillery).

The first few planes used for test-firing the weapon would not take the beating and therefore one of the newer and better type medium bombers was used. The B25G model plane manufactured by North American Aviation Inc. was developed for conducting gun tests. Several alterations and modifications were necessary. This plane has a long narrow bombardiers crawl tunnel in the front left hand side of the plane which made it easily adaptable to take the 75mm gun. Following modifications in the nose section of the plane and various other alterations, the gun was successfully mounted in the desired position. After many tests the gun and plane finally were ready for combat service.

All types of exhausting and detailed tests prove that this plane and gun did have a purpose and would have a number of uses as the newest and largest aircraft weapon. The big problem of controlling the recoil and counterrecoil of the gun so that the flight of the plane would not be affected was overcome and all tests proved to be successful.

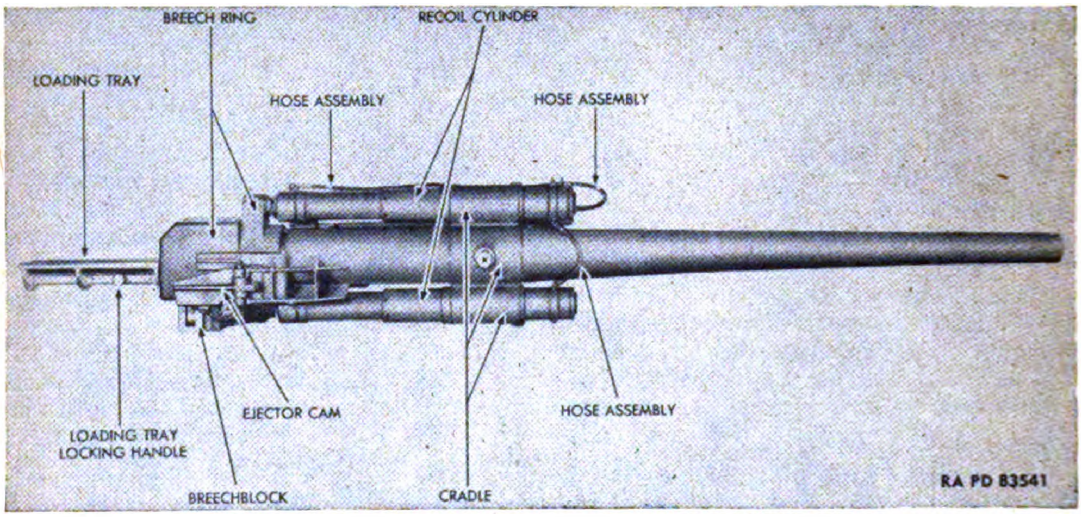

Figure 192. 75mm Gun M4 and Mount M6. Right Side.

Description. The recoil and counterrecoil of the gun is controlled by hydro-spring action, on counterrecoil the breechblock is operated automatically and stays locked in the open position until a round is manually loaded into the chamber. The weapon is mounted as a fixed gun in the B25G and H models. It is fired by remote control through the use of a solenoid controlled by the pilot. It fires outside of the arc of propeller rotation and is mounted in the nose of the plane. Being a single shot, hand loaded weapon, the gun is manually loaded by one man and the pilot aims and fires the gun. The normal supply of ammunition for any one mission is 21 rounds of either armor-piercing capped or high explosive Ammunition. The principal use of the weapon will be against enemy ground targets or installations, i.e., tanks, armored cars, motor convoys, locomotives, landing barges, and other types of light vessels. However, it will be of some use in air to air combat against enemy transports and troop planes as well as ground targets.

Tube. The tube is of one piece construction. Rear of bore is tapered to form a firing chamber. The rifling is uniform right hand twist. The breech end of the tube has a continuous thread for attaching the breech ring.

There is a shoulder at the forward end of the threads cut so that a keyway can be used for locking the tube to the breech ring. The tube has a smooth and polished surface to provide a bearing surface in the cradle. The rear face of the

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tube at the breech end is recessed to allow for clearance of two extractors which permit extraction of the fired cartridge cases.

Breech Ring. The breech ring is the means of anchoring the 2 recoil cylinders and connecting the gun to the mount. The rear end of the recoil cylinder piston rods are attached to the lugs of the breech ring by retaining nuts which thread into the lugs and are locked by two Allen set screws and two bronze plugs. Two lugs project down from the bottom of the breech ring. These lugs are drilled to provide bearing surfaces for the operating crank on the right side and for the chain terminal crank on the left side of the breech ring. An additional lug on the left side is provided to receive the rear end of the closing spring cylinder. Holes are provided in the breech ring for screws to hold the loading tray, breech ring key, operating crank detent, two breech ring bushings, two chain terminal crank detents, two extractor plugs, the firing plunger retainer and firing plunger.

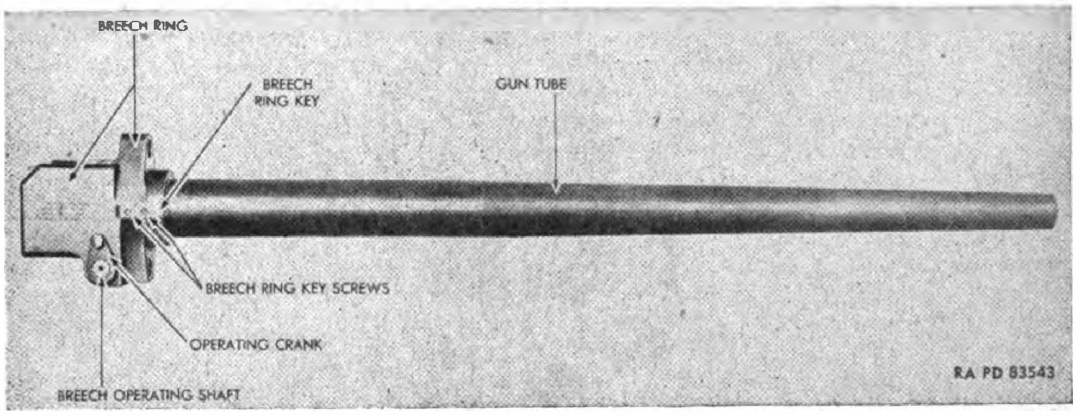

Figure 193. Gun Tube and Breech Ring Assembly. Cradle Removed.

The forward end of the breech ring is threaded to receive the tube and a slot is provided for locking the tube to breech ring.

The large rectangular opening in the breech ring is provided to receive the breech block. The rear end is U-shaped to clear extracted rounds and provide space to load new rounds. Short curved grooves in both side walls of ring provide a means to receive and guide the outer trunnions of the left and right hand extractors. Three threaded holes in the rear surface provide a means of receiving the loading tray screw and the two extractor plunger plugs.

A bronze rectangular breech ring key is mounted at the front right face of the ring to lock the tube to the breech ring and the outer surface of the key engages in a keyway in the cradle, preventing the gun from rotating in the mount.

Breech Block and Breech Mechanism. The vertical sliding wedge type of breech block is used in this gun. A guide land is provided on either side of the breechblock. These lands slide in corresponding grooves in the breech rings.

The top of the breechblock is beveled and rounded to assist in chambering the cartridge when the breech block rises to the closed position. The rear face and the lands of the breech block as well as the guide ways of the breech ring are inclined so that as the breechblock rises it moves forward slightly.

Grooves in each side of the breech block are inclined forward from the bottom to the top of the block and they control the movement of the extractor imparting an accelerated motion to the extractor during extraction and ejection of the spent case.

An inclined T-slot in the bottom of the breech block in which the cross heads of the breechblock crank ride provide the means to raise and lower the breechblock.

The center of the breechblock is bored to receive the percussion mechanism group. The front end of the hole is threaded to take a breech block bushing which is locked in place with a locking screw. A shoulder is provided in the hole to lock and guide the movement of the percussion mechanism assembly.

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Engraved lines on the rear face of the breech block mark "Lock" and "Open" positions of the firing spring retainer.

A cocking lever and cocking fork move the percussion assembly into a cocked position when the breech is opened. The sear holds the percussion assembly in the cocked position. The sear is mounted with its spring and retainer in a recess bored at right angles to the centered hole housing the percussion assembly. When the firing plunger is pressed in from left to right it compresses the sear spring and causes the percussion assembly to be released.

Extractors. The extractors (left and right) are short heavy levers supported vertically between the sides of the breech block and the inner walls of the breech ring.

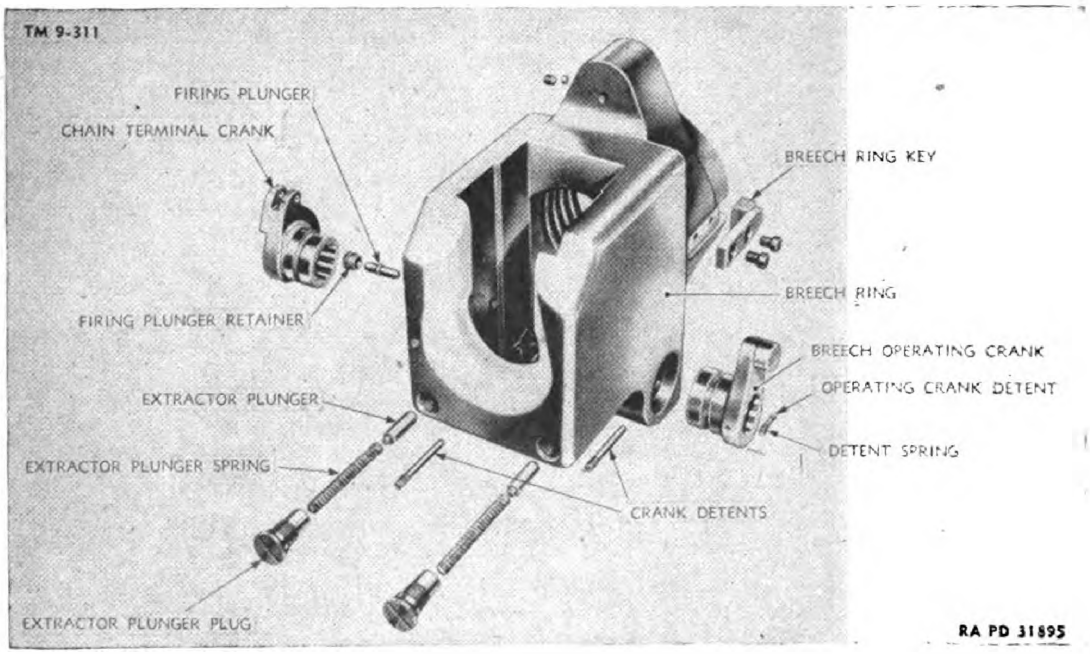

Figure 194. Breech Ring Group.

The lower end of the extractors have an inner and outer trunnion. Outer trunnions slide in kidney shaped recesses in the inner walls of the breechring and prevent any vertical movement of the extractors. Inner trunnions slide in the curved grooves of the breech block and as the breech block is raised they force the extractors forward. When the breech block is raised the lips of the extractors fit into recesses in the breech end of the tube and are under the rim of the cartridge. The front surface or edge of the extractors are curved convexly and have a rolling contact causing a prying action to be transmitted to the fired case when the breech block opens. The rolling action completes the accelerator action of the extractors and ejects the spent case clear of the gun.

Extractor Plungers. Small cylindrical extractor plungers slide in longitudinal holes in the breech ring that extend from the rear to the kidney shaped recesses in the breech ring where the outer trunnions of the extractors fit. Extractor plunger springs inserted in the rear of the plungers bear against the extractor plunger plugs which screw into the rear of the breech ring. The force of the springs transmitted to the plungers and to the extractor trunnions locks the breech block in the open position. The shoulders of the extractor plunger plugs provide a means of mounting and supporting a loading tray if it is used.

Operating Shaft. The breech operating shaft (this shaft may be in two sections) originally was of one-piece construction but was later modified and now has its ends fitted into the splined hub of the operating crank and the chain terminal crank. The breech block crank is located and operates between the two cranks. All three cranks, since they are connected and joined by the splined shaft mating

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with the splines of the cranks, will move as a unit. A plunger and plunger screw used in conjunction with a detent in the operating crank locks the shaft to the operating crank. This detent can be depressed so that the shaft may be removed during disassembly.

The breech block crank is an internally splined hub which slides on the central part of the operating shaft between the lugs of the breech ring. The large central lever arm of the breech block crank extends up into the rear and ends with a pivot pin extending to the left and right. On this pivot two oval shaped cross heads engage and slide in the inclined T-slot of the breech block in order to raise and lower the breech block (older type guns may have diamond shaped cross heads). A large lug projecting downward from the hub contacts a stop surface on the under side of the breech ring and limits the downward travel of the breech block.

The operating crank is an internally splined hub. An arm of the hub extends upward and terminates in a terminal lug projecting outward. This terminal lug forms a contact point for the operating cam located on the cradle. This lug is a means of automatically rotating the operating crank due to the cam action of the operating cam causing the breechblock to open and extract and eject the spent case. The outer machined surface of the hub acts as a bushing and rotates and is supported in a lug of the breech ring. A hole bored through the crank houses the detent which locks the crank to the lug. The operating crank detent and shaft plunger spring locking the shaft and crank is held in place by a cotter key.

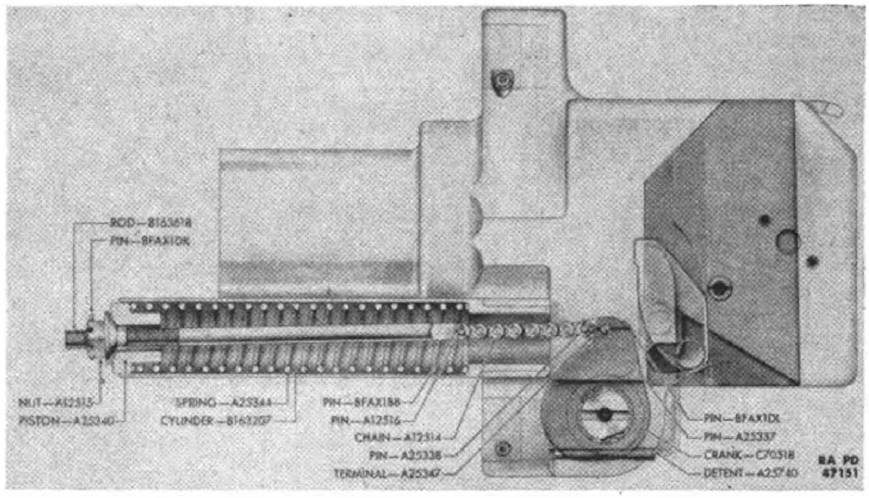

Figure 195. Chain Terminal Crank Showing Closing Spring Assembly.

The chain terminal crank is an internally splined hub and is machined on the outside. A short lever extends upwards and ends in a fork for attaching the chain terminal of the closing spring mechanism. As in the operating crank the machined surface is supported and rotates in the lug of the breech ring. The left end of the operating shaft slides through the splined hub. A hole through the crank provides a means of housing a detent used to lock the crank to the lug of the breech ring.

The closing spring is of the coil type. A piston rod, piston, and chain are connected to the chain terminal of the chain terminal crank. The assembly is housed in a cylinder. The cylinder is attached at the rear to a lug of the breech ring by two screws. An internal shoulder of the cylinder provides a seat for the closing spring.

The closing spring piston rod is slotted at one end for attachment of the piston rod chain by means of a link pin and cotter pin. The opposite end is threaded to receive the piston rod nut. A series of holes equally spaced along the threaded part of the rod provides a means of locking and adjusting the nut with the use of a cotter key. By tightening or loosing the nut the speed through

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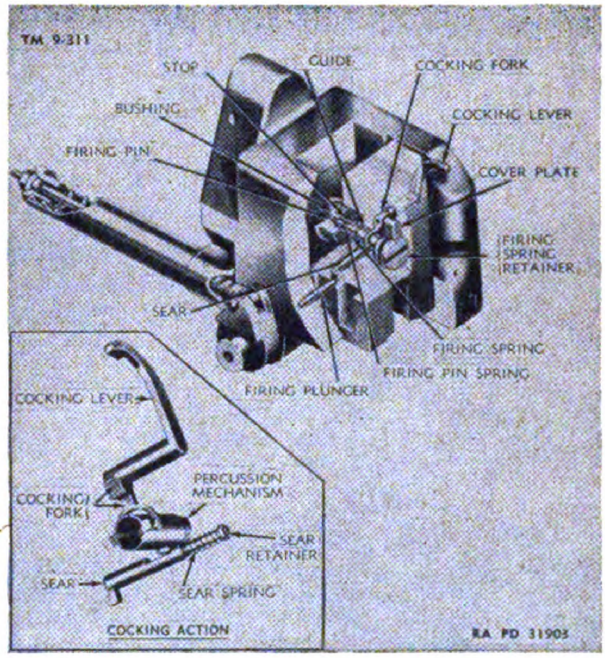
which the breechblock is raised can be controlled. The closing spring piston fits and works freely in the cylinder which is bored centrally to fit over the piston rod. A shoulder at the end of the piston provides a seat for the front end of the closing spring.



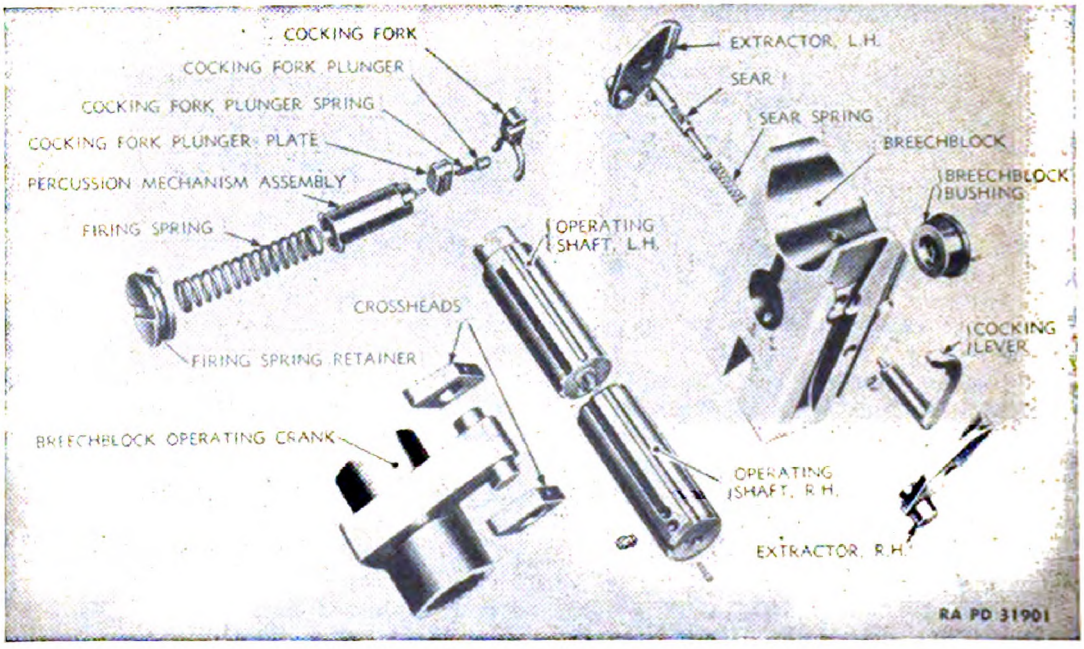


Figure 196. Breech Mechanism Showing Percussion Mechanism Assembly.

The closing spring piston rod nut is tapped to screw to the rod. The rear end is machined to fit into the piston and helps to align the nut and piston. Forward end of the nut is hexagon shaped to provide means of adjusting closing action of the breech block.

The closing spring is a heavy compression type spring. The chain is a com-

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mercial or common type. The chain terminal is a small steel block drilled for attachment to chain terminal crank by means of a link pin.

Opening the breech rotates the operating shaft, turning the chain terminal crank and pulling the closing spring piston farther into the spring cylinder. This compresses the closing spring and thus the spring force is transmitted to shaft and in turn to the breech block crank so that the breech block will close when a cartridge is loaded or the breech block is unlocked manually.

Percussion Mechanism Assembly. In the breech block the percussion mechanism is housed in the central bore of the breech block. The mechanism and its control actuates the firing pin to fire the round.

The percussion mechanism is composed of a firing spring which is a cylindrical body fitted into the bore of the breechblock, two slots in a shoulder, one of which locks over a retainer pin in the breechblock and the other over a lug on the cover plate to lock the retainer to the breechblock.

Etched lines in the rear of the breechblock and on the retainer designated the lock and open positions. In front of the firing spring retainer is the firing spring, one end of which seats inside the firing pin guide and against the firing spring stop; the other end seats in the spring retainer. The spring maintains spring pressure on the percussion mechanism and supplies the force to drive the firing pin forward when released.

The firing pin guide houses the firing pin, the firing pin spring, and firing spring stop. Two exterior lugs are engaged by the prongs of the cocking fork, a cam shaped lug for engagement with the sear and a guide lug are on the under side of the guide. The firing pin is threaded into the guide and locked by the guide pin and the retracting spring is assembled between the head of the firing pin and has its forward surface against the firing spring stop. The firing spring stop fits through two slots in the guide and contacts the rear face of the breech block bushing. The pressure of the compressed retracting spring forces the firing pin to retract after firing and prevents over-travel of the firing pin.

The cocking lever rides over a cam on the rear of the breech ring. Opening the breech block cams the cocking lever forward. The lower end of the cocking lever is in engagement with the cocking fork which is in the bore of the breech block. The two fingers of the fork engage the front of the firing pin guide; therefore it cams the guide to the rear as the cocking lever moves forward. A cocking fork spring and plunger housed in the cover plate which is assembled in a slot in the rear of the breech block is used to maintain and position the cocking fork and the cocking lever.

The sear is located in a recess which is at right angles to the central bore of the breechblock. The sear is keyed on one end to prevent its rotation in the recess of the breech block.

The opposite end of the sear is retained by a sear retainer. The sear spring maintains constant pressure on the sear, forcing it to the left. The side wall of the breech ring holds the sear in place. On the top of the sear is a cam lug which contacts and works with the lug on the underside of the firing pin guide. As the guide moves to the rear on cocking, the lug on the guide acts against the lug of the sear and cams the sear to the right, compressing the sear spring. As soon as these lugs override the sear, the sear spring forces the sear to the left and locks the guide in a cocked position.

The sear is released by the pilot pressing the firing button which forces the firing plunger into engagement with the sear. The sear moves to the right releasing the firing pin guide, the percussion mechanism moves forward and the primer is struck by the firing pin. The final action of the firing pin is due to inertia. This force compresses the firing pin spring which supplies the force to return the firing pin.

Cradle. The cradle or main support of both gun and mount is in three sections one above the other, the upper and lower sections provide the means of mounting the two recoil cylinders. A key on the top of the upper section and a key on the top of the lower section fit corresponding recesses in the recoil cylinder. This prevents rotation of the recoil cylinders. The recoil cylinders are locked

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to the rear end of the cradle by means of splined lock washers. Notched spanner nuts screw into threads of the cylinders and draw the cylinders against the cradle.

Two trunnions on the central section of the cradle support the gun and mount and provide a means of mounting the gun and mount in the plane. Three bronze bushings on the inside of the cradle provide a bearing surface for the gun tube during recoil and counterrecoil. Two lubrication fittings provide the means to lubricate these bearings.

Two blocks and a plate welded to the left rear side of the central section provide a means of mounting the firing mechanism and the solenoid.

The operating cam bracket is welded to the right side of the cradle. This is used to mount the operating cam mechanism. This bracket also has a keyway to guide the gun in part of recoil and counterrecoil phase. A hole bored in this bracket is the means of mounting and securing an elevation post used to lock the gun in the rear when it is mounted in the plane.

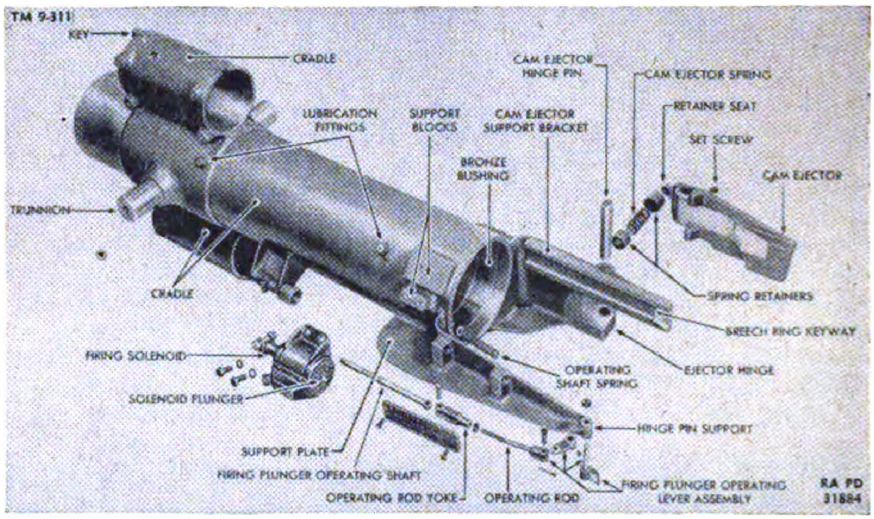

Figure 197. Exploded View of Cradle.

Recoil Cylinders. The recoil mechanism is the hydro-spring type. It consists of a spring operated piston in recoil oil. Two identical cylinders, one above and one below the central section of the cradle, are secured and locked to the cradle. The rear ends of the piston rods are secured into the lugs of the breech ring and locked by two set screws and bronze plugs.

Holes in the front end of the cylinder walls receive fittings for filling with recoil oil. Holes in the bottom of the top cylinder and at the top of bottom cylinder provide the means of connecting the oil system through the use of a connecting hose. Appropriate fitting, drain and purge plugs are also located in the two cylinders.

A recoil cylinder sleeve is installed inside of each cylinder. These sleeves have two tapered cutouts on each side wall. These throttling slots taper to the rear and are widest at the front end and they provide the means of stopping and controlling some of the recoil of the gun. A copper washer seals the oil between the sleeve and the cylinder. Six key ways in the recoil cylinder mate with six keys on the sleeve and prevent rotation of the sleeve in the cylinder.

The recoil cylinder cover (rear end cap) is threaded and closes the rear end of the cylinder. Appropriate packings provide the proper oil seal around the outside edges of the cover and also around the piston rods. A follower and a bushing inside the cover provide a guide and bearing surface for the movement of the piston rod. Packing inside the cover provides an oil seal around the piston rod where it extends through the cover.

The counterrecoil buffer (front end cap) is the spear type (or dash pot) buffer; it seals the front end of each cylinder—appropriate packings act as a seal around the outer surface. This spear type oil buffer controls counterrecoil of the gun.

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The buffer, being stationary, slips into the hollow head of the recoil cylinder piston and piston rod as the gun moves forward in counter-recoil. The counter-recoil buffer is hollow and has holes drilled at right angles to the centrally bored hole. Two of these are relief holes and the two forward holes are throttling holes; in conjunction with a valve, valve spring, and adjusting screw located in the rear of the hollow spear they provide a means of controlling the flow of oil through the hollow spear, therefore, control the speed of counter-recoil. Both cylinders, being identical, must have the same adjustment of these two adjusting screws on the counter-recoil buffers. Appropriate packings around the adjusting screws prevent oil leaks.

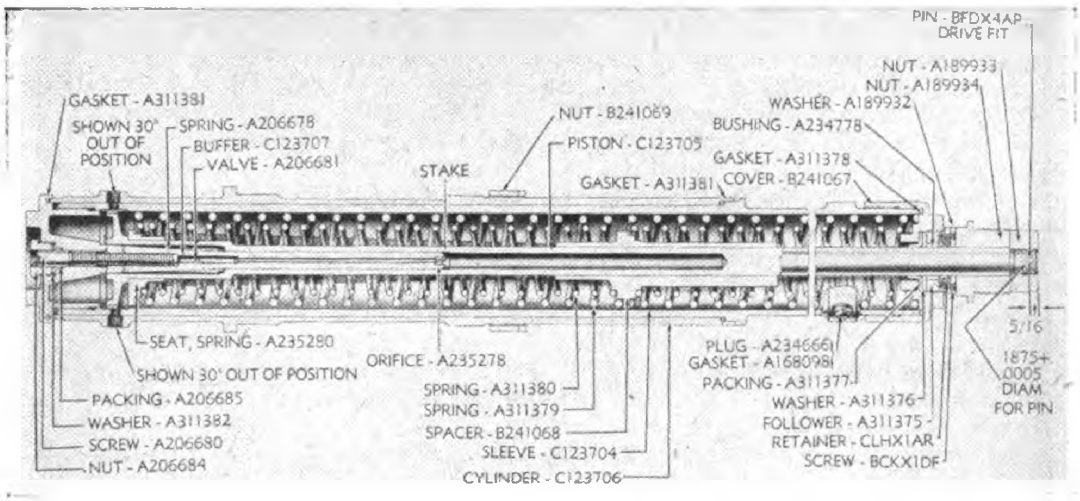

Figure 198. Recoil Cylinder Assembled. Sectional View.

Four coil springs are mounted to each recoil cylinder piston rod. These springs—two large and two small springs—are separated by a bronze spacer which provides a seat for each spring and also acts as a guide inside the cylinder. The two forward springs are seated against a spring seat and do not bear directly against the piston. The piston head is an integral part of the piston rod. Both the piston head and piston rod are hollow to receive the counterrecoil buffer. There is only one land on the piston which functions in recoil to provide the proper braking action to overcome and stop the recoil of the gun. The rear ends of the two rear springs are seated against the recoil cylinder cover (rear end caps). The piston rod end nut and retaining pin lock the recoil cylinder piston rod retaining nut to the piston rod.

Front and Rear Tubes. Mounted to the front end of the central section of the cradle by six cap screws and lock washers is a large cylindrical tube. This tube serves as a jacket for the gun tube. It is called the rear tube. Telescoped inside the rear tube is the front tube. The front tube extends 2½ feet beyond the front end of the rear tube and has two small holes drilled into its left front side for attachment of two screws and lock washer to lock the front tube to the rear tube.

A muzzle close—off assembly and part of the plane is positioned against the front tube to seal off the front end of the opening in the nose of the plane to prevent the air from blowing back into the gunner's position in the plane. The gun tube moves in recoil and counterrecoil inside the front and rear tubes and does not contact either tube.

Replenisher. A replenisher cylinder is mounted on the left side of the upper recoil cylinder. It is attached to the upper section of the cradle. A replenisher filler hose and piston rod guard are mounted in a bracket on the left rear side of the upper recoil cylinder. The replenisher serves as a recoil oil reservoir, When the temperature or heat devloped during firing expands the oil, the excess volume of oil is taken up by the replenisher. When the oil contracts because

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of falling temperature the replenisher keeps the recoil cylinders filled with oil. A purge plug is located at the front end of the replenisher. The replenisher is filled through a check valve mounted at the rear end of the filling hose. The replenisher therefore is connected to both recoil cylinders by means of connecting hoses. The volume of oil in the replenisher is checked by means of a replenisher gage. Later models of replenishers have the gage calibrations scribed on the piston rod guard.

Inside the replenisher cylinder is the replenisher piston and piston rod. The head of the piston is composed of a series of chevron type ring packings held in place by a seat and lock nut. (Newest piston heads are of metal with a neoprene ring seated in a recess in the head of the piston). Behind the piston is the replenisher spring; this coil spring is seated at the rear end on the piston rod guard and on the piston at the forward end. Oil added through the check valve and filling hose under pressure therefore forces the piston to the rear, compressing the spring. For air holes behind the piston prevents a vacuum from forming and only the spring tension of the replenisher spring functions as the oil is either forced into the cylinder or returned to the replenisher due to the expansion of the oil in the cylinders.

The replenisher piston rod guard seals the rear end of the cylinder and is secured by four bolts and nuts; a packing prevents oil leaks. At the front end, a flange with its connection and packings seals the front end of the cylinder and prevents oil leaks.

Firing Mechanism. Two blocks and a support plate are welded to the left side of the cradle. They are used to mount the firing mechanism. A firing plunger shaft, shaft spring, operating rod, and lever assembly are assembled to the rear of the solenoid. The solenoid is mounted to the bracket by two cap screws. The solenoid plunger is energized by the pilot of the plane. The plunger of the solenoid moves the operating shaft to the rear compressing the shaft spring. The shaft moves the operating rod to the rear, actuating the firing plunger lever assembly, thereby, pressing the firing plunger into the breech ring, releasing the sear and firing the gun. When the pilot releases the firing button the operating shaft spring returns the parts to normal position.

Operating Cam Mechanism. An operating cam mechanism is mounted to the right rear side of the cradle. This mechanism is mounted to a bracket welded to the cradle. The cam itself is machined on its rear face and on the inner surface of the front end are two lugs used to mount the cam. A hinge pin secures the cam to the bracket and two lock screws lock the cam securely in place. At the extreme front end of the cam a spring and two spring retainers are seated. This spring is compressed in recoil of the gun by the movement of the terminal lug on the operating crank; as the lug clears the cam, the compressed cam spring forces the cam to pivot so that there will be positive engagement of the lug and the cam on counterrecoil hence the breech block will open automatically. The inner surface of the cam is machined to allow for clearance of the lug on the operating crank when the breech block closes. A bronze insert on the rear machined surface of the cam prevents battering of the cam during the opening operation of the breech block.

Operation. The following step by step operation covers a complete firing cycle of the gun and mount and will start with the breechblock open and the cartridge chamber empty.

Loading. The gun is loaded by entering and forcing the cartridge into the chamber all in one motion with sufficient force to unlock the breechblock. As the band on the cartridge engages the claws of the extractors, they are moved forward, releasing the breechblock and permitting it to close by force of the closing spring.

The chambering of the cartridge is accomplished by a beveled surface on the face of the breechblock which forces the round forward as the breechblock moves vertically to battery position. Final chambering is accomplished by the inclined guides in the breech ring which cam the breechblock forward one degree and 30 minutes as it moves into battery.

Firing. The gun is now ready to fire. Operation of the trigger button will energize the solenoid, actuating the firing plunger. The firing lever contacts

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the firing plunger which moves inward, depressing the sear. This releases the firing pin guide assembly, allowing it to be driven forward under force of the firing spring. Before the firing pin strikes the primer, the forward projections of the firing spring stop strike the rear face of the breechblock bushing, thus stopping the action of the firing spring. The firing pin guide and firing pin are carried on by inertia to strike the primer. This final forward motion compresses the firing pin retracting spring between the stop and the head of the firing pin. After the round has been fired, the firing pin retracting spring returns the firing pin so that it does not project beyond the face of the breechblock.

As soon as the gun fires, the reaction of the expanding gases causes the gun to recoil in its mount.

Recoil. Recoil and counterrecoil of the gun is controlled in two ways; hydraulically and by recoil springs. The recoil cylinder mechanism is attached to the cradle and to the breech ring.

The recoil cylinders being attached to the cradle remain stationary. The recoil cylinder pistons, attached to the breech ring, pull the recoil pistons through the recoil cylinder sleeves. This action compresses the recoil springs as the piston travels rearward through the sleeves. Their movement is slowed down gradually since the flow of oil is restricted by the taper of the elongated slots in the recoil cylinder sleeves.

At this time the terminal lug on the breechblock operating crank cams the operating cam outward and travels on to the rear as the operating cam snaps back under its spring tension.

When the gun reaches approximately 21 inches of recoil the pistons reach the end of the slots in the recoil cylinder sleeves. The flow of oil is stopped and then, because oil cannot be compressed and presents a solid wall of resistance to the piston, recoil action stops.

Initial Counterrecoil. The counterrecoil springs, which have been compressed, now force the gun forward in counterrecoil. As it moves forward, the operating crank terminal lug contacts the rear of the operating cam causing the crank to rotate downward. Rotation of the crank turns the breech operating shaft, to which is mounted the breechblock crank, that carries a crosshead pivot and two bronze crossheads which operate in a T-slot on the lower side of the breechblock.

Cocking. As the breechblock is moved downward, the end of the cocking lever is cammed forward cocking the gun by riding over a cammed surface on a notch on the right rear corner of the breech ring. The rotation of the cocking lever rotates the cocking fork. The two prongs of the cocking fork force the firing pin guide to the rear compressing the firing spring. The cocking notch of the guide overrides the notch on the sear and compresses the sear spring. The sear spring moves back to the left, locking the guide to the rear.

Extraction and Ejection. As the breechblock continues downward, the top of the two extractors are cammed rearward by means of integral trunnions following grooves in each side of the breechblock. This rotation of the extractors causes first, initial extraction, and then complete extraction which is followed by ejection of the spent round.

When the breechblock reaches the end of its downward travel, the lower ends of the extractors are moved forward by means of the camming grooves in the breechblock, assisted by the extractor springs and plungers which act against the outer trunnions of the extractors.

This forward movement of the lower end of the extractors locks the breechblock in the open position by means of the inner trunnions of the extractors coming in contact with the flats of the vertical lands on each side of the breechblock.

Completion of Counterrecoil. As the breech is opening ready to reload, the gun has continued to move forward on counterrecoil. Therefore, the spearheads of the oil buffers have entered the piston rods.

As the spearhead of the counterrecoil buffers enter the piston rods a buffer action results; further movement of the piston to the front forces the oil through the orifice and against the buffer valve. The pressure of the oil against the valve

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moves it forward against the valve spring tension, thus controlling the flow of oil. This buffer action slows down and cushions the shock of counterrecoil.

Final stopping of the gun is accomplished when the recoil piston rod retaining nuts contact the fibre washers on the recoil cylinder follower.

75MM GUN M5 AND MOUNT M9

Since the Army Air Forces and the Ordnance Department had been able to successfully mount and fire a 75mm from a plane in flight, it was decided that a 75mm gun designed especially for aircraft use would be possible and practical. The M4, 75mm, was a modified M3 Tank Gun and weighed more than 1200 pounds complete with mount. Therefore the idea of a light weight 75mm was very desirable.

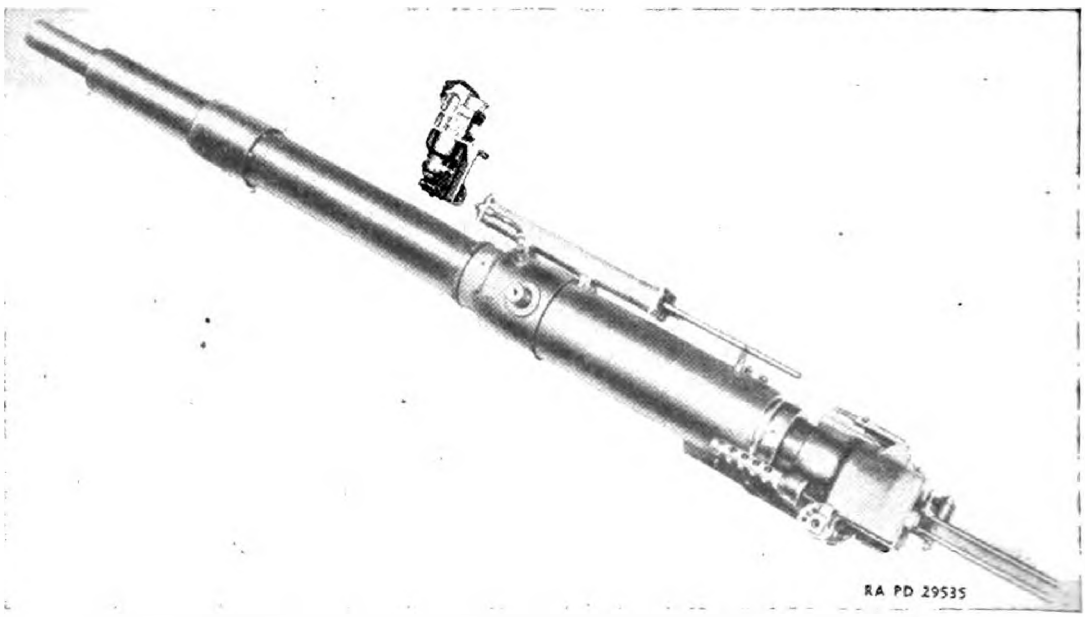

Figure 199. 75mm Gun M5 and Mount M9. Left Side View.

With this thought in mind the weapon started through the blue print stage; finally a model was produced and tests were started. In appearance the new T13E1 Gun was a miniature of the M4. This gun through its development stage was known as the T13; it was later standardized as the M5, 75mm Aircraft Gun. The mount T13 used to mount the M5 gun was standardized as the M9 Mount, Aircraft. Throughout the manual we shall refer to the gun as the M5 and the Mount as M9.

The M5 Gun in outward appearance and construction was very similar to the M4. Since the M4 gun's description and operation have been covered thoroughly we shall discuss here only the differences between the two guns.

Comparison of the M5 with the M4 75-mm Gun. The gun tube was reduced greatly in weight, being much thinner and lighter. In no way did this weaken the gun tube, as the tube is for aircraft use and it was designed along newer and more practical lines. The tube is threaded at the rear and screws into a breech ring of the same basic construction as the M4 breech ring. The tube was locked to the breech ring by a bronze breech ring lock key. The breech ring is rectangular in form except for the front end being cylindrical. The remainder of the breech ring is the same as the M4. The tube is the same length and has the same number lands and grooves and the same uniform right hand twist as the M4.

One difference between the M4 and the M5 tubes and breech rings is that a collar is mounted in front of the M5 breech ring. A shoulder is provided on the front of the threaded breech end of the tube. An integral collar mounted be-

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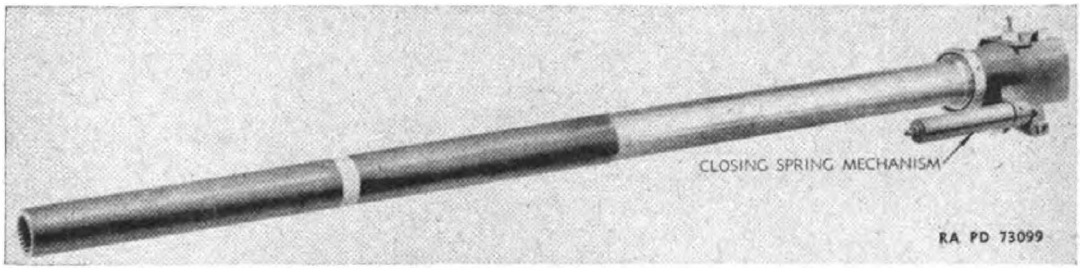
tween this shoulder and the breech ring is threaded and is screwed to the recoil mechanism of the mount. This connects the gun to the recoil cylinder piston. At the front of the tube beyond the machined bearing surface and on the exterior surface an integral collar is provided. A split ring is held in this collar and the ring forms a seat for the counter-recoil spring.

The breech operating mechanism; that is, the operating shaft, the chain terminal



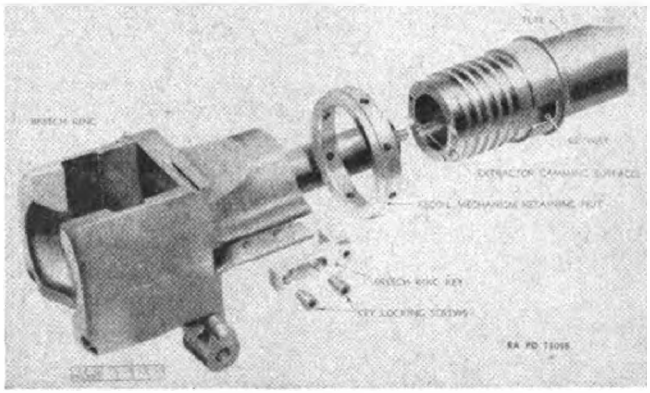


Figure 200. Tube Assembly. General and Exploded Views.

crank, the operating crank, the breechblock crank, and the closing spring mechanism are the same as in the M4 except that they are much lighter in weight and There are no cross heads on the M5 breech block crank; just a pivot pin. Cross heads are not required. The two extractors are located in similar positions in both weapons. The M5 extractors are much smaller and lighter.

The breech block is of the same type in both weapons, being the vertical sliding or drop type. The M5 being lighter in weight and small in size uses smaller and lighter mechanisms to raise and lower it. The type of firing or percussion mechanism is entirely different. The M5 is designed to take the M15 firing lock which is a continuous pull type of firing lock (See Section No. 2 Artillery—Firing Lock M13). The M15 firing lock is locked into the breech block by lugs which mate with lugs in the central bore of the breech block. A trigger shaft extends out of the right top side of the breech block and an actuator (electric motor which delivers impulses when actuated) and actuator plunger contacts and forces the firing pin spring in the firing lock to be compressed; this compressed spring supplies the force to drive the firing pin forward upon release of the sear which is also a part of the lock group.

This type of firing action is very compact and complete and quite practical. From the brief description of the gun assembly (tube, breech ring, and breech block) it can be seen that the gun functions the same as the M4. In recoil the gun moves to the rear in its mount, and on counter-recoil the breechblock is opened, the spent round extracted and ejected, and then the breechblock locks in the open piston. Upon insertion of a new round the breechblock is unlocked and rises to the closed and locked position, ready to fire a new round when the firing button is pressed.

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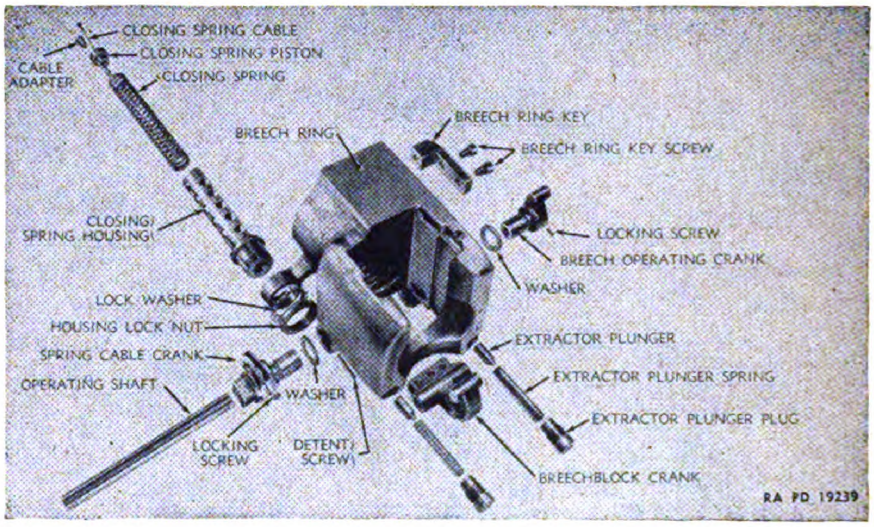
The Mount M9 presents a radical change from the M6 mount though the principal of operation is, relatively speaking, the same. The M9 Mount employs a hydro-spring type of recoil mechanism. The system is concentric, *i.e.*, the piston and spring are mounted around the recoiling and counterrecoiling tube and gun,

The cradle or main support of the mount is one large, bored cylindrical section. This forms the outer cylinder. Two trunnions located on the cradle provide a means of mounting the gun and mount in the plane. Welded to the rear right side of the cradle is a bracket with six holes. This bracket is used to mount



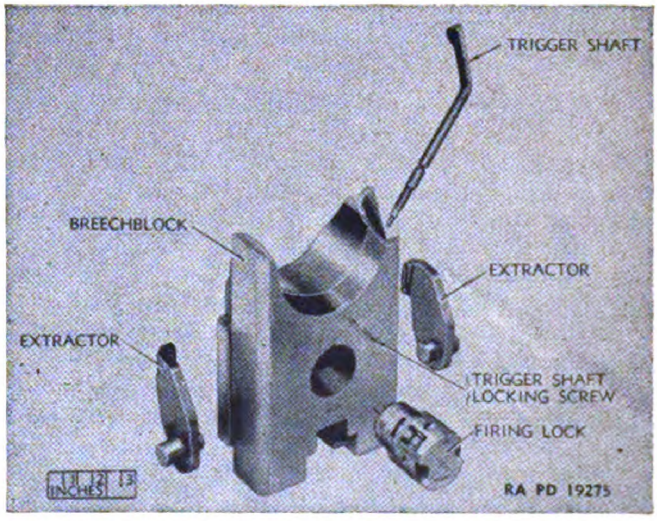


Figure 201. Breech Mechanism and Breechblock.

the operating cam and the breech ring key guide. The M5 gun is guided and controlled through its entire length of recoil and counterrecoil by this guide which prevents rotation of the gun in the mount. The rear end of the guide is hinged and can be swung to the left to reduce the overall length. When the guide is continuous it is locked in place. The operating cam is the same in general appearance and operation in both guns. The method of mounting is slightly different; the M9 operating cam is much smaller and lighter in size and weight as the parts moved by the cam are smaller and lighter.

Four threaded studs on the top central portion of the cradle provide a means

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of mounting the replenisher. Two threaded studs at the rear top of the cradle are used to mount the replenisher piston rod guard bracket.

The recoil cylinder piston fits inside the cradle; the inner walls of the cylinder are so constructed that they taper gradually to the rear and are widest at the front end. At the extreme front end of the cradle, the inner wall is shouldered to provide the necessary throttling action to control counterrecoil and stop the forward in counter-recoil the oil pressure in front of the piston closes the valve, to the rear provides the required throttling action to brake the recoil of the gun in the mount, this action being very smooth and gradual.

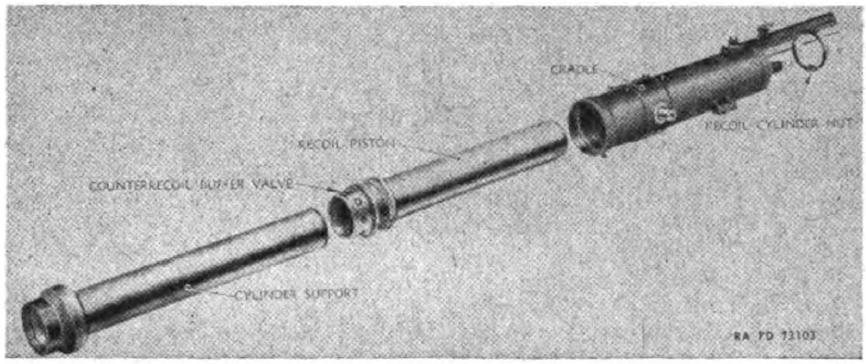

Figure 202. Exploded View of Cradle, Cylinder Piston and Cylinder Support.

The recoil cylinder piston is threaded and locked at the rear to the gun tube by means of a collar. This connection causes both the tube and piston to move as one. At the front end of the piston are the two lands or heads of the piston. The front land is slotted to allow oil to pass both around the outside of the land and inside the slots. A counter-recoil valve and spring positioned in front of the front land is the means of controlling counter-recoil. As the gun moves forward in counter-recoil the oil pressure in front of the piston closes the valve

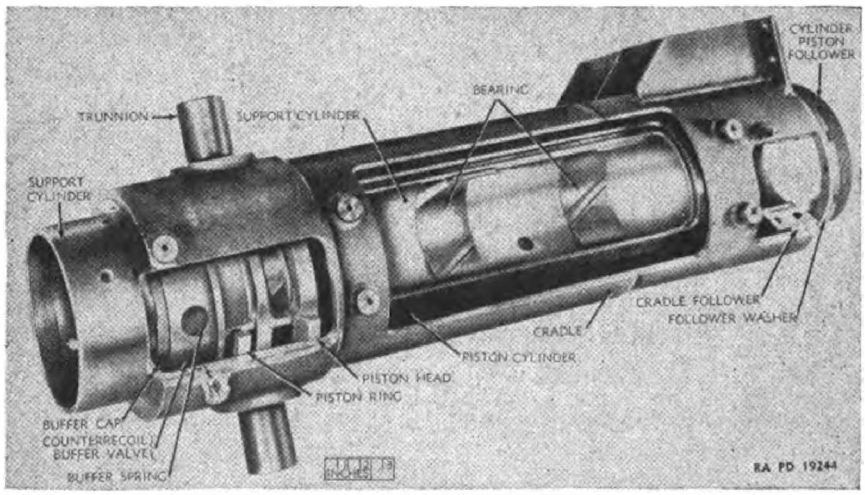

Figure 203. Cradle, Sectional.

shutting off the flow of oil through the slots and also compressing the valve spring.

Near the very end of counter-recoil the valve spring overcomes the force of the oil and opens these ports or slots and allows the gun to move completely forward into position. At the rear of the piston where it works through the cradle, a neoprene packing ring, seated in a recess in a bronze collar threaded to the rear of the cradle, prevents oil leaks between cradle and the piston as the piston moves in recoil and counter-recoil with the gun.

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The recoil cylinder piston rides over the piston support. The piston support is a long cylindrical tube fitted inside the piston. On the inside of the piston support there are three bronze bearings that provide a bearing surface for the gun tube as it moves in recoil and counterrecoil. On the outer surface of the support additional bronze rings provide a bearing surface for the piston as it moves in recoil and counterrecoil. The front end of the support is flanged and threads into the front of the cylinder. This locks the support in a stationary position. A neoprene packing ring provides an oil seal to prevent oil leaks around the support. At the rear of the support a neoprene packing ring is located in a recess in the piston support preventing oil from escaping between the piston and support. The counter-recoil spring is assembled inside a cylindrical spring housing the rear end of the spring seats against a ring spring type buffer (Belleville Spring). The ring spring in turn is seated against a collar. The rear end of the housing is threaded into the support cylinder and therefore is held stationary. The front end of the spring is seated against a seat, the seat is held in place by a collar threaded to the front end of the housing. A split ring in turn is assembled in the recess in the gun tube and contacts the seat at the front end of the counter-recoil spring. Therefore, as the gun recoils the split ring seated on the spring seat compresses the spring as the gun tube moves to the rear inside of the spring housing. The spring being compressed and the oil being throttled in the cradle, stop or overcome the recoil force of the gun. The compressed counter-recoil spring therefore returns the gun to its normal position in the mount as the spring expands. There is enough force in the assembled and compressed spring to hold the gun in its forward position at all times.

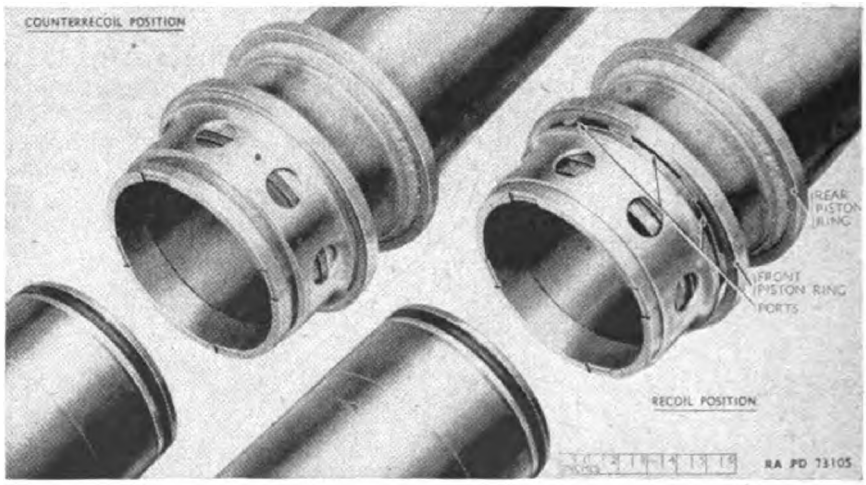

Figure 204. Counterrecoil Buffer Valve.

A cylindrical tube called the front cover fits over the front end of the counter-recoil spring housing and is locked by four latches to the spring housing.

Some of the first M9 mounts had two counter-recoil springs separated by a spacer assembled in the spring housing. The ring spring used with one large spring gave much better results. Therefore, all the newer M9 mounts are manufactured with the latter type of spring and ring spring. (See T.B. 9-1313-2 dated August 2, 1944).

The replenisher is the same as the replenisher used on the M4 gun. No replenisher gage is needed though as the calibrations are painted on the piston rod guard, and the filling hose is protected and covered with a mesh wire cover.

Drain and fill plugs located in the cradle are used to fill the cradle when it is completely empty. Normally oil is put into the system through the check value and filling hose of the replenisher.

The actuator is an electric motor driven at all times during flight. When the pilot presses the firing button a clutch in the actuator engages and imparts an impulse to the actuator rod. The rod, through its linkage and cable, therefore

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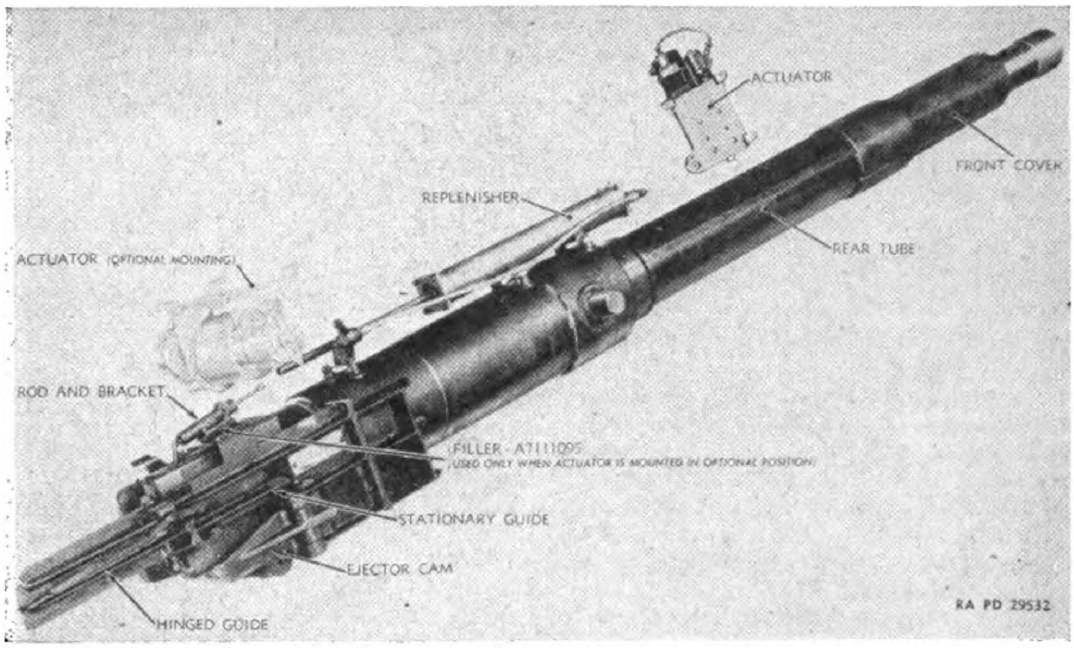

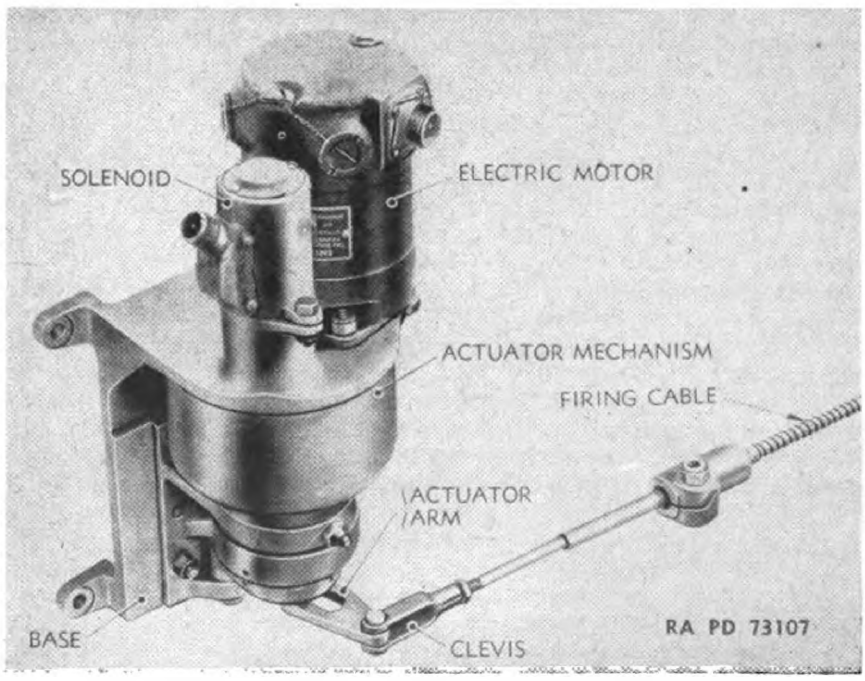

Figure 205. Firing Mechanism Actuator Assembly.

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delivers this impulse to the plunger which is in contact with the trigger shaft in the breechblock. As the shaft rotates the firing pin spring is compressed and then released driving the firing pin forward to strike the primer.

The clutch is disengaged from the motor automatically therefore only one impulse is delivered to the trigger shaft. The gun returns in counter-recoil and the trigger shaft returns to position behind the actuator plunger. The pilot must press the firing button again in order to release the firing pin to fire the gun. The actuator may be mounted at alternate places in the plane. When the forward mount is used an actuator cable is used; when the rear mount is used the linkage connection is converted directly to the plunger.

Operation. The operation of both the M4 and M5 guns is the same but the hydro-spring concentric recoil system of the M9 mount is a little different. Therefore the operation of the M9 mount will be covered.

When the gun is fired the force of the expanding gases propel the projectile forward; the same force expanding in the opposite direction forces the gun to move to the rear inside the mount as the breech end of the gun is closed by the breechblock.

As the gun moves to the rear, it carries with it the cylinder piston. The oil at the rear of the piston is forced around the piston rings. The bore of the cylinder of the cradle is tapered gradually to the rear and as it decreases in diameter, the oil is gradually throttled around the ring of the rear piston and the recoil of the gun is stopped in a slow and smooth manner. During recoil, the collar machined on the front end of the tube bears on the split rings and carries them back, compressing the counter-recoil spring. The ring spring provides the proper buffer action. The spring working with the throttling action of the piston in the cradle produces a smooth action; hence the recoil force is overcome so evenly that the force does not materially effect the flight of the plane when the gun is fired.

When the recoil of the gun is stopped, the counterrecoil springs bear on the collar machined on the gun tube and force the tube forward. The cylinder piston being attached to the gun tube will therefore move forward at the same time. The recoil oil is now forced around the piston rings and into the rear of the cradle. At this time the oil pressure in front of the piston is greatly increased. The increase in oil pressure forces the counterrecoil buffer valve to move to the rear, overcoming the spring tension of the valve spring. As the buffer valve moves to the rear against the front piston ring, the ports in the ring are closed. The front en dof the cradle, having a distinct shoulder of smaller diameter than the bore, will throttle the oil around the head of the piston and thus control the counterrecoil of the gun. The gun is slowed down in counterrecoil rather quickly. The movement is not slow, nor gradual, as it is in recoil. The force of the compressed counterrecoil springs and the inertia of the gun itself permit the gun to be returned quickly to its forward position; therefore, the buffing action is required only in the final stage. When the gun is almost in position the buffer valve spring overcomes the oil pressure and opens the buffer valve, allowing oil to pass through the ports in the front piston ring. By the action of the counterrecoil buffer the gun is returned to battery position without shock or damage to the gun and mount. The fibre washer on the front end of the recoil cylinder follower prevents damage to the gun or mount at the point of separation of the gun and mount and also buffs the final movement of the gun in counterrecoil.

The operation of the M5 Gun is the same as the M4; on counterrecoil the breechblock opens, and the spent case is extracted and ejected. The breechblock remains in the open position until a new round is manually loaded and the breech block returns to the closed and locked position, ready to fire a new round.

The inspection, care, preservation and maintenance of the M5 gun and M9 mount are similar to the M4 gun and M6 mount. For this reason inspection data generally applicable to both weapons is furnished below.

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GENERAL DATA FOR THE 75mm AIRCRAFT GUNS

	Gun M4, Mount M6	Gun M5, Mount M9
Weight of Gun Assembly (Gun, Breech Ring and Breechblock)	893 lbs.	410 lbs.
Weight of Tube	628 lbs.	.....
Weight of Gun M4 and Mount M6 (approx.)	1200 lbs.	763 lbs.
Length of Bore, calibers	37.5	37.5
Length of Tube	116 ins.	116 ins.
Length of Gun (overall)	118 ins.	129 ins.
Type of Breechblock	Vertical sliding wedge.	Vertical sliding wedge.
Muzzle Velocity (HE M48 w/super charge)	1970 f.p.s.	1970 f.p.s.
Muzzle Velocity (APC M61)	2030 f.p.s.	2030 f.p.s.
Muzzle Velocity (AP M72)	2020 f.p.s.	2020 f.p.s.
Rate of Fire (normal)	3-5 rds. per min.	.....
Rate of Fire (maximum)	30 rds. per min.	.....
Chamber Pressure (maximum)	38,000 p.s.i.	36,000 p.s.i.
Weight of Fixed Round (APC)	19.92 lbs.	19.92 lbs.
Weight of Fixed Round (HE)	19.56 lbs.	19.56 lbs.
Weight of Fixed Round (AP)	18.80 lbs.	18.80 lbs.
Weight of Powder Charge (APC and HE)	2.0 lbs.	2.0 lbs.
Weight of Powder Charge (AP)	1.9 lbs.	1.9 lbs.
Weight of Projectile (APC)	14.96 lbs.	14.96 lbs.
Weight of Projectile (HE)	14.40 lbs.	14.40 lbs.
Weight of Projectile (AP)	13.94 lbs.	13.94 lbs.
Recoil Length, normal	21 ins.	21 ins.

INSPECTION OF 75MM AIRCRAFT GUNS M4 AND M5

General. Maintenance inspection is for the purpose of determining by critical examination the condition of materiel in order to see whether repairs or adjustments are required, that all modifications authorized by Field Service Modification Work Orders have been made, and to insure that the materiel is in serviceable condition and will function properly.

Maintenance, and to a certain extent inspection, is the joint responsibility of both the Air Force Armament Section and Ordnance personnel. But maintenance, of necessity, must be primarily the responsibility of the using arm since it is so closely linked with the use of the weapon. Ordnance inspection is largely a check to make sure that the materiel is properly cared for and is also a check on matters beyond the scope of the using arm.

Visual Inspection. Visual inspection is of the utmost importance to this materiel. It will consist generally of the following:

1. Check for proper assembly of both gun and mount and of assembly of gun to mount.

2. Check for completeness with emphasis on oil and refill plugs, and check hose connections for leakage of oil. Check for presence of cotter pins, springs and plungers.

3. Check for proper cleaning and observe the general appearance. Check the bore for copper deposits on lands and in grooves; also for erosion at origin of rifling. Check for pits and scratches which effect the accuracy of the weapon. All moving parts should be cleaned thoroughly. Special attention should be given to the recesses in which springs and/or plungers work.

4. Check for proper lubrication; the proper lubrication prevents wear, scoring, cracks, burrs, pitting and rust. Oil is a vital necessity but should be used sparingly. Only prescribed lubricants will be used. Check for use of the proper type of recoil oil and that the oil level is correct in both recoil cylinders and in replenisher.

5. Check for proper action of the parts when breech block is hand operated and a dummy round inserted in breech.

6. Check for broken, rusty, burred or worn parts. Check for sharp edges on all parts, both stationary and moving.

7. If possible, check for proper action of the gun when it is test fired or consult crew chief for action during firing.

Gage Inspection. Gage Inspection consists of those points of inspection which must be done with rulers, depth micrometers, feeler gages, etc. For the ordnance man gage inspection is of great importance and usually he is the only person able to do such inspecting.

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(In the following points of inspection, CF stands for "Check for", and CA stands for "Corrective Action.")

Bore. CF—Copper deposits on lands and in grooves. Erosion of tube, nicks, scratches, pitting, scoring in bore.

CA—The effect of above listed defects may be due to accidents or improper care. These defects allow leakage of gas from the rotating band of the projectile and thereby promote further erosion of the forcing cone, or cause wear to the rotating band. When this occurs the projectile does not attain its proper rotational velocity. Such defects should, therefore, be smoothed and rounded, and on basis of their location, and extent, determination should be made as to whether they are apt to be injurious from the point of view of gas leakage or wear on the rotating bands. No definite rule can be used in making this determination. Tubes badly scored beyond the forcing cone should be reported to the Chief of Ordnance for final action.

CF—Normal or abnormal wear and erosion of bores and chambers of cannon to determine their remaining accuracy life and their fitness for use.

CA—Average life of the gun tube is approximately 6,000 rounds. The guns in service should be star gaged after approximately 10% and 90% of their estimated accuracy life, and thereafter at each 10% during the remainder of their service. Tubes are star gaged any time an inspector may find it is desirable due to unusual wear or other irregularities in the bore. Star gaging equipment is not issued to all ordnance companies but may be obtained from a heavy ordnance maintenance company or the Army inspector of Artillery. When star gaging equipment is not available, the inspection report on "diameter of the bore at a point 95.8 inches from the muzzle" must be recorded as "not taken". The point of maximum wear of the lands is 95.8 inches from the muzzle. Tubes must be withdrawn from service when wear at this point is in excess of 0.025 inch increase in diameter. Record of all star gaging will be entered in the gun book assigned to the gun.

CF—Pastilles (defects that do not show up until some wear on bore uncovers them).

CA—The effect of pastilles upon the safety and accuracy of the gun is thought to be negligible. However, as a precautionary measure, guns having more than 3 pastilles the size of a 5 cent piece are withdrawn from service.

CF—Deformation of the rifling at the origin, in general, consists of sheared lands and a flow of the metal in the grooves so that the effectiveness of the rifling for the first inch or two is considerably reduced.

CA—This is a serious defect and gun tubes showing it to a marked degree will be withdrawn from service.

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TM 1980-4	Bombs for Aircraft
TB 980-2	Bombs for Aircraft; Painting and Marking
TB 9-1980-17	Bomb Fragmentation, 260# M81 (T10)
SNL S-1	Part I and II—Aerial Bombs and Fuses
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Depth Bombs, Aerial Mines, Torpedoes, and Their Fuses

TB 1900-16	Open Storage, Depth Bombs, Equipped with Transverse Hydrostatic Fuses
TB 1975-2	Mine, Aircraft Mk 13, (Navy)
O.P. (Navy) No. 950	U. S. Navy Torpedoes Mark 13, Mod. 1 and 2
O.P. (Navy) No. 988	U. S. Navy Fuses

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TM 9-395	4.5 Inch Rocket Materiel
	The Ordnance Sergeant
OS 9-63	Rockets and Launchers All Types, Feb., 1944
W.D.T.B. 9x-48	Preliminary Instruction on 4.5" Rockets
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TM 1-500	Bomb Racks, Tow Target Equipment, and Flare Racks
TM 9-760	Bomb Trailer M5
TM 9-762	Lift Truck M22
TM 9-765	Bomb-Service Truck M6 (Chevrolet)
TC 79 Sec 1	Lift Truck M22
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Aircraft Armament—Gun, Automatic, 20mm, M1, AN-M1, AN-M2, AN-M3

TM 9-227	20mm Automatic Gun M1, and 20mm Automatic Gun, M1 and AN-M2
TM 9-1227	20mm Aircraft Gun M1 and AN-M2
TO 11-1-21	Air Corps Technical Order (Ref. 20mm Automatic Gun M1)
OS 9-45	Gun, Automatic, 20mm, M1 and M2
SNL A-47	Gun, Automatic, 20mm, M1 and AN-M2, List of Parts
TB 227-1	Gas Port
TB 227-3	Ammunition
TB 227-5	Rear Buffer Sleeve 20mm Aircraft Gun M1 and AN-M2
TB 1227-2	Breech Block Slides
TB 1227-3	Firing Pin

Aircraft Armament—37mm Automatic Gun M4, M9, and M10

TM 9-235	37mm AA Gun Materiel
TM 240	37mm Aircraft Gun Materiel M4

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TM 241	37mm Automatic Gun, M9
TM 9-1240	Ordnance Maintenance 37mm Automatic Gun M14 (Aircraft)
	37mm Automatic Gun M4 and M10
SNL A-57, A-46	37mm Automatic Gun M9

Aircraft Armament—75mm Aircraft Gun M4 and M5

TM 9-311	75mm Aircraft Gun
TM 9-312	75mm Aircraft Gun
SNL C47	75mm Aircraft Gun M4 and Mount, Gun, Airplane M6
SNL C60	75mm Aircraft Gun M5 and Mount, Gun, Airplane M9

Aircraft Armament—General

SNL A-35	Tools, Maintenance for Repair of Automatic Weapons
SNL K-1	Cleaning, Preserving, and Lubricating Materials; Recoil Fluids, Special Oils, and Miscellaneous Related Items
SNL R-1	Ammunition, Fixed and Semi-Fixed All Types
TM 9-850	Cleaning, Preserving, and Lubricating Materials
TM 9-1900	Ammunition, General
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CHAPTER 5

AUTOMOTIVE

INTRODUCTION

A fundamental change in the art of war was effected when armies were put on wheels. No longer was the speed of advancing columns limited to the plodding pace of the pack horse. World War One witnessed a logical development, the tank, from which has sprung a whole family of armor clad vehicles. Today our army lives, moves, and fights to the rhythm of the internal combustion engine. During the past decade our automotive equipment has increased both in quantity and quality until today we are equipped with the finest and most capable motorized equipment in the world. Our vehicles are numbered in the millions; and one of the functions of the Ordnance Department is the development, storage, issue, and maintenance of this gigantic fleet.

In view of the immensity of the problem, it would be an ideal situation if all military personnel were conversant with the problems of automotive operation and maintenance, but this is obviously impractical. It would seem essential, however, that all officers, particularly Ordnance officers, be armed with at least a working knowledge of automotive materiel. The pages which follow will provide that working knowledge. The treatment of basic functions of automotive components presented here is necessarily general in nature and hence will be of value to a qualified automotive officer only as an interesting review of underlying principles, but, the officer who has had little or no previous experience with automotive work will find the succeeding pages immensely valuable since they offer a wealth of information in a highly condensed form. He should, however, read and reread this text and supplement his studies with the references furnished at the end of this chapter which consider the various topics in more comprehensive detail.

The importance of automotive maintenance cannot be overemphasized. One of our highest ranking officers made the statement that far more materiel is deadlined as a result of improper maintenance than by enemy action. By the same token, a large percentage of our materiel will reach the scrap heap long before it should because of abuse in operation and maintenance. If Ordnance officers as a group were to assimilate and apply the lessons in the section which follows, our tanks and self-propelled artillery, our jeeps, our trucks, and our tractors would give better service for a longer period of time. If this were so, the transportation problem would be greatly alleviated by the additional vehicles being available for duty and the logistics involved in planning campaigns would be further simplified.

If an additional incentive were required to convince the Ordnance officer that this section of the book warranted his attention, it would be found in the fact that American mechanical genius is contributing heavily to improvement in design and performance abilities of military vehicles. The world justly considers the United States the treasury of 'know how' in the mass production and intelligent use of automotive equipment. Then again, men of other branches of the Army look to the Ordnance soldier and particularly the Ordnance officer for expert advice regarding all Ordnance materiel whether it be automative, artillery, small arms, fire control or other sections in the broad field of Army Ordnance.

The automotive power train is developed in logical sequence starting with engine theory, design, functioning, construction and accessories and continuinig through such assembly components as clutches, transmissions, transfer cases, hydraulic drives, differentials, final drives, axles and the wheel and braking systems. The broad subjects of tires and tubes, automotive electrical systems, vehicle accessories, vehicle characteristics, suspension systems and ytpes of vehicles, although lightly touched, contain much information even for the initiated automotive officer who (like so many specialists in this war) has had difficulty in keeping abreast of rapid developments in the field.

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Perhaps better sources of automotive problem solutions than the data given here will be available to many ordnance officers in the field, but readers should bear in mind that the bedding-roll is yet to be made which is capable of carrying the size book which would be needed to furnish all the answers.

ENGINES

Introduction

In the "Age of Power" we have come to accept large numbers of different types of engines as typical means of converting the large amounts of heat energy contained in various fuels into useful work. This work provides a means of transporting man over land, sea, and air; whether his mission be war or peace. External Combustion Engines (principally steam engines) power vast armades of mighty fighting and cargo vessels while Internal Combustion Engines are used as power plants for airplanes, tanks, and transport vehicles.

This discussion will be limited to Internal Combustion Engines and will only outline the general theory and principles involved. The purpose of the article is not to swamp the reader with equations and advanced theory, but rather to cover the fundamentals in such a manner as to clear up any misconceptions that he may have and to instill the confidence which comes of having reliable information.

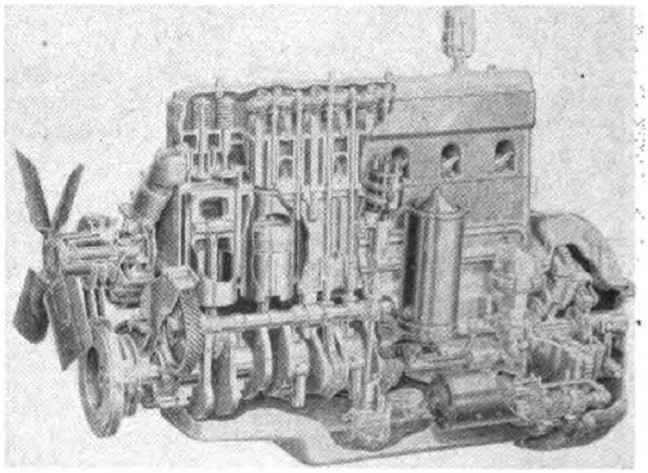

Figure 1. Cutaway View of Engine.

BASIC PRINCIPLES

Internal combustion is the burning of fuel inside of a closed chamber. An internal combustion engine is a device for converting the heat energy produced by burning fuel in a closed chamber into the form of torque (turning effort) at the output shaft or crankshaft.

Just as a boulder perched on the edge of a cliff has potential energy which it would release upon falling, so engine fuel (usually a petroleum extract) has potential energy which it will convert into heat energy upon burning in air. A gas, when subjected to the heat produced by burning fuel, will act in accordance with a physical axiom which states that a gas under constant pressure will expand if its temperature is raised. In an engine, however, heat energy is added to the gas which is confined and can *not* expand. Under these conditions a sharp increase of pressure is produced, which presses down on the piston head thereby setting the entire engine mechanism in motion.

Let us consider the minimum essentials necessary to convert fuel energy into mechanical energy and translate it into power at the crankshaft.

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For conversion of the fuel energy to heat energy the engine requires *oxygen* which, by volume, is one-fifth of the atmosphere. Therefore, air will be introduced inside of the engine to react with *fuel*, the source of energy. The combination of fuel and air brings us to our third indispensable factor—*ignition*. Ignition is the initiation of the oxidation of the fuel air mixture. Ignition must occur at precisely the right moment to enable the piston to convert the power of the expanding gases into mechanical energy. In the process of energy conversion, the engine must be capable of inducting fuel and air into the combustion chamber, compressing the mixture, igniting it, and utilizing the high pressures developed during combustion and expansion of the gases.

To be of practical use, output power must be furnished by the engine in a smooth, continuous flow. This is accomplished by running the engine in a definite, repeating sequence of operations or 'events.' During an event the piston makes one complete traverse of the cylinder, hence the words stroke and event have become synonomous. A complete series of events constitutes one cycle. An engine will run on either Two or Four Stroke Cycle operation depending upon its design. Four stroke cycle operation engines are found in most service vehicles and equipment although two stroke cycle operation is common in Diesel engines.

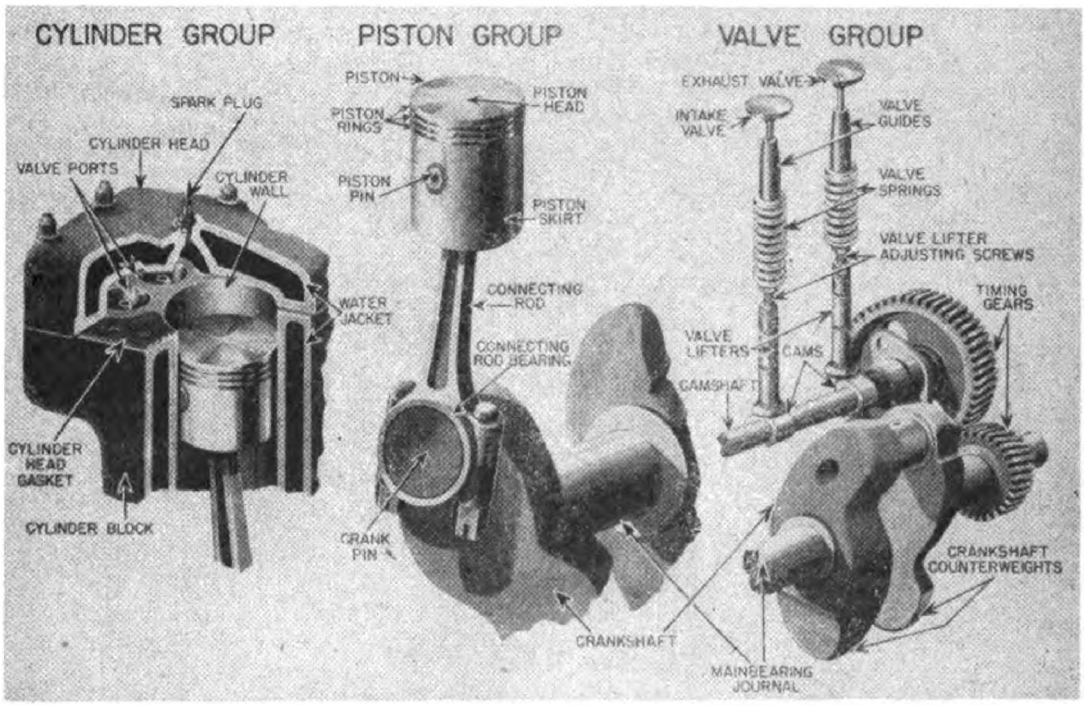

Figure 2. Operating Parts of Otto Four Stroke Cycle Engine.

To control combustion the fuel-air mixture is ignited in a *cylinder* of nearly straight bore which is closed at one end. Closure of the opposite end of the cylinder is effected by the *piston* which has grooved slots for fitted *piston rings* that insure a tight gas seal along the cylinder wall and afford a means of transfering heat of combustion from the piston to the clylinder wall. Below and attached to the piston is a *connecting-rod* which transfers the reciprocating motion of the piston to the rotary motion of the *crank*. Normally, two, four, six or more cylinders are inter-connected within a single engine, the various cranks merged into one integral part called the *crankshaft*. The cylinder is covered at the closed end by a *cylinder head* which contains *ports*, which are alternately opened and closed by the *intake* and *exhaust valves*. Depending on the particular engine design, valves and ports may also be located in the engine block *beside* the cylinder. An opening also is provided for the *spark plug*, which, at the proper

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instant, will furnish the spark for ignition of the fuel-air mixture in the cylinder.

It can be readily understood how the engine translates piston movement of the cylinder to rotary motion of the crankshaft by comparing the motion to that of a bicycle-rider's leg. The piston pin corresponds to the rider's knee, the connecting rod to his lower leg, the crank to the bicycle pedal, and the crankshaft to the pedal sprocket spindle. Since the crank can travel only in a circular path, it is seen that rotary motion of the crankshaft will result. Note also that, by virtue of the position of the crank relative to the crankshaft and piston, the piston traverses the cylinder *twice* for each revolution of the crankshaft. *Two* strokes or events will occur during this movement of the crankshaft. In following the discussion of two stroke and four stroke cycle operations, bear in mind that the crankshaft moves the piston except when the piston is driven downward by gas pressure in the cylinder. The opening and closing of valves is effected by cams connected to a *camshaft* which in turn is driven by the crankshaft. As will be discussed later, the time of ignition is also controlled by gear linkage with the crankshaft.

In 1876, Dr. N. A. Otto determined the most efficient thermodynamic relationship of harnessing the power in an internal combustion engine.

Today, most gasoline engines use his principle. The 4-stroke "Otto" cycle is as follows:

Intake Stroke. The intake valve is open and the exhause valve is closed. The piston at the end of its upward stroke (Top Dead Center) in the cylinder. As the piston moves down, it produces a partial vacuum within the cylinder causing air and fuel (pre-mixed in correct proportions) to be drawn into the cylinder through the intake port by atmospheric pressure or a blower. At the end of the downward stroke of the piston the intake valve is closed.

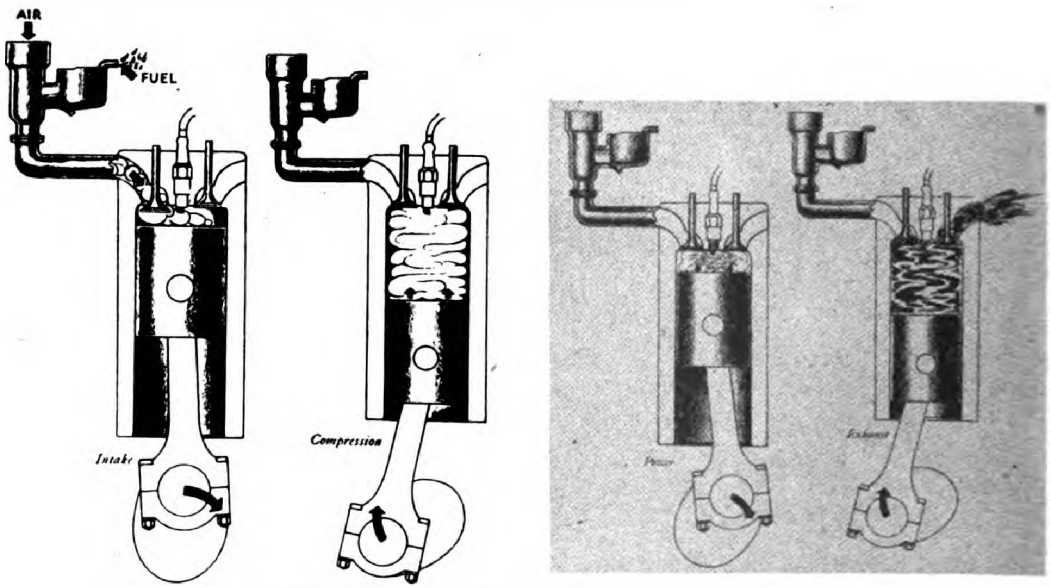

Figure 3. Events of the Four Stroke Cycle.

Compression Stroke. Intake and exhaust valves are closed. The piston is at the bottom of its stroke (bottom dead center) in the cylinder. As the piston moves up, it compresses the fuel-air mixture into a fraction of its former volume at the top of the cylinder. At the completion of the intake and compression strokes, the crankshaft has made one complete revolution.

Power Stroke. Both valves remain closed. The piston is at top dead center. The compressed fuel-air mixture is ignited and a very rapid increase of pressure results. This pressure forces the piston downward, delivering power to the crankshaft.

Exhaust Stroke. Intake valve remains closed but the exhaust valve opens. The piston is moved upward by the crankshaft and pushes the products of combustion

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out the exhaust port. When the piston reaches top dead center, the exhaust valve closes and the intake valve opens. The crankshaft has made two complete revolutions and the 4-stroke cycle is completed.

The reader will note several important points about the four stroke cycle operation. The exhaust valve and intake valve each opened once during the cycle. Separate cams affixed to a single camshaft actuate this valve movement. Since the valves move once and the crankshaft makes two revolutions per cycle, it follows that the camshaft runs at one-half crankshaft speed (Engine R.P.M.).

Gearing for the ignition will provide only one electrical impulse to each cylinder at the beginning of its power stroke during one cycle. Logically, smooth power output in a multi-cylinder engine will be achieved by timing the power strokes of the various cylinders so that they occur at equal intervals over the two crankshaft revolutions necessary for all cylinders to fire. One revolution of the crankshaft sweeps through a complete circle of 360° and two revolutions through 360 x 2 or 720°. Hence, in a six cylinder engine, power strokes will be 120° apart. Armed with this principle, it is possible for the reader to see why the cranks are arranged 120° apart on the crankshaft of a six cylinder engine.

An engine operating on the principle of the Otto cycle has the following advantages: low weight per horsepower, low cranking effort, wide speed and load variation, good mechanical efficiency, and relatively low fuel consumption at full throttle. These factors are necessary for a practical internal combustion engine. This discussion has been limited to the theoretical cycle whereas in reality each type engine operating on the four stroke cycle has its own design features in which the valve and ignition operations vary slightly.

The Two Stroke Cycle. The reader is again referred to basic engine operation factors. In two stroke cycle operation, two 'events' occur each time the piston traverses the cylinder. In effect, power is developed on alternate strokes of the piston. This cycle represents a slightly modified four stroke cycle and is commonly used in the operation of diesel engines and some motorcycle and outboard engines. The principle design difference between two and four stroke cycle engines is the location of the valves about half-way down the cylinder bore such that the piston movement opens and closes the ports. Ignition may be automatic from compression of the fuel mixture (diesel operation) or by spark-ignition. The air flows into a separate crankcase where it may be used at atmospheric pressure or compressed by a blower prior to entering the cylinder. The cycle is the same in either case. In diesel engines, the fuel is injected directly into the combustion chamber; hence, the crankcase compression of the air or mixture. Large engines usually employ valves or ports and vales and a separate compressor or blower for further building up the crankcase pressure.

Exhaust and Intake. Consider the piston to be moving downward from TDC (top dead center) before a power stroke. The exhaust valve or port is opened prior to the piston's reaching the bottom of its stroke, thereby beginning the expulsion of the combustion products. Moving further downward, the piston uncovers the intake port. At this stage both valves are open; fresh air or mixture under pressure is flowing into the cylinder and pushing out or 'scavenging' the remaining exhaust gases from the combustion chamber.

Compression and Power. The piston is now moving upward from BDC, (bottom dead center). Both the intake and the exhaust valves or ports have been closed. The air or mixture is being compressed. With the injection operation commonly used in diesel engines, fuel is forced into the combustion chamber as the piston nears TDC, and ignition of the fuel air mixtures comes either as the result of heat produced by the piston's highly compressing the air (diesel cycle), or by electrical spark ignition. The crankshaft has made one revolution.

The reader may at once observe certain advantages for two stroke cycle operation. For example, there are twice as many power strokes as compared to four stroke cycle operation at the same speed, which means an increase of 50 to 80 percent in power output with the same piston displacement. A 100 percent gain in power is not obtained because in scavenging burned gases from the cylinder, some of the fresh air or mixture is lost out of the exhaust port. Also a portion of the burned gases becomes mixed with the new charge, resulting in higher fuel consumption.

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General. Before proceeding, it would benefit the reader to become familiar with certain terms pertaining to engine operation since their usage in discussions of engine performance is very common.

Compression Ratio. The compression ratio of an engine is the ratio of the total volume of the cylinder as uncovered by the piston in completing its downward stroke to the clearance volume or the volume in the cylinder when the piston is at the top of its stroke:

$$\text{Comp. Ratio} = \frac{\text{Piston Displacement plus Clearance Volume}}{\text{Clearance Volume}}$$

Common compression ratios for gasoline engines lie between 6 and 7.5 to 1. For diesel engines, the compression ratio goes up as high as 16 to 1 for reasons which will be explained later in this section.

The engineer frequently speaks in terms of 'efficiency'. With engines, we are concerned chiefly with volumetric, thermal, and mechanical efficiency.

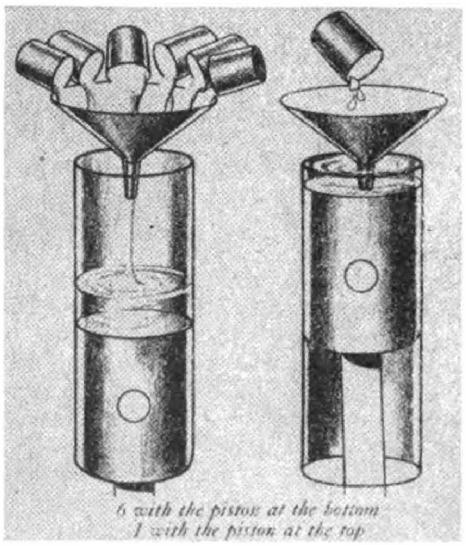

Figure 4. Compression Ratio.

Volumetric Efficiency is defined as the ratio of air or air-fuel mixture actually taken into the engine to the piston displacement. The volumes of these gases are measured at equal temperatures and pressures.

$$\text{Volume Efficiency} = \frac{\text{Volume of charge entering engine}}{\text{Piston Displacement of Engine}}$$

Sometimes this ratio is referred to as the 'breathing capacity' of the engine, since an engine may actually be considered to be an air pump. The engine must 'breathe' large quantities of air, and its power output will vary according to the amount of air it receives. Means of introducing fuel into this air is a delicate and technical task in itself, but not so vital to engine output as is providing maximum amounts of air. In general, this 'breathing capacity' will vary with valve timing, the elimination of sharp curves or restrictions to flow in the intake pipe or manifold, and presence of a fan or blower which would force air or mixture into the cylinders.

Thermal Efficiency is defined as the ratio of heat developed into useful work by the engine to the potential heat energy of the fuel. Since the metals of the combustion chambers could not stand the consistently high tempratures of the burning gases, provisions must be made to cool the metal to within safe limits. Cylinder walls are, therefore, cooled by water or air passing over the outside surface. This heat loss represents up to 35% of the fuel's energy. In addition, it will be seen that exhaust gases will be expelled while at a very high temperature, and will therefore carry away a great deal of energy. This loss represents about 40 percent of the fuel's input energy. Friction between moving parts of the

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engines absorbs about 5% of the heat energy. *These losses leave only about 20% of the heat energy of the fuel being converted to useful work at the engine crankshaft.*

In speaking of loss through friction within the parts of the engine itself, the engineer uses the term 'mechanical efficiency.' Excluding the heat losses, mechanical efficiency is the ratio of the power output of the crankshaft to the power developed at the piston. The losses through bearing friction and the power to operate various accessories and valve trains are appreciable to the extent of absorbing up to 15% of the available power at the piston.

GASOLINE ENGINES

In determining the reasons for the success of the internal combustion engine, a discussion inevitably leads to the development of petroleum fuels as the source of power for these engines. Gasoline, for example, has far more potential energy per unit weight than any of the common high explosives. In addition, it is comparatively safe to control and handle, and can be carried in a vehicle or airplane in quantities capable of driving the unit hundreds or even thousands of miles.

In referring to gasoline or spark ignition engines in particular, the fundamental requirements of *air, fuel, and ignition* as applied to the standard four stroke cycle will be considered.

Air. The gasoline engine 'breathes' a mixture of fuel and air supplied by the carburetor through the intake manifold in a ratio of approximately 15 parts of air to 1 part of gasoline by weight. This ratio will vary somewhat either way, depending upon whether power output or economy is of prime importance. Gasoline weighs approximately 600 times as much as air at sea level so that the ratio of air to gasoline by volume is approximately 9000 to 1. It is logical, therefore, to consider the gasoline engine as an air pump.

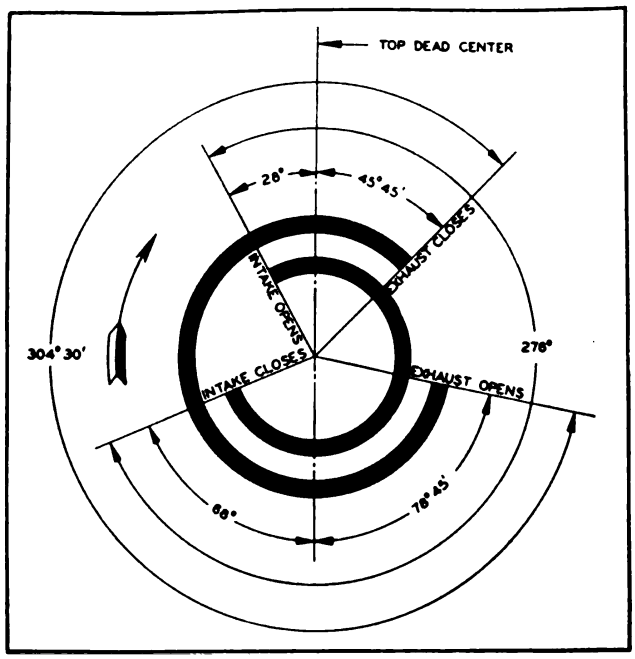

Figure 5. Typical Valve—Timing Diagram.

In the discussion of volumetric efficiency, it was mentioned that valve timing played an important part in keeping the breathing capacity of an engine at its peak. In basic considerations it was assumed that the intake and exhaust valves opened and closed at TDC; however, considering the amount of air 'breathed' by the engine, this moving air has enough mass to cause an inertia effect, and it is by properly applying this effect to valve timing that breathing capacity is greatly

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increased. In a standard cycle, the intake valve is open during the intake stroke and is permitted to remain open as long as 30 to 75 degrees after BDC, because the inertia of the moving air will cause it to continue to flow into the cylinder regardless of the piston's upward motion. Approximately two-thirds of the way down on the power stroke the exhaust valve opens in order for the pressure in the cylinder to help push the burned gases out. The exhaust valve remains open during the exhaust stroke and the first 5 to 20 degrees of the intake stroke, again taking advantage of the inertia of the moving gases. During the flow of gases out of the exhaust port, a low pressure area is created under the intake valve so that this valve can be opened effectively before TDC. This situation, arising when both valves are open as long as 30 degrees between exhaust and intake strokes is termed 'valve overlap.' Valve overlap increases with high speed engines; this results in fairly rough operation of such engines when running at idle or low speeds.

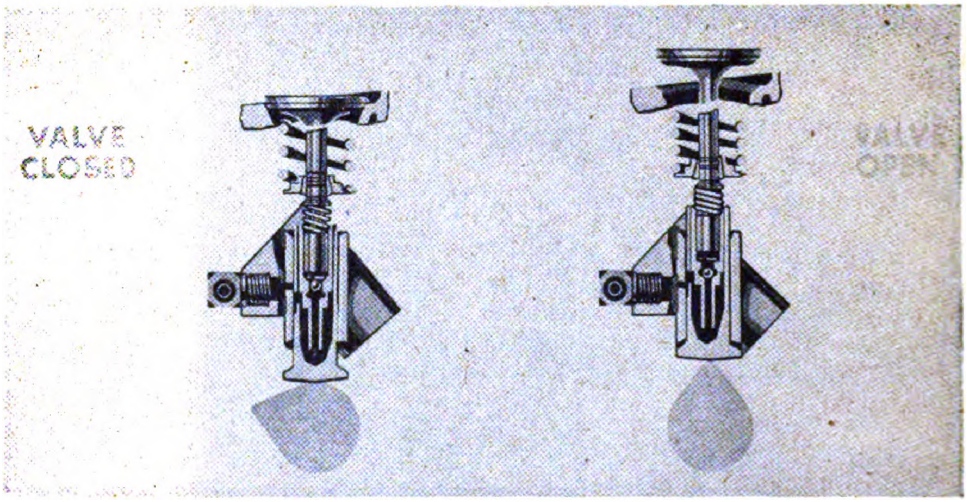

Figure 6. Automatic Hydraulic Valve Lifter.

Although the camshaft (camring in radial engines) has a fixed relationship with the crankshaft through its connection by gears or a timing chain, a variable affecting valve timing lies in valve clearance—the distance between the end of the valve stem and the mechanism which operates it. (Valve trains and their components will be discussed under *cylinder head construction).* Valve clearance is necessary because the valve trains will expand due to the heat of engine operation. If there is not enough clearance to allow for expansion, the valve will not be able to seat due to the increased length of the mechanism. Without going into detail, it can be said that changes in clearance will not only affect the time at which the valve train responds to action of the cam, but the amount of opening of the valves proper.

Some engines are now equipped with hydraulic valve lifters which automatically adjust themselves for changes in length of the valve train due to heat and wear. This keeps the valve train in constant adjustment without clearance and assures positive and quiet valve operation under all conditions.

Ignition. Spark ignition is common to all types of gasoline engines, whether the source for this electrical energy is a battery or a magneto. These sources in addition to ignition wiring and spark plugs, will be discussed in detail under *engine accessories.*

Fuel. Both gasoline and diesel fuels are petroleum products. The chemist, however, in his analysis, sees two vastly different mixtures of hydrocarbon compounds designed to be burned in different manners. Gasoline is composed of molecules of complicated structure designed for slow burning. Diesel fuel molecules offer a straight chain reaction for very rapid burning. Therefore, special considerations must be made when attempting to derive the maximum amount of energy from a fuel.

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Raising the compression ratio of engines increases the overall thermal efficiency, but while compression ratios of gasoline engines have been rising to an average of 7 to 1, they are now going no higher. The reason is that gasoline will not stand up under high compression. Its burning characteristics change from a gradual pressure rise in the cylinder and a resulting 'push' on the piston

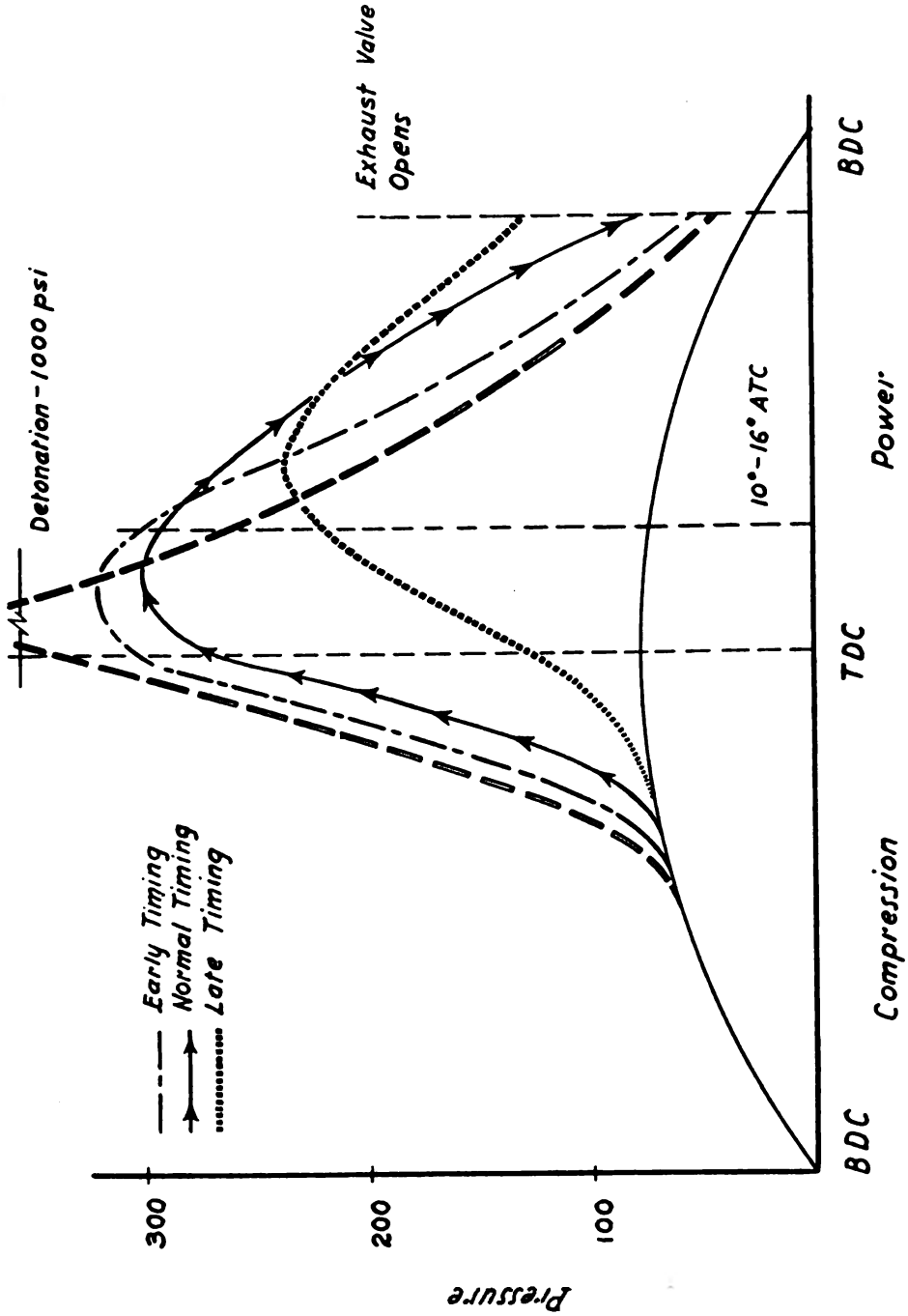

Figure 7. Cylinder Combustion Pressure.

head, to a violent explosion or hammering action on the piston which is termed 'detonation.' Detonation is the cause of the common 'knock' or 'ping' sometimes heard in gasoline engines under load. Whereas normal combustion pressure reaches 300 to 400 psi (pounds per square inch), detonation will cause a hammer blow of up to 1000 psi to strike the piston suddenly, resulting in terriffic strain on engine parts. Detonation being the limiting factor in gasoline engine output,

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the variables which affect it as well as engine operation in general will be discussed here.

Spark Setting or ignition timing is one important variable in the operation of the gasoline engine, and is comparable to the time of injection of fuel into the diesel engine. Theoretically, it has been determined that for an engine to operate at peak efficiency, the maximum pressure rise in the cylinder should be 10 to 16 degrees after TDC on the power stroke.

Although the rate of burning of the fuel is extremely fast (4/1000 sec.), it must be remembered that the crankshaft is turning so fast that this relative burning time has a very marked affect on fixing the time for ignition to take place. In order to obtain this pressure rise at a given time, the charge must be ignited earlier as engine speed increases. This is done automatically by the distributor of both the battery and magneto ignition systems. Too late a spark will cause

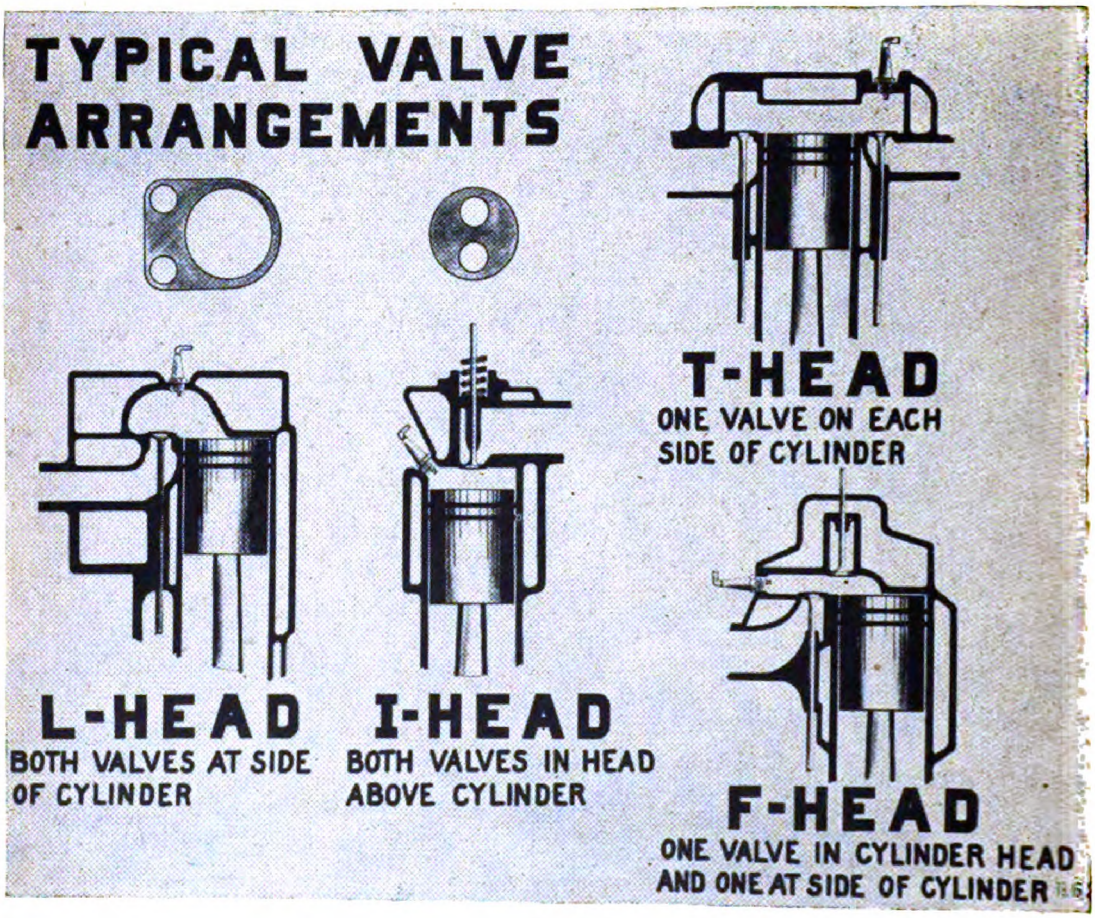

Figure 8. Typical Valve Arrangements.

the engine to lose power because of late pressure rise and also will cause the exhaust gases to be ejected before burning is completed, resulting in engine overheating. Too early a spark will cause the pressure rise to come too soon and the charge will still be in the early compression stage when burning occurs; the heat of compression and burning combining to raise the pressure to a point where gasoline will detonate.

Air-Fuel Ratio, or proper mixture of the air and fuel by the carburetor, is an important factor. As fuel economy is highest slightly below the speed of maximum power, the mixture will be varied depending upon desirability for maximum power or economy, or from 12.8-1 to 15-1. A good figure for the average

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fuel consumption of a properly adjusted gasoline engine is .6 lb. per horsepower per hour. Sending excess fuel into the cylinder has a cooling effect and is utilized on many engines for this reason, but the lack of fuel in the mixture often causes trouble. A lean mixture will burn more slowly than normal and will lead to an overheated condition in the cylinder which in turn can readily be the cause of detonation.

Fuel itself is an important variable; gasoline being a mixture of various hydrocarbon compounds is available in various anti-knock ratings. In raising the performance of engines by means previously described, the anti-knock qualities of the fuel are being extended to the limit; therefore, it is evident that some sort of rating must be used in order that the results of using a particular fuel might be anticipated. The procedure consists of comparing the performance of the fuel with a blend of two known reactionaries; iso-octane (trimethyl-pentane) a perfect anti-knock fuel, and normal heptane, a 100 per cent knock fuel. The ratio of the blend, by volume, is known as the octane rating. A fuel of 80 octane rating would have the same anti-knock characteristics as a blend of 80 per cent iso-octane and 20 per cent normal heptane under exactly the same conditions. Fixed engines and conditions for these tests are set up and practiced by the American Society for Testing Materials and the Cooperative Fuel Research Committee. Road performance not meeting these fixed standards will not always match test results. Results are, however, closely parallel.

In many instances, engines have been operated using high octane fuels with the idea that improved performance would result. An improvement, however, is possible only if the compression ratio is increased and variables previously discussed are operating toward most efficient performance.

Combustion Chamber Design is another factor of engine performance. These designs can best be classified according to valve arrangement. The 'I-head' and 'L-head', with certain modifications, are the most common at the present time.

The I-head engine has both the intake and exhaust valves mounted in the cylinder head, the arrangement calling for a special valve operating mechanism consisting of a cam follower, pushrods, and rocker arms to operate the valves which are held in place by conventional valve springs and keepers.

The L-head engine has both the intake and the exhaust valves placed on one side of the cylinder and mounted in the engine block. The valve operating mechanism consists chiefly of a cam follower or valve lifter which operates from the camshaft directly against the end of the valve stem.

Variations of the original 'Ricardo' head, a prominent turbulent-type combustion chamber design, cause the burning of the mixture to progress to a smaller area, compressing the unburned charge in a manner that eliminates detonation tendencies. It has been incorporated into both L-head and I-head designs by shaping of the cylinder head or the raising of a portion of one side of the piston. The 'dome' combustion chamber is worthy of mention because of its prominence in radial engines. It has provision for very large valves to operate in an overhead arrangement. This design provides a low surface-volume relationship in the combustion chamber which results in a high out-put coupled with detonation tendencies.

One important result of engine operation with regard to improper functioning of the variables already mentioned, is the possibility of the combustion chamber becoming so hot in operation that fuel-air mixture will actually start to burn before the desired spark occurs. This is *preignition*. It has the same effect as early spark timing and leads immediately to detonation. Preignition may be caused by hot spark plugs (those of an improper heat range that become heated above the ignition point of the fuel after prolonged operation), hot spots in the chamber due to flaws in the metals themselves, or an overheated exhaust valve (caused principally by late ignition timing, which resulted in gases being pushed out of the cylinder through the exhaust ports while still burning).

In this section we have dealt with the gasoline engine exclusively, pointing out variable factors effecting its performance. In operating any engine, however, it is of the utmost importance that the operator follow *manufacturer's specifications* in all cases. After consideration of the characteristics of the diesel engine, construction of parts common to both types will be discussed in detail.

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THE DIESEL ENGINE

Introduction

Most people consider the diesel engine to be a comparatively new power-producing machine. It may surprise some therefore to learn that it was originated in 1893. It was conceived by Dr. Rudolf Diesel, an eminent German scientist, who displayed remarkable foresight in the treatment of theories on the internal combustion engine, then in a very early stage of development.

The principles of operation of the diesel is similar to that of any other common internal combustion engine. The outstanding differences between diesel and gasoline engines are the compression ratios and the methods of ignition. In a diesel engine the compression is far higher than that used in gasoline engines and the fuel is ignited solely by the heat of compression. The air is compressed in the cylinder and the fuel injected in at the proper time by the injection system. In a diesel engine the compression ratio may be as high as 16 to 1, which causes the compressed air to reach a temperature of about 1000°F. Since the self-ignition point of the diesel fuel oil is at about 450°F, the fuel will burn the moment it is injected into the super-heated air of the diesel engine cylinder.

In direct contrast to the gasoline engine, the economy of a diesel engine increases as the power output decreases, due to the fact that more air and less fuel is drawn into the cylinder. As soon as the injected fuel reaches the heated air, it is ignited regardless of how much or how little is injected. In other words, in a diesel engine there is no need for the maintenance of any specific mixture ratio in order to obtain ignition and the amount of air in the cylinder remains practically the same regardless of speed or power output and the controlling factor in the development of speed or power is the amount of fuel oil injected into the cylinder.

Since the quantity of air in the cylinder remains almost constant under all conditions, there is always a considerable quantity of excess air in the *combustion chamber* which accounts for the low temperature developed during the burning of the mixture. It is a fundamental law of thermodynamics that, other factors being held constant, the rate of heat flow increases with temperature. Therefore, the lower temperature in the diesel cylinder causes less heat to be wasted and more of it to be utilized to generate pressure on top of the piston and drive it down. Therefore, the diesel engine wastes less heat than the gasoline engine at full or part load and, consequently, is more efficient in the use of the energy contained in the fuel.

As previously mentioned, diesel fuel is a very specialized mixture of hydrocarbon compounds designed to burn rapidly when injected into the combination chamber of the engine. Whereas gasoline is rated according to its anti-knock capabilities, diesel fuels are rated on a basis of the ability of the fuel to ignite upon contact with hot compressed air. The primary reference fuels are cetane, a paraffin-base compound, and alphamethylnapthalene. The percentage by volume of the two fuels is the 'cetane number' of the unknown mixture. The higher the cetane number, the better are the ignition and burning qualities of the diesel fuel.

Combustion Chambers. In order to obtain the best performance from diesel engines, various combustion chambers are employed, all of which have distinct characteristics suited to certain type of service. Many are the result of years of research on the part of a manufacturer who obtains from his particular system that performance which he considers most reliable and satisfactory. Generally speaking, there are three types of combustion systems:

1. The Open Chamber
2. The Pre-Combustion Chamber
3. The Divided or Auxiliary Chamber

In *Open Chamber* engines the fuel is injected directly into the combustion space above the piston. Open chamber arrangements are *generally* confined to engines of large bore and stroke running at comparatively slow speed, but common exceptions to this rule are present in modern design.

In the *Pre-Combustion Chamber* type of engine the fuel is injected into a chamber inserted in the cylinder head. From there the fuel is directed into the

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main combustion space directly over the piston by the initial pressure created by partial or complete combustion of the fuel in the pre-combustion chamber. Pre-combustion chambers are generally found on small to medium size engines running at moderate speeds.

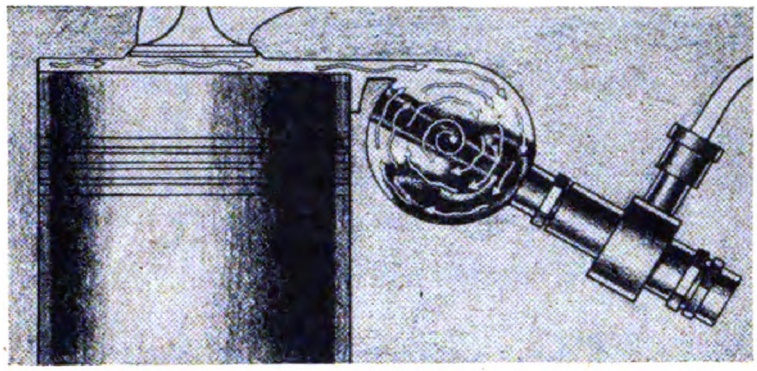

Figure 9. Pre-Combustion Chamber.

In the *Divided* or *Auxiliary Chamber* engines the fuel is injected across a combustion chamber, which resembles a figure 8, into an energy cell or receptacle with a restricted opening. The injection first takes place in the main combustion chamber and works its way into the energy cell where it begins to burn. It is then forced back into the main combustion chamber, completely mixing the fuel and air and providing complete combustion. This system is used extensively in small high speed engines.

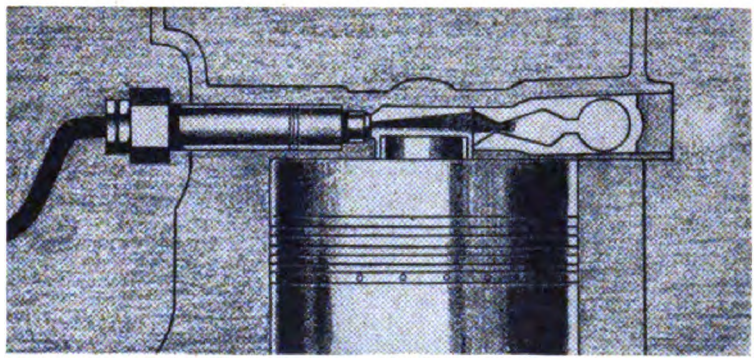

Figure 10. Energy Cell.

Regardless of the type of combustion system employed in the combustion chamber, turbulence of air just as the fuel is injected is of the greatest importance. This insures a thorough mixing of the fuel with the air and results in complete combustion or burning of the fuel and the utilizing of a very large percentage of the oxygen in the air. This turbulence is accomplished in various ways: the shape of the top of the piston, the size of the opening through which the air must pass, the shape of the combustion chamber and others. All have the same effect. Diesel engines, until a few years ago, were large and heavy, often weighing two hundred and fifty pounds per developed horsepower. The speeds at which they could be operated successfully were low, and they could be used only in stationary and large marine applications. Even with important progress made in construction improvements the situation could not be materially altered because the required injection systems still remained relatively unsuccessful for high speed operation. In practically all cases, air under high pressure, produced by large compressors, was used to force the fuel oil into the engine cylinder. It was finally the development of the solid injection

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type of fuel injection system that made possible the successful development and operation of the small bore, medium and high speed diesel engines.

The purpose of the fuel injection equipment is to meter the fuel accurately and to deliver it under high pressure to the spray nozzle located in the cylinder of the engine at the right time. Furthermore, the pump must deliver this meas-

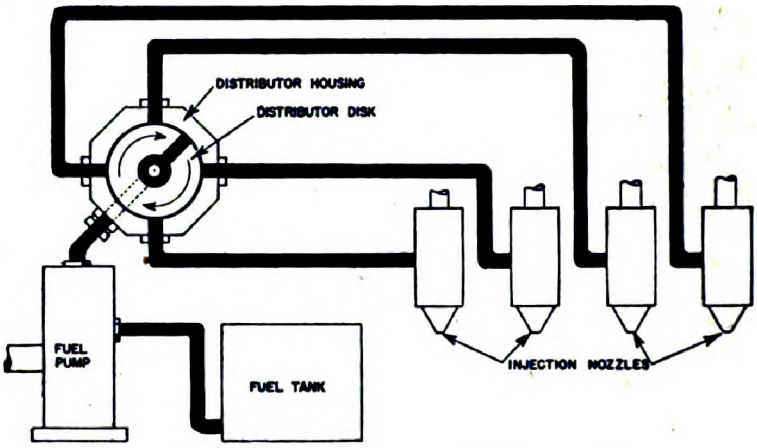

Figure 11. Distributor System of Fuel Injection.

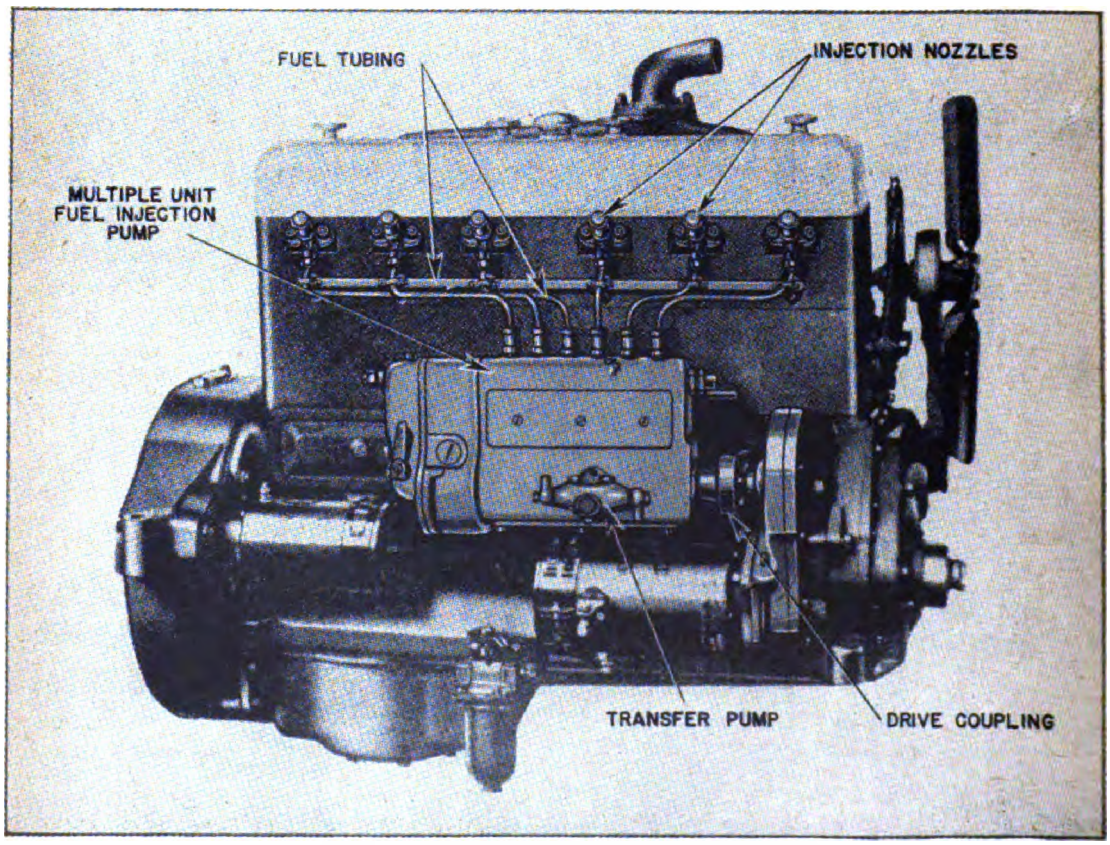

Figure 12. Multiple—Unit Pump Installations.

ured fuel charge within a required time. Because of these exacting requirements the manufacture of the vital parts demands the greatest accuracy. For example, the fit of the plunger in the barrel of the injection pump is held to an accuracy of thirty-nine millionths of an inch (0.000039") which is about equal to the 1/20th part of the thickness of the average human hair. This close fit is necessary in

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order to provide the enormous pressure required to inject the fuel into the fully compressed charge of air with a minimum of injection lag.

There are several general types of fuel-injection equipment commonly used on diesel engines today. Mechanical injection systems have almost universally replaced the old air injection system so that the latter no longer merits discussion. Among the various mechanical types, we find the common rail system (now obsolete), the distributor system, in which the fuel is sent to the various cylinders from a single pressure line as demanded by the engine timing, the individual pump system, and the unit injector. The latter two systems are

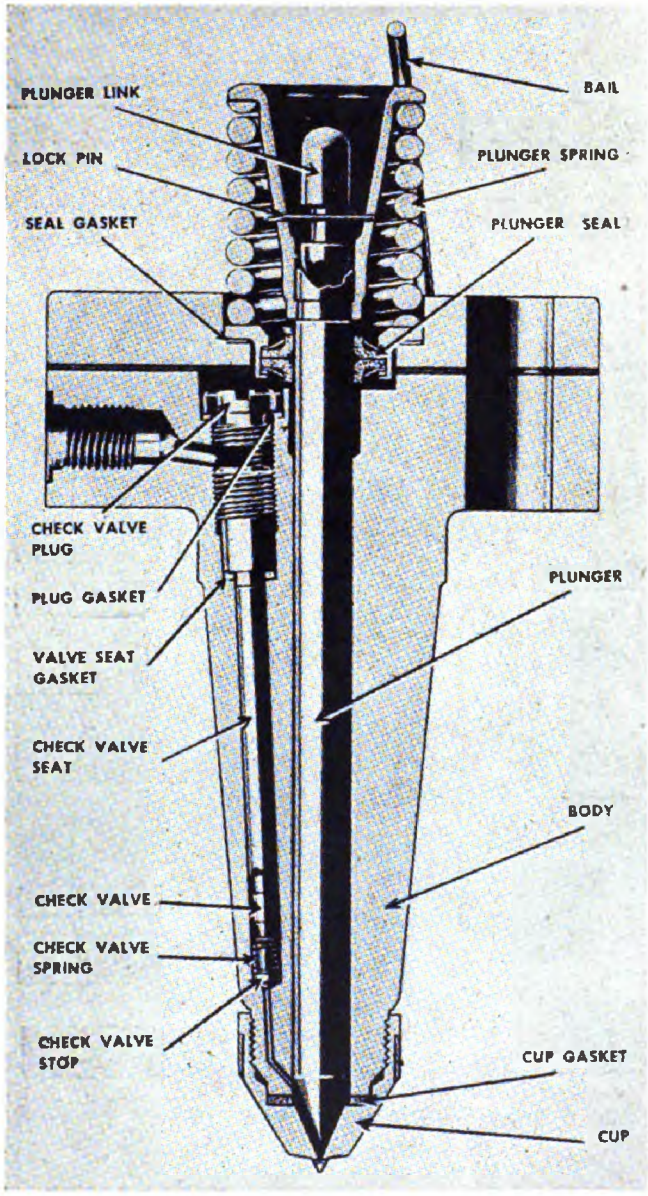

Figure 13. Cross Section View of Unit Injector.

most commonly used so parts common to both will be described in detail. The constructional difference lies in the fact that the unit injector combines both pump and nozzle into one assembly as compared to the two mechanisms connected by fuel lines.

Pump Operation. Injection pumps are built in units ranging from one to twelve cylinders and are available in three basic sizes, thereby providing a capacity

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range covering a wide variety of cylinder displacements. They are of the so-called constant stroke, cam-actuated, lapped plunger type. They are supplied with fuel by a transfer pump which transfers the fuel under low pressure from the supply tank to the sump of the fuel injection pump. Through the inlet connection the fuel enters the sump in the upper part of the housing. As soon as the upper edge of the plunger, during its downward stroke, opens the two radially opposite ports in the barrel (inlet and by-pass ports), the fuel rushes into the barrel while the plunger is at the bottom of its stroke. During the first part of the upward stroke of the plunger, some of the fuel in the barrel is displaced back into the sump through the inlet and by-pass ports until these two ports are completely closed. Shortly afterwards the fuel is placed under pressure; a spring-loaded delivery valve is lifted off its seat, and the fuel is delivered through the discharge tubing into the spray nozzle which discharges it into the combustion chamber of the engine.

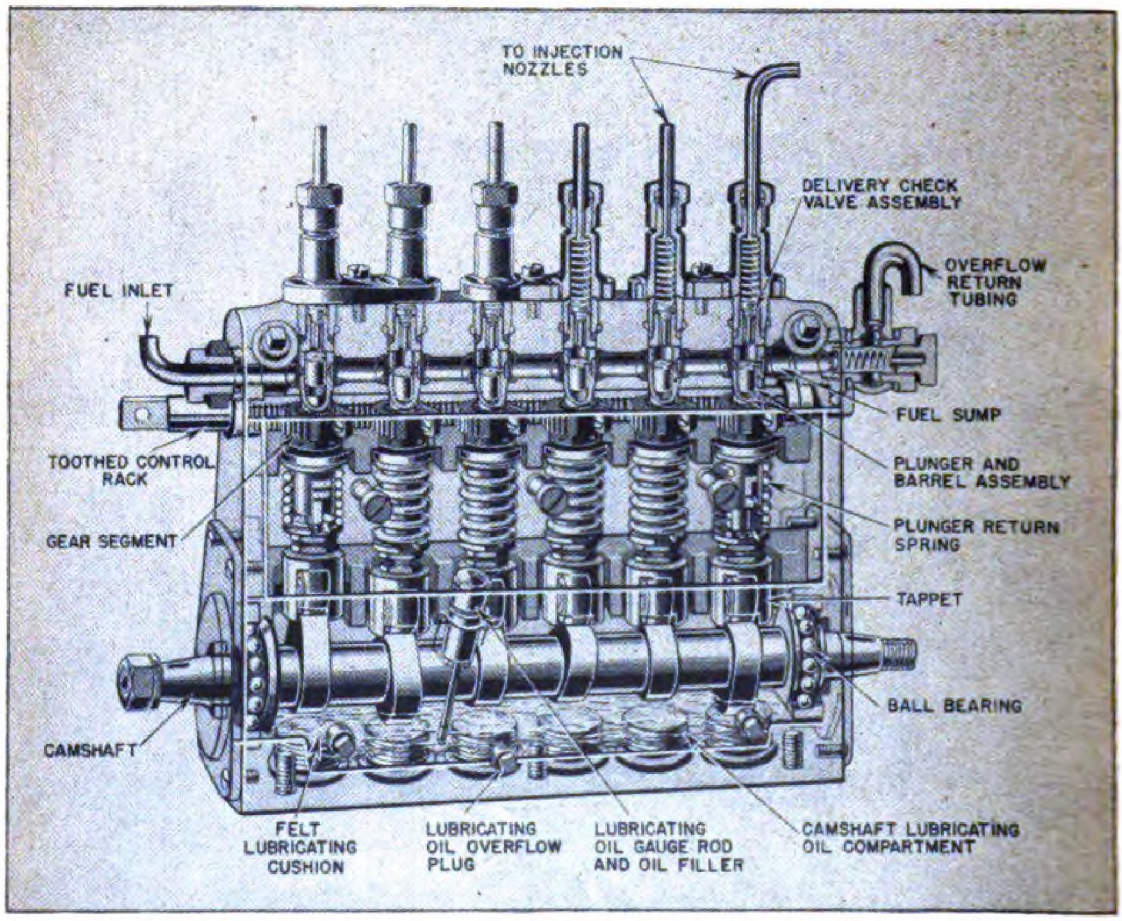

Figure 14. Phantom Cross Section View of Typical Multiple Unit Fuel Injection Pump.

Delivery of fuel ceases as soon as the helix on the plunger passes the by-pass port in the barrel, for at this instant the pressure chamber communicates with the sump by way of the vertical groove and helix on the plunger, allowing the fuel not yet delivered in the discharge tubing to by-pass back into the sump.

The termination of the fuel delivery, which controls the quantity of fuel delivered per stroke, is varied by turning the plunger in its barrel, *i.e.*, by bringing the helix into various positions with relation to the by-pass port. To accomplish this, a control sleeve is slipped over the barrel, the sleeve being provided with a toothed segment at its upper end and with two longitudinal opposite slots at its lower end, in which the cross flange of the plunger is guided. The teeth

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of the toothed segment engage corresponding teeth on the control rod and, by shifting the latter either manually or automatically by means of a governor, the plunger is rotated in its barrel in either direction.

The less the control rod is moved away from its 'stop' position and the less the plunger is thereby turned in its barrel, the sooner the helix opens the by-pass port and the smaller the fuel delivery per stroke will be. In contrast, the

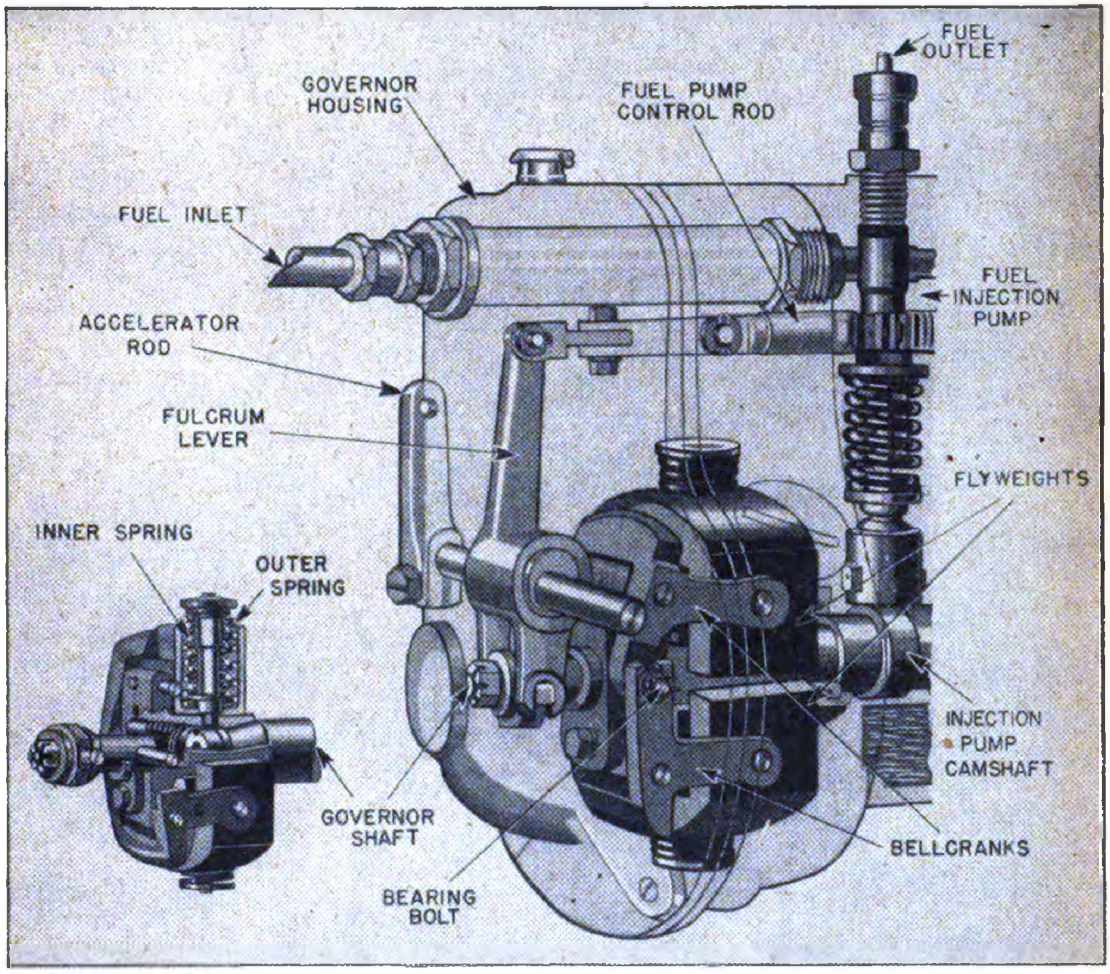

Figure 15. Operation of Port Control Fuel Injection Pump.

farther the control rod is moved away from its 'stop' position and the farther the plunger is turned in its barrel, the later the helix opens the by-pass port and the larger the fuel delivery per stroke will be.

For maximum fuel delivery, the plunger, by moving the control rod farthest away from its 'stop' position, is turned farthest in its barrel, resulting in very late opening of the by-pass port by the helix, *i.e.*, in the maximum effective plunger list. For zero delivery, with the control rod in the 'stop' position, the plunger is turned in its barrel until its vertical groove registers with the by-pass port. In this position, the pressure chamber in the barrel is in constant communication with the sump during the entire mechanical stroke of the plunger; therefore no fuel is delivered by the latter.

In diesel engines speed and power output are controlled solely by a variation of the amount of fuel injected into the combustion chamber. As explained in the preceding chapters, this variation of the amount of fuel delivered by the injection pump to the nozzles is regulated by the simple and fool-proof action of the helix on the plungers.

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For proper engine performance the fuel oil must be injected into the engine cylinder as a spray. This is done by a spray nozzle, which is held in the correct position in the cylinder head by the nozzle holder. The type of nozzle employed on a diesel engine depends largely upon the type of combustion chamber used. The nozzles in open combustion chambers, which lack turbulence and into which the fuel is injected directly, must discharge the fuel in several fine streams so that it will vaporize and ignite rapidly. This requires holes of such minute size that fuel will flow through them only when backed by exceedingly high pressure. On the other hand, combustion systems with ample turbulence will satisfactorily atomize coarser fuel streams backed by lower pressure issuing from larger holes. Nozzles are designed to deliver a fuel spray that conforms as far as practicable to the shape of the combustion chamber so that the fuel particles will be well distributed in the combustion chamber and thoroughly mixed with the compressed air.

Fuel Nozzles. The nozzle itself may either be of the open or closed type. An open nozzle does not control the flow of fuel. A nozzle is termed 'closed' if it contains a spring-loaded metering valve near or at its orifice. In the open type, fuel injection is controlled by the injection pump, while in the closed type it is controlled by the spring-loaded valve which is actuated by a cam, hydraulically by the fuel pressure, or magnetically by an electrical circuit.

Most standard spray nozzles consist of only two main parts, nozzle body and

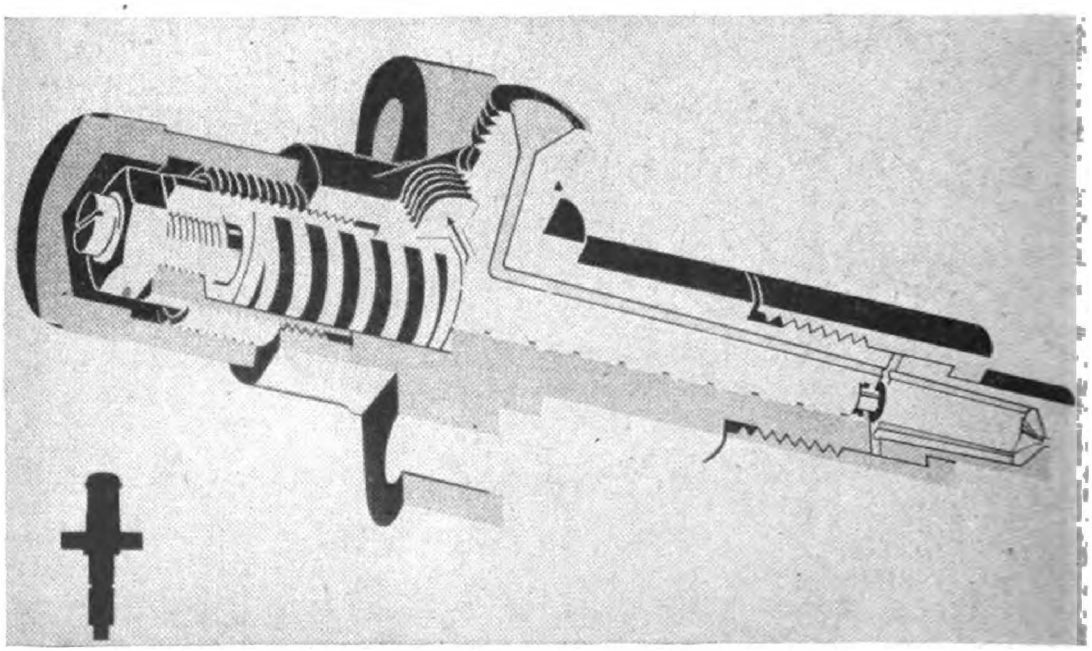

Figure 16. Hydraulically Controlled Closed Nozzle.

nozzle valve. The nozzle body and valve of both nozzle types are individually lapped to form a mated assembly. Neither body or valve can, therefore, be exchanged singly, and must be kept together at all times.

As shown in Figure 16 above, the nozzle body is provided with a groove from which the fuel ducts lead down to the pressure chamber and at the lower end of which the sear for the nozzle valve is located. At its upper end the nozzle valve has an extension of smaller diameter than the valve itself. This extension, referred to as 'stem,' makes contact with the lower end of the spring-loaded spindle of the nozzle holder. The nozzle body is provided with a highly ground and lapped surface at its upper end, which makes a leak-proof and pressure-tight seal with the corresponding sealing surface at the lower end of the nozzle holder shank.

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The operation of the nozzle holder in combination with the nozzle assembly is as follows: The fuel delivered by the injection pump flows through the discharge tubing and enters the nozzle holder inlet stud. It then passes through the edge filter and flows through the ducts in the holder and nozzle body and down into the pressure chamber of the spray nozzle above the valve seat. There the pressure of the fuel oil acts on the differential area of the nozzle valve. At the moment when the pressure of the fuel exceeds that of the pressure exerted by the adjusting spring, the nozzle valve is lifted off its seat, and the fuel is forced through the spray orifice or orifices and sprayed into the combustion chamber of the engine. The nozzle valve returns to its seat after the injection pump has ceased to deliver fuel, since this causes the pressure of the fuel to drop below that of the pressure adjusting spring. The hydraulic opening pressure of the spray nozzle may vary from 1000 pounds to 4000 pounds per square inch depending upon engine combustion chamber requirements.

Engine manufacturers are aware that satisfactory nozzle operation is greatly dependent upon the cooling of the nozzle holder and nozzle assembly. For this reason they endeavor to bring the cooling water of the engine as close to the nozzle holder and nozzle assemblies as practical.

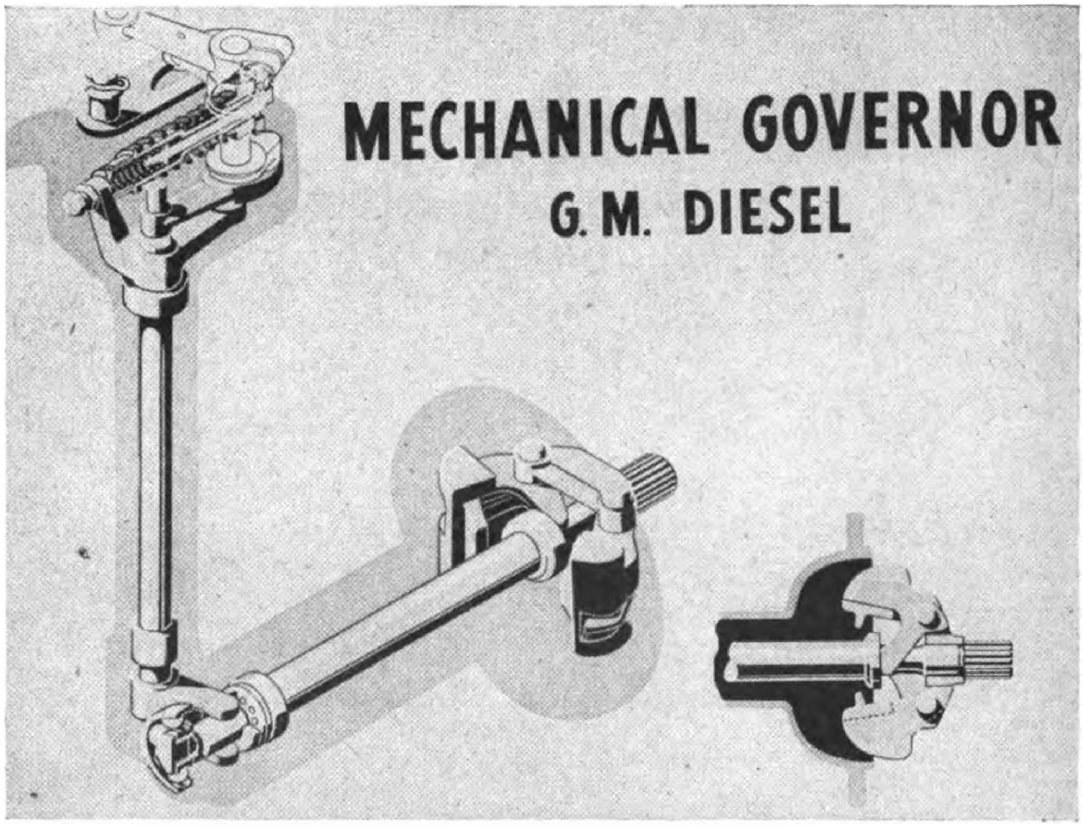

Figure 17. Minimum-Maximum Mechanical Governor.

The Governor. All diesel engines require a governor. The prime purpose of the governor is to serve as a means for pre-setting and maintaining within close regulation any desired engine speed within the nominal idling and nominal maximum speed range, irrespective of engine load. In addition, the governor controls the engine idling speed to prevent stalling and the maximum speed to prevent racing.

Several types of governors are used, but possibly the most widely used is the centrifugal type. In this governor a large gear is mounted on the end of the camshaft which extends into the governor housing and drives a smaller gear connected to the governor flyweight shaft. Through this combination of gears,

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the flyweight shaft is caused to travel at a higher speed than the injection pump camshaft. The centrifugal force exerted by the revolving weights causes a movement of the sleeve assembly which is opposed by the compression of the governor springs. The governor is internally connected to the injection pump control rod.

ENGINE CONSTRUCTION

After one is familiar with the operations and fundamentals of gasoline and

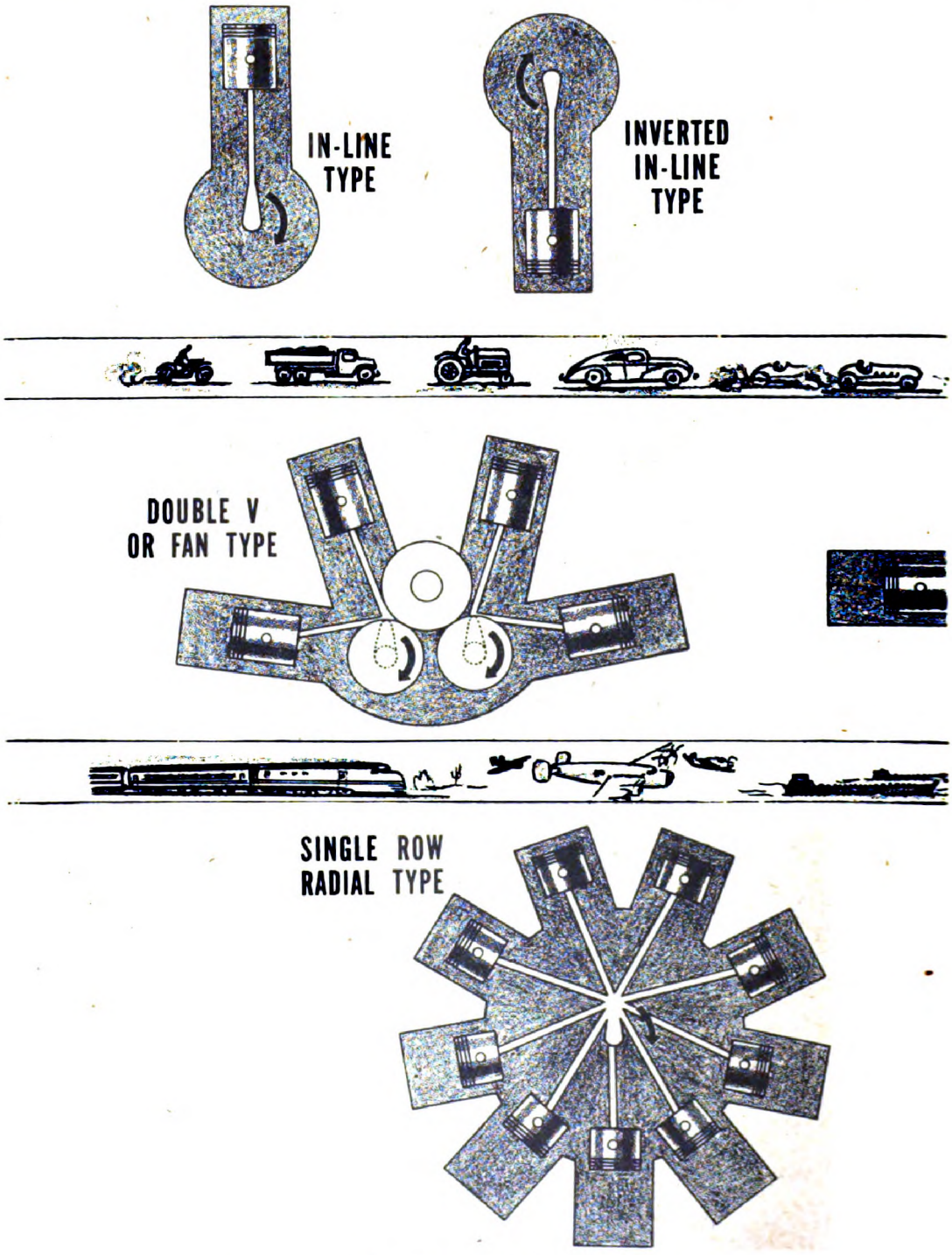

Figure 18. Engine Types.

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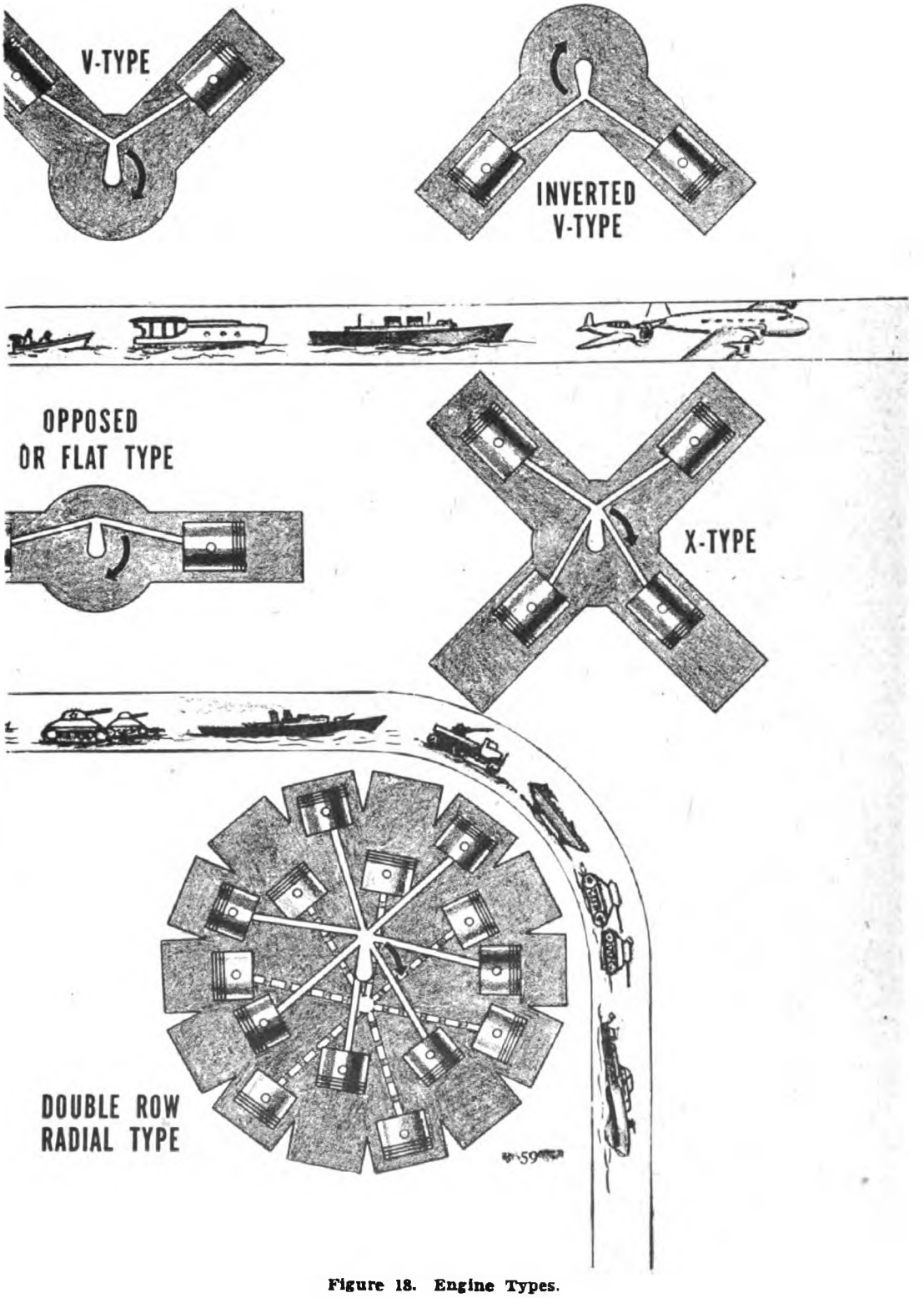

Figure 18. Engine Types.

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diesel engines, it becomes important to observe the internal working parts in detail, paying particular attention to construction. Up to this point we have discussed engine types from the constructional standpoint, only in connection with cylinder arrangements. It is desired to treat the discussion in a strictly non-biased form, bringing to the reader technical explanations in the simplest and most understandable form. No attempt will be made to limit explanations or cite examples which are peculiar to one manufacturer since new models are almost as regular as the reason. Yet, fundamental principles and constructional features are basically the same.

Because in-line engines are more familiar to the general reader, their functional components will be discussed and comparisons to other cylinder arrangements will be made when the basic principles differ.

The Crankcase. The crankcase and block are the main parts of the engine body. In or on these parts the other components and accessories are fastened; within this framework are the cylinders. Generally the entire unit is referred

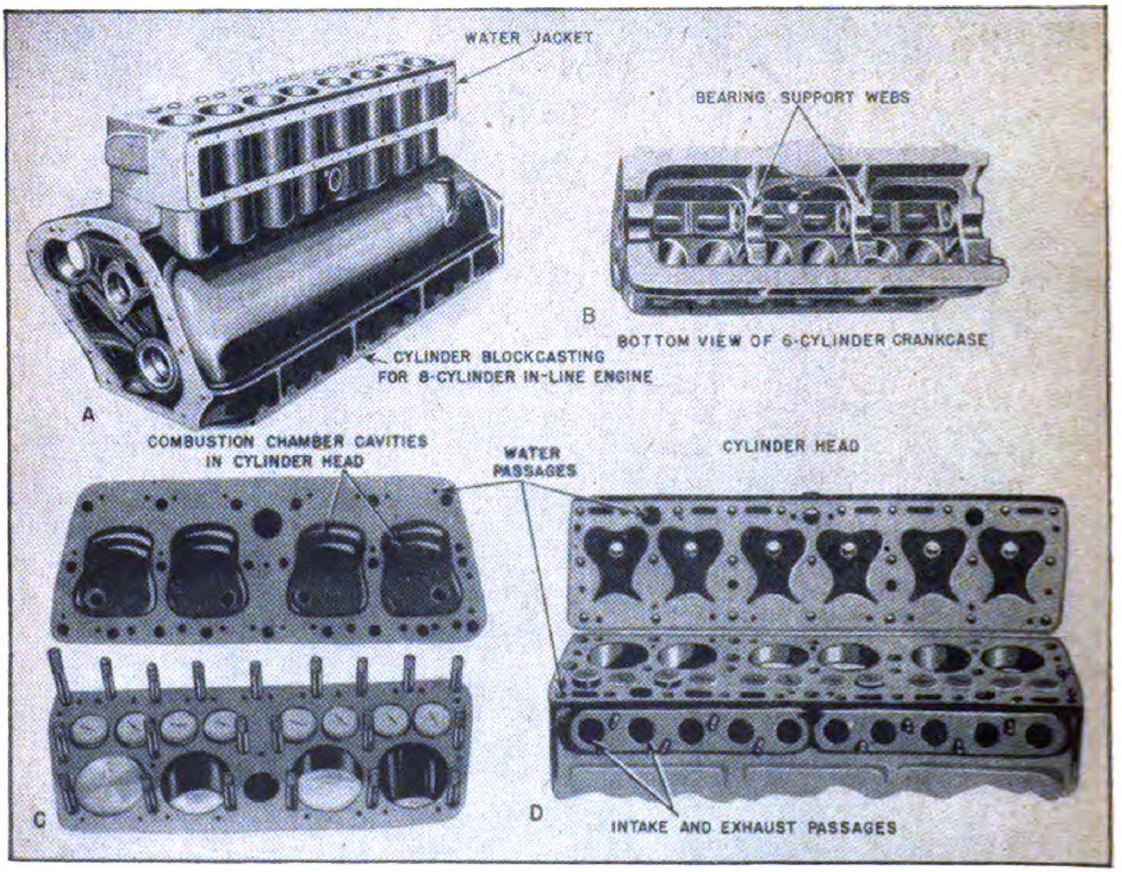

Figure 19. Cylinder Castings for Automotive Engines.

to as the 'block.' Actually the upper part of the casting (usually one piece and made of a special alloy iron containing chromium, molybdenum, and nickel) contains the cylinders, and the lower portion, the webs or supports which hold the crankshaft in place. Generally the cylinders are cast and machined in the block; however, a few models incorporate cylinder sleeves which, as the name implies, are merely inserts which are pressed into place and encompass the combustion chamber. Sleeves are usually divided into two classes; wet sleeves that come in direct contact with the coolant, and dry sleeves that are simply inserted in the block and are not in direct contact with the coolant. Water jackets and oil passages are usually cast integrally in the block.

The Cylinder Head. The cylinder head is the part which completes our dis-

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cussion of the combustion chamber. It serves as the sealed, removable cover for the top of the cylinder. It forms the top of the combustion chamber and in some cases contains the valve assemblies. Cylinder heads are usually cast in one piece according to the number of cylinders in the engine. Sometimes one finds separate heads for three cylinders of a six cylinder in-line engine or for each bank of a 'V' type engine. This reduces the cost of production and replacement when failure occurs. Cylinder heads are made from either a good grade of alloyed iron or aluminum. The latter is used because of its ability to quickly dissipate heat and thereby afford a cooler engine operation and less tendency toward detonation. Cylinder heads are cast with integral oil and water passages and are separated from the block by a copper-asbestos gasket. Complete circulation throughout the block and head is possible through corresponding passages in the head and block.

The combustion chamber is composed of the highly machined cylinder and the cylinder head and the shape and finish of the cylinder walls are of utmost importance to the engine's performance. After combustion takes place, the first unit to operate is the piston.

PISTONS

Pistons must be of exceptional construction in order to receive the full energy of combustion and transfer this force to the connecting rods. They are usually made of grey cast-iron, semi-steel, or aluminum alloy all of which are light and have a high tensile strength and good wearing qualities. The piston is a hollow cylindrical unit closed on top and open at the bottom. Provisions are made for the piston pin which is usually located a little below the midsection between the head and the skirt. The piston pin 'bosses' are machined to receive a bushing which supports the piston pin. It would be difficult to make a solid piston fit accurately enough in a cylinder to seal compression, so, toward the top of the piston are three or four grooves which are fitted with the piston rings.

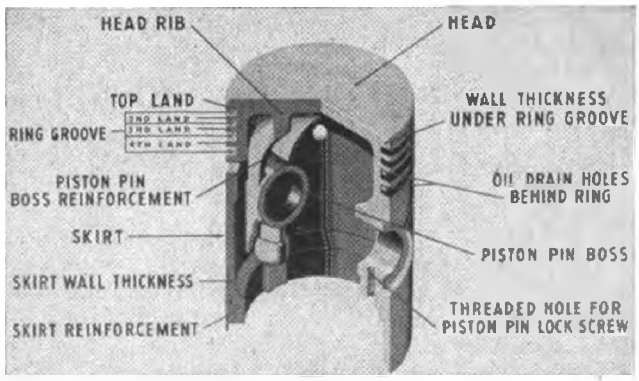

Figure 20. Piston Nomenclature.

Due to the extreme operating temperatures in the combustion chamber, provisions must be made for the expansion and contraction of the piston. This is done in two ways; either by expansion slots or by relieving a portion of the piston nearest the piston pin boss. Pistons so treated are said to have been 'cam ground.' Actually the piston is not entirely round until it reaches operating temperature. All pistons incorporate one or both of the above features. The development of newer low-expanding metals has given the matter of piston clearances much prominence and it is very important when fitting the pistons to follow the exact instructions and specifications outlined by the manufacturer.

Piston Pins. Piston pins are the means by which the piston is linked to the connecting rod. They fit into the piston pin bosses and through the small end of the connecting rod. Piston pins are classified according to the way they are held in the piston—set screw, semi-floating (pin locked to connecting rod) and full floating (pin can turn in both connecting rod and piston bosses). The piston pin is tubular and made out of high grade alloy steel which is case-hardened and machined to a high finish.

Piston Rings. Piston rings are constructed of cast iron and are split at one

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point. The split enables them to expand against the cylinder wall and exert slight pressure to furnish a gas seal and oil seal. They also transfer heat from the piston to the cylinder wall where it can be dissipated by the water jacket. There are basically two types of rings; compression rings keep compressed gases from leaking down around the piston during compression and power strokes, and oil control rings prevent excessive amounts of oil from entering the combustion chamber. The oil control rings contain slots or holes to permit the oil to return through holes in the piston behind the ring groove.

Connecting Rods. Connecting rods, as the name indicates, serve as the link between the piston and crankshaft. They are usually of I-beam construction and of a steel alloy capable of withstanding heavy loads without twisting or bending. The upper or small end of the rod, equipped with a bronze bushing, holds the piston pin while the lower and large end fits over the crankshaft throw, also

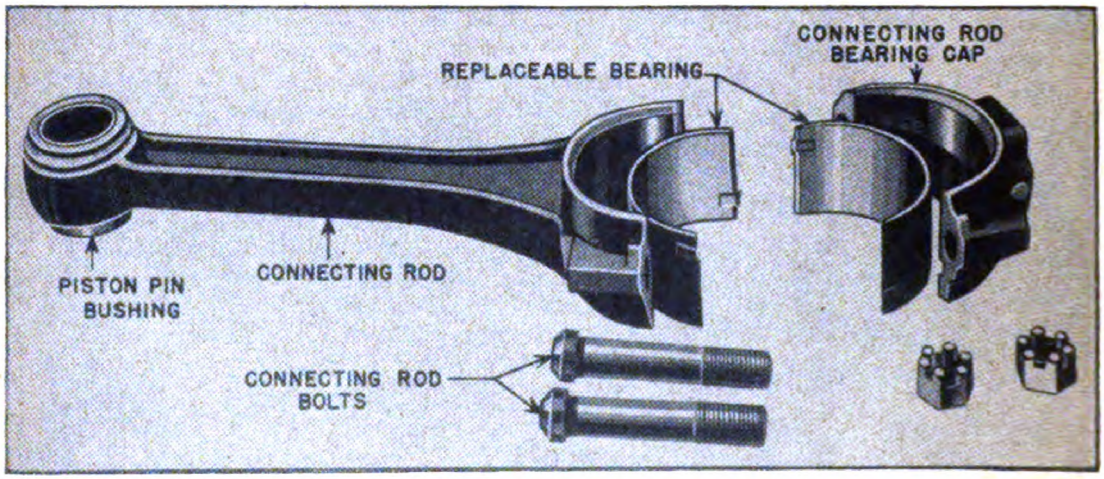

Figure 21. Connecting-Rod Assembly, Showing Interchangeable Crank-Pin Bearings.

riding in suitable bearings. The bottom portion of the rod is removeable and serves as a cap, thereby facilitating the removal and adjustment of the unit and its bearings.

Crankshaft. The crankshaft might well be called the 'backbone' of the engine in that it is subjected to all the forces developed by the engine. It consists of a shaft with one or more cranks along its length. The cranks, or throws, are formed by forging offsets into the shaft before it is machined. The arrangements of cranks along the shaft influences the firing order of the engine. Crankshafts are usually forged from an alloy of steel and nickel; however, the war has brought the success of cast crankshafts as well as those of built-up construction. After rough finishing the bearing surfaces are usually case hardened and ground to a close tolerance, demanding extreme care in reconditioning in order that the depth of case hardening is not exceeded. In order to run smoothly, the crankshaft must be balanced statically while at rest, and dynamically while running at high and low speeds. Counterweights aid in balancing the crankshaft, thereby overcoming vibration and load deflection. Torsional vibration due to twists in the shaft as loads are applied is the most common source of failure and many types of vibration dampeners are being used and tested constantly. The front end of the crankshaft carries a keyed gear for driving the camshaft and the rear contains a flange to which the engine fly-wheel is bolted and balanced.

Camshafts. Camshafts, driven by timing gears or a timing chain directly from the crankshaft, are usually of drop-forged steel or chilled cast iron construction. The series of cams with their lobes provide a source of reciprocating motion for the valves, fuel pump, and similar accessories. The cams may either be made separately and pinned or keyed to the shaft or made as an integral part, the latter being common practice now. Camrings for radial engines resemble a wheel with a series of camlobes on its circumference.

Valves. Valves, being of the poppet type with very few exceptions in present

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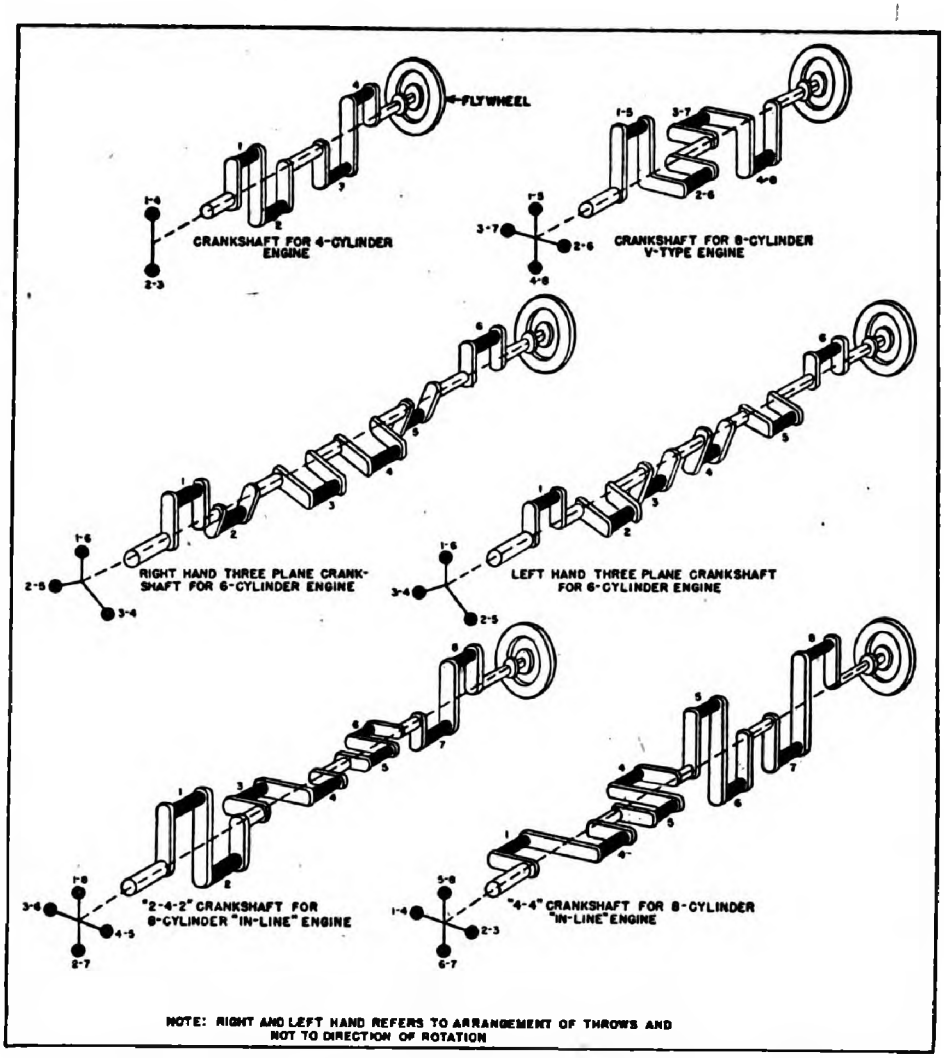

Figure 22. Crank Throw Arrangements Most Commonly Used.

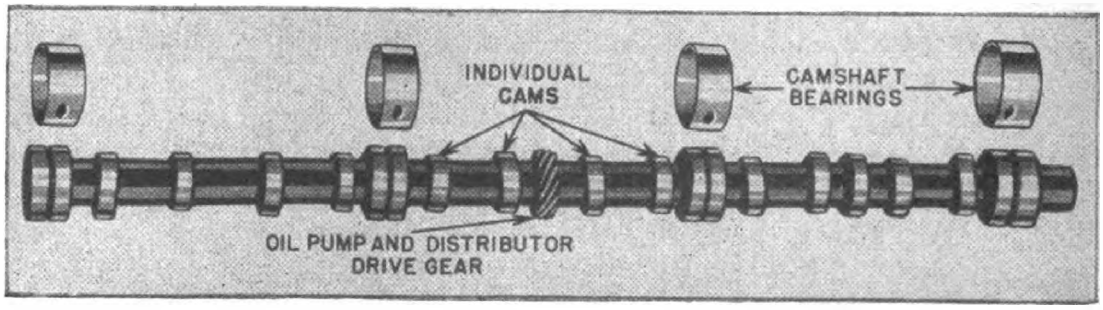

Figure 23. One Piece Camshaft With Camshaft Bearing. Distributor and Oil-Pump Drives Gear in Center of Shaft are Integral With It.

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day practice, have had their purpose and operating mechanism previously described. A chromium-nickel alloy is ordinarily used for intake valves, but silichrome alloys are usually used for exhaust valves because of the temperature. Sodium-filled exhaust valves are sometimes used, sodium being an excellent conductor of heat and capable of carrying it away from the valve head to the stem where it can be transferred to the block. Ordinary valve seats and faces are subject to intense heat, pitting, burning, and pounding so that in some cases the faces and seats incorporate stellite inserts in their construction in order to maintain good operating characteristics. Removable valve guides are generally constructed of case iron or bronze. With valves operating in aluminum heads, special inserts are necessary to withstand the shock of operation as the compressive strength of aluminum is far below requirements in this respect.

Valve Lifters or Cam Followers. Valve lifters or cam followers may have a face-hardened mushroom head or a roller-follower operating against the cam of the camshaft and a face-hardened portion which operates against the valve train. In L-head and 'V' type engines, the hydraulic valve lifter previously described is a comparatively new innovation. Mechanical lifters incorporate a screw adjustment in their design, while the rocker arms used in I-head construction have the adjustment device self-contained.

Bearings. Bearings, in general, are supports. In connection with engines, a bearing is usualy considered as that part which supports and guides the motion of a rotating member. The parts must be held in position within very close tolerances to provide efficient and quiet operation and yet allow freedom of motion. To accomplish this and at the same time reduce the friction of these moving parts to a point where the power loss is not excessive, lubricated bearings of different kinds and types are used.

The rotating parts of engines are generally supported on plain bearings with the journals turning within a bearing of anti-friction material such as babbit,

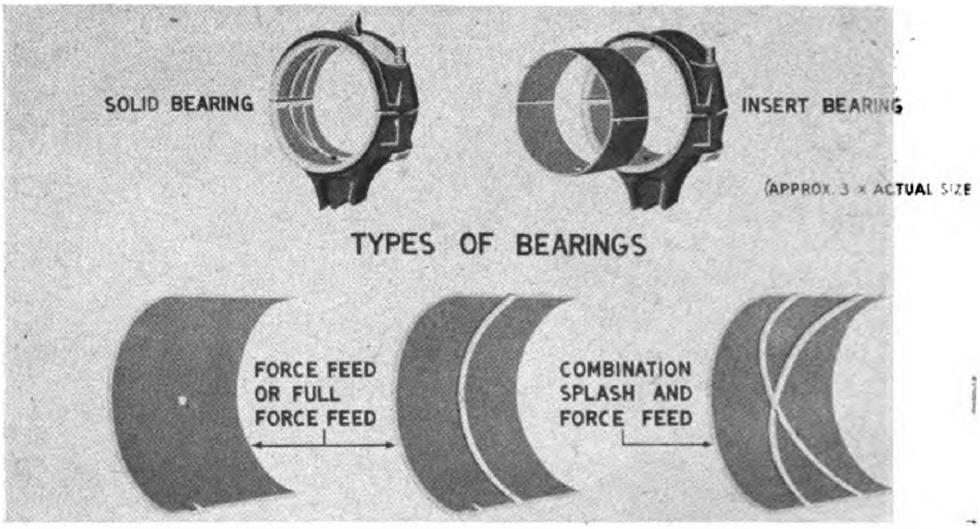

Figure 24. Types of Grooving in Connecting-Rod Bearings for Use With Force-Feed Lubricating Systems.

bronze, or special alloy. Babbitt has a very low coefficient of friction but it is too soft to withstand high pressures. Bronze has a high compressive strength but a higher coefficient of friction that babbitt. In order to combine the advantages of these two metals, the bronze-backed bearing was developed, composed of a thin layer of babbitt on the inside surface of a bronze body. Other more satisfactory lining and backing materials have been developed. A lining of bronze with a high lead content produces a bearing with a fairly low coefficient of friction, high load capacity, and long wearing life. An alloy of cadmium, silver, and copper has proved extremely satisfactory as a bearing-lining material. It

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melts at a higher temperature than babbitt, can be fitted with the same clearance, and holds readily to the shell material.

Plain bearings of different classifications are used, depending upon their being woven (spun) or semi-precision types. In this case the bearings are fitted by hand to each journal (compare with line-reaming set for installing crankshafts and camshafts—Chapt. VIII). The precision type is one in which the backing as well as the bearing surface is very accurately finished by the manufacturer to simplify installation. Anti-friction bearings, ball (thrust) and roller types, are used in certain high output engines, or where bearing loads are exceptionally high, (i.e. radial engine crankshafts supported by 3 bearings).

ENGINE ACCESSORIES

Fuel Pump. In order to supply an internal combustion engine with a reliable flow of fuel from the tank, a number of systems are employed. Common are gravity feed, wherein the fuel tank is above the carburetor, and pressure, wherein gas or air is utilized to force the fluid through the lines. The most widely used method consists of a diaphragm-type fuel pump, placed between the fuel tank and the carburetor and operated by the camshaft of the engine. This arrangement allows the fuel tank to be mounted in a convenient location in the chassis for refueling, without concern as to its proximity to the carburetor.

In operation, the engine camshaft actuates a pump arm, which in turn moves a flexible diaphragm displacing a small amount of air. This suction or negative pressure causes the greater (atmospheric) pressure on the fuel in the fuel tank to move a quantity of fuel into this space. The Diaphragm is forced back to its

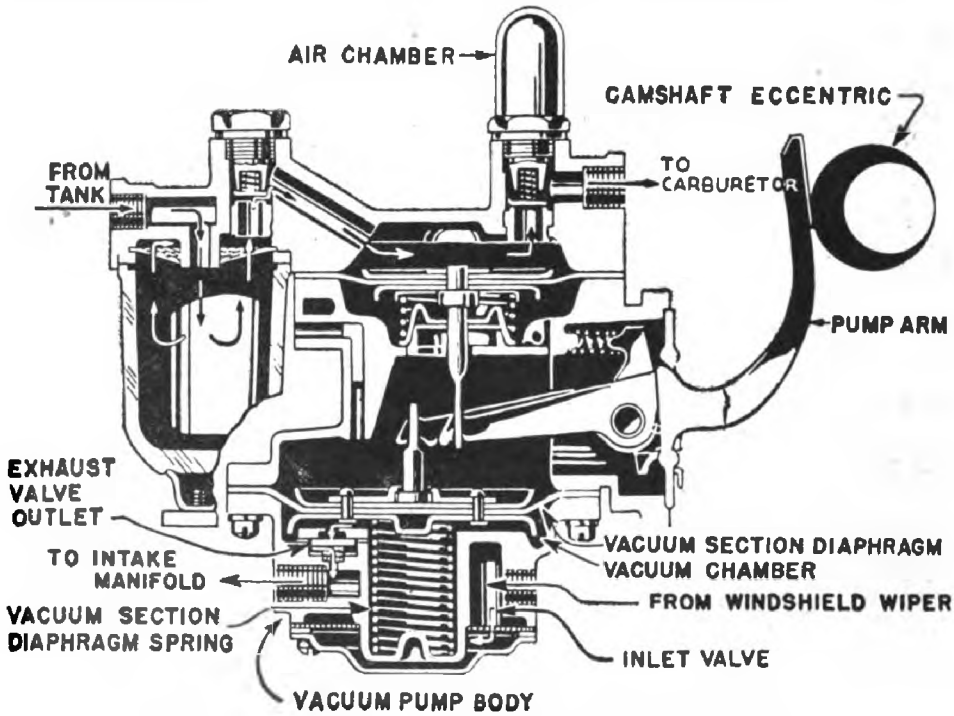

Figure 25. Mechanical Fuel Pump With Vacuum Section.

original position by a spring. The intake pipe from the tank is closed by the action of a one-way check valve, and the fuel is forced through the outlet check check valve into the outlet line at a pressure equal to the tension of the spring forcing the diaphragm into its original position. On the next stroke, the check valve of the outlet side closes, allowing no fuel to enter from the outlet pipe. At the same time, the check valve of the inlet side opens upon the downward movement of the diaphragm and the pump allows more fuel to enter. When engine requirements desire no extra fuel at the carburetor, a needle valve in the

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carburetor shuts off the outlet pipe and the pressure in this pipe builds up until it equals the force of the spring actuating the diaphragm. When this condition exists, the diaphragm is held to the bottom of its stroke, and the pump arm merely 'rides' the camshaft of the engine, performing no work, until the carburetor again demands fuel. The normal pressures in fuel pumps vary from one and one half pounds to five pounds pressure depending upon the vehicle.

Sometimes variations of fuel pump designs include a vacuum booster used to assist the windshield wiper when the engine manifold vacuum is low due to acceleration or heavy loads. Fuel pumps actuated by electricity employing a solenoid principle are being used extensively, especially on heavy equipment.

Most common failures of fuel pumps lie in the diaphragm and the linkage operating the diaphragm. Replacement kits furnish quick, easy repairs in most instances.

Carburetor. The carburetor long ago lost its original function as an instrument for solely vaporizing fuel. It has reached a comparatively high state of development as an instrument for metering fuel and air, and as a means of atomizing and vaporizing the fuel charge. When the engine piston descends on the intake stroke, it creates a partial vacuum within the cylinder and air tries to get in to fill this partial vacuum. The only entrance to the cylinder is through the carburetor. As the air rushes through the venturi tube in the carburetor, it creates a partial vacuum at the carburetor nozzle. In some carburetors, the float bowl is opened to the atmosphere so that atmospheric pressure is exerted on the fuel in the bowl; in others, the float bowl is vented to the carburetor horn and the pressure in the bowl is the same as that in the horn. Since this horn pressure is greater than the pressure at the carburetor nozzle, fuel is drawn from the float bowl to the nozzle and out into the passing air stream. As the fuel is drawn from the tip of the nozzle it is struck by the rapidly moving air stream and carried with it into the engine cylinder. The force of the air stream striking the fuel atomizes it into a mist, which is the first step toward vaporization and the mixing of the air and fuel.

The delivery of fuel at the nozzle is controlled by a needle valve, jet, or metering rod. These may operate anywhere and in any combination along the fuel passage from the float bowl outlet to the top of the nozzle. For convenience in servicing, they are generally placed at the float bowl outlet.

Most modern carburetors employ a combination or all of six separate circuits. These are: the *choke,* for supplying an extra percentage of the more volatile fuel particles for starting with a cold engine; the *idle circuit,* for supplying fuel up to speeds of 18 to 20 miles per hour when the velocity of air flowing through the carburetor is comparatively low; the *main circuit,* for supplying and metering fuel during all normal ranges of driving; the *power circuit,* for supplying a rich mixture of fuel for wide open throttle operation; the *accelerating pump circuit,* for an additional fuel charge when accelerating to prevent a lagging condition or 'flat spot'; and the *float circuit* which maintains the proper level of fuel in the bowl of the carburetor at all times by the action of a float with a needle and seat valve to shut off the flow of gasoline from the fuel pump.

If a constriction (Venturi) is placed in a pipe and air flows through it, the speed of the air will increase while passing through the restriction. This increased speed of air results in a pressure drop at this point. A problem in carburetion is to secure the correct amount of suction around a needle valve, or jet, at slow engine speeds and still allow enough air to enter at high engine speeds to maintain the desired ratio of air and fuel. This ratio consists of about fifteen parts of air to one part of fuel, by weight. The Venturi lends itself to these extremes by increasing the vacuum at low speeds without restricting the air at high speeds. A round disc or butterfly valve placed beneath the venturi of the carburetor allows manual control of the amount of air being drawn through the carburetor. This, in turn, meters the amount of fuel being forced into the air streams by the difference in pressures on the surface of the fuel in the bowl and at the tip of the nozzle. Therefore, manual control of the mixture going into the cylinders is effected, giving the operator complete control over the speed of the vehicle's engine.

Certain engine designs incorporate a carburetor which is a composite of two

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single carburetors. These 'dual' carburetors employ two venturis and two separate idle, main, and power circuits, while sharing a common accelerating pump and choke circuit.

The majority of carburetor difficulties can be traced to dirt or moisture which

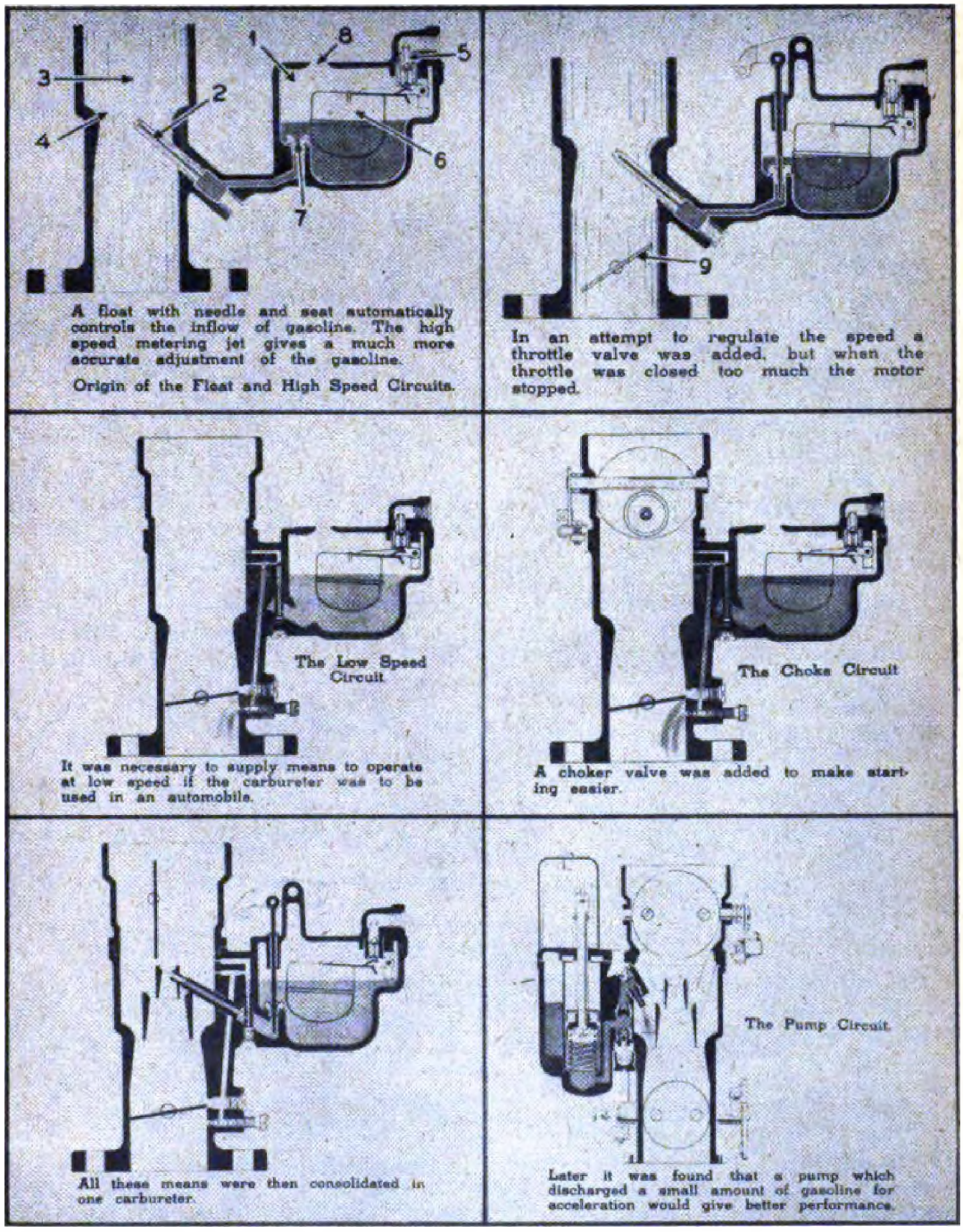

Figure 26. The Origin of the Circuits of a Carburetor.

is carried into the unit by the fuel. Since the operation of the carburetor depends upon the exact metering of gasoline through tiny orifices, any presence of dirt will restrict these small openings and cause malfunction. Small particles in the fuel which pass through these orifices, as well as the fuel itself, have an abrasive effect on the openings after long operation. The jets and small openings are

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replaceable to return the carburetor to its original efficiency. Kits, containing parts which experience has shown to wear the most and are likely to need replacing, are provided by the various manufacturers to affect easy and quick overhauls. Special tools must be employed in the replacement of these parts to prevent damage to them.

Replacement carburetors as well as overhauled carburetors must be calibrated after they are installed on the vehicle. The throttle valve should be adjusted to give the engine the proper idling speed to prevent stalling, and the idle adjusting screws should be adjusted while employing a vacuum guage to give the best performance.

Priming Systems. Prior to the starting of a large engine, it is sometimes necessary to provide a supply of fuel to the cylinders from some other source than the carburetor. The ability of the choking system to provide enough fuel for quick starting is limited to smaller sized engines. The priming system usually consists of an auxiliary pump, lines, and a jet leading into the intake manifold of the engine. The supply to the pump is tapped from the fuel line; therefore, when the pump is not being used, it must be locked in the closed position to avoid the possibility of the fuel being syphoned through the pump into the manifold during operation of the engine.

Filters. Filtering elements capable of removing dirt and foreign material from the large quantities of air and fuel that are constantly entering the engine are of vital importance to prolonged engine life, particularly during operation under adverse conditions.

The most common type of fuel filter is placed between the fuel tank and mechanical fuel pump. In this type, the fuel enters a bowl and passes up through the filter screen outlet. Dirt in fuel generally comes from rust scales in tank cars, storage tanks, and drums. Water in the fuel usually comes from the condensation of moisture in metal containers or tanks. Additional filtering elements are being incorporated in present day systems, the disc types filter serving as one of the leading additions at present. In desert operation during the North African campaign, where fuel of foreign manufacture was used, it was necessary to clean the fuel filter daily.

Air filters and cleaners are designed to separate dust and other foreign matter from the incoming air before it enters the carburetor. Since thousands of cubic feet of air are drawn in through the carburetor and passed through the engine cylinders, it is important that the cleaner be of sufficient capacity to clean thoroughly. The early oil-saturated type filter containing copper gauze or wool has been succeeded largely in military and heavy duty vehicles by the oil bath type: In this type, the air is directed above the surface of an oil reservoir where the dirt clings to the oiled surfaces and passes through an oil-saturated screen before reaching the carburetor air inlet.

THE IGNITION SYSTEM

General Theory of Ignition. Ignition is the process of supplying electric power within the engine which is capable of firing the air-fuel charge in the proper cylinder at the proper instant. Automotive ignition is commonly classified by power source as battery ignition and magneto ignition. The electrical principles are identical in both types of operation although the mechanisms differ widely. The ignition system consists of a source of power (the battery-generator combination in battery ignition and the magneto in magneto ignition), the ignition coil, condenser, low and high tension wiring, distributor, and spark plugs.

Battery Ignition. There are two circuits in the ignition system; primary and secondary. The primary circuit is opened and closed by means of the circuit breaker cam and contact points on the distributor. When the contact points close, current from the battery begins to flow in the primary circuit. This causes a magnetic field to build up in the ignition coil. The flow of current and, consequently, the magnetic field take a definite period called build-up time to occur. Any change in the amount of current flowing in a winding causing a change of magnetic strength produces a counter-voltage in the winding which opposes the voltage causing the change. Normally the current and magnetic strength do not

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reach their possible maximum because the points remain closed for such a short time. However, coil characteristics are balanced with available 'build-up time' so that even at top speed there is sufficient build-up for good ignition. The requirements for an ignition system will be set up in the following discussion, while the mechanism itself will be covered under a separate heading.

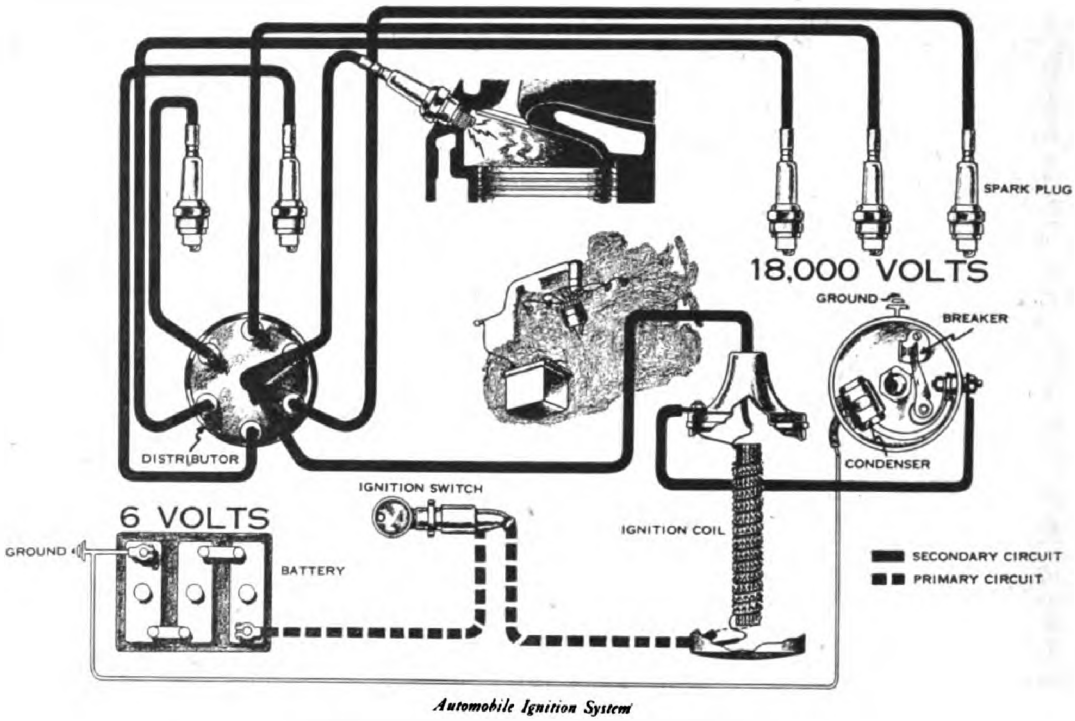

Figure 27. Automotive Ignition System.

The distributor points open when a cam lobe strikes the breaker lever rubbing block. The current attempts to continue to flow in the primary circuit as the points open, and if it were not for the condenser connected across the contact points, the current would establish an arc across the points. The energy stored in the coil (in the form of magnetic strength) would be dissipated in this arc and no high voltage would be induced in the secondary coil. However, the condenser momentarily provides a place for the current to flow and brings it to a quick, controlled stop. Consequently, the magnetic field in the coil, produced and sustained by the current flow, quickly collapses. The quick collapse of the magnetic field induces high voltages in both the primary and the secondary windings of the coil. The voltage induced is proportional to the turns of wire in the winding and, therefore, the voltage in the secondary could go as high as 20,000 volts. However, the secondary voltage increases only to a value sufficient to establish a spark at the spark plug gap. Variations in voltage required are due to engine compression, speed, mixture ratios, spark plug temperatures, width of spark gap, etc.

Timing of the spark to the engine should vary according to the engine speed and the vacuum conditions in the intake manifold in order to realize maximum power and efficiency. Consequently, nearly all distributors are equipped with a centrifugal advance mechanism which consists of two weights which throw out against spring tension to advance the breaker cam with increased engine speed. This advances the time of the spark in accordance with engine speed. The correct centrifugal spark advance for a particular engine is determined by operating that engine approximately full throttle and varying the spark advance at that speed until the advance is found which will give maximum power. Centrifugal spark advance parts such as the weights, centrifugal cam, and springs are then selected to provide this advance.

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During part throttle operation there is a vacuum in the intake manifold and, consequently, the charge taken into the cylinder is not so highly compressed. With this condition an additional spark advance will increase fuel economy. Consequently, on many applications where part throttle operation predominates, a vacuum advance mechanism is used to secure this additional advance. The vacuum mechanism consists of a spring loaded diaphragm connected through linkage to the distributor. The spring loaded side of the diaphragm is air tight and is connected through a vacuum passage to an opening in the carburetor. This opening is on the atmospheric side of the throttle valve when the throttle is in the idling position so there is consequently no vacuum advance. When the throttle is opened. it swings past the opening of the vacuum passage, the intake manifold vacuum moves the diaphragm, and the distributor is rotated on its mounting. This produces a spark advance based on intake manifold vacuum. In addition to the type application which causes the complete distributor to be rotated for vacuum advance, there is another type in which the breaker plate is supported on bearings and linked to the vacuum advance diaphragm so that the breaker plate alone is rotated for vacuum advance. The total advance obtained is the result of the centrifugal advance plus the vacuum advance. Thus, when operating at partial throttle, full advance may be exacted giving maximum economy, and at full throttle the spark will be less advanced, eliminating 'spark knock' or detonation.

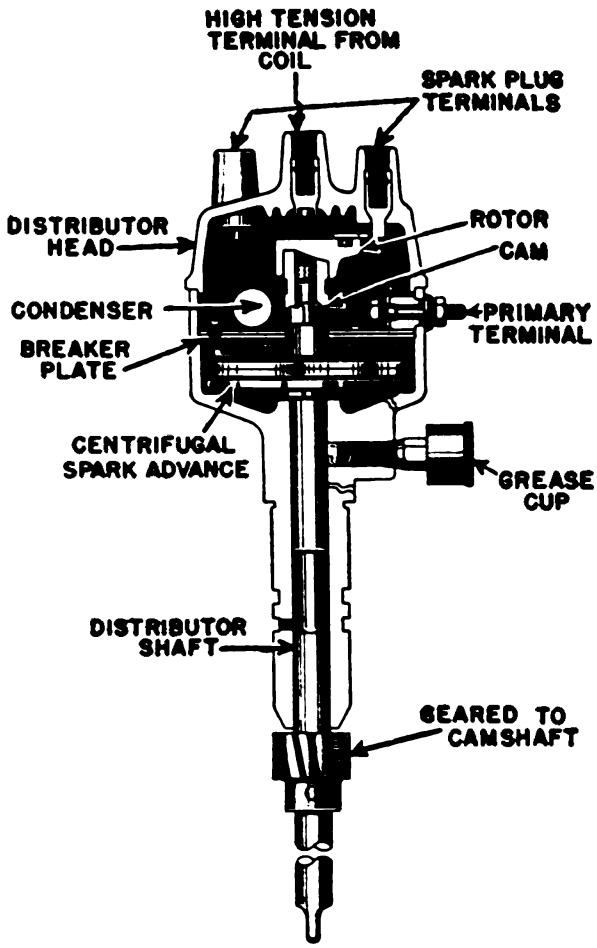

Figure 28. Timer-Distributor in Cross Section.

Distributor. Principle means of accomplishing the requirements we have set up for the battery ignition system is the distributor. It performs the two functions of alternately making and breaking the primary of the low tension circuit and directing the secondary or high tension circuit to the proper spark plug ac-

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cording to the engine firing order. The typical distributor has a metal housing, a centrifugal advance unit, a plastic rotor and cap, and a provision for a vacuum advance unit if one is required. The rotor cap has on its exterior a large, center terminal of the female type through which high tension current can be conducted from the ignition coil to the rotating arm. It also has one outer terminal on its circumference for each cylinder which is connected to a stationary contact inside the cap.

The distributor housing is circular in shape and provides mountings for the drive shaft which transmits properly timed motion from the camshaft to the rotor and the breaker plate on which is mounted the breaker contact points, breaker springs, condensor, and wiring. The housing also includes the centrifugal advance units coupled to the drive shaft, and the vacuum advance unit coupled to either the breaker plate or housing. The breaker contacts consist of two small points, one stationary and one on a movable arm which is under direct tension of the breaker spring. The contacts are together when not being moved by the lobes of the breaker arm.

As the rotor revolves, the cam on the drive shaft (having a number of lobes equal to the number of cylinders of the engine) causes the moveable point to separate from its mate and break the primary circuit. At the same instant, the rotor contact is opposite a contact in the distributor cap and an effective bridge is produced so that the high tension circuit is complete from coil to distributor to spark plug.

The points, being the most vital and sensitive part of the unit, are made of tungsten or platinum alloy to resist burning and pitting and are hard enough to withstand the hammering action caused by rapid closing at high speed. Too great or too little spring tension on the breaker point will cause a 'bouncing' or 'floating' action at high speeds which results in the coil not having the degree of saturation of magnetic field that is necessary for good ignition. A misfiring condition results.

The opening of the contact points should be carefully checked to be sure that they open the amount indicated in the vehicle's specifications. The normal gap, obtained when the movable point rubbing block is resting on the highest portion of one of the cam lobes, varies from fifteen to twenty-two thousandths of an inch, the average gap being eighteen thousandths of an inch. The correct gap setting allows the contact points to remain closed for the proper length of time during the revolution of the cam assembly, allowing the coil magnetism to build up to its required saturation. The angle through which the cam assembly moves while the points remain closed is referred to as the 'cam angle.' Very expensive machines are sometimes used to check this angle for obtaining the best possible operation characteristics. Care must be taken when installing new contact points or replacing old ones which have been cleaned that the faces of the contact points are exactly parallel when closed. The contact point faces must touch over the entire surface or a small area of contact will result and limit the amount of current which will pass into the coil. Improperly aligned points cause hard starting and intermittent missing when the engine is under load.

Adjusting Timing. In adjusting ignition timing, whether by advance units or settings of the engine operator, it must be remembered that moving the distributor body in the direction of drive shaft rotation retards the spark (causes the contact points to open late), and moving the body against the rotation of the drive shaft advances the spark. Relatively, the cam, moving in the direction of rotation advances the spark while movement against rotation retards it. The direction of rotation of the distributor rotor, therefore, can be quickly determined by applying pressure to the rotor to determine which way it will move the cam against spring pressure. The direction that the rotor will turn is the direction in which the shaft rotates.

Coil. The coil is essentially two windings and a magnetic core which acts as a transformer to change the low voltage of the primary (usually 6 to 12 volts) to the high voltage of the secondary (ranging from 8,000 to 20,000 volts, depending on fuel mixture, speed, spark plug gap, compression pressure, etc.) When the contact points are closed, the primary current running through the primary winding of the coil (a few turns of fairly heavy wire), builds up a strong magnet in the magnetic core. When the points are just separated, the current in the

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primary winding collapses and consequently the magnetism in the core collapses also. The resultant movement of the magnetic lines of force (flux) through the many turns of fine wire in the secondary winding transform the energy into extremely high voltage, capable of jumping a gap of one-half inch or more in normal air pressure. No adjustments can be made on a coil to increase or decrease its out put so if it does not furnish the proper amount of voltage due to a shorted or grounded winding, the coil must be replaced.

High tension leads and spark plugs carry the spark from the distributor cap to the cylinder. Since the voltages carried are extremely high, the insulation on the wires must be of the best quality. Any bare spots or frayed insulation will allow the spark to jump to the metal of the engine, thereby failing to fire the cylinder desired. The high tension leads are sometimes equipped with resistors to eliminate the spark noise picked up by the radio of the vehicle. These do not materially effect the output of the coil.

Spark plugs are devices that provide a spark gap inside the combustion chamber. They must be able to withstand sudden heat rises as well as to conduct any excess heat, caused by the burning of the air-fuel mixture, into the coolant surrounding the cylinder walls or head. The gap within the combustion chamber must be within specified limits to provide ease of starting as well as good ignition after starting. Spark plug gaps vary from twenty thousandths of an inch to forty thousandths of an inch, the average being around twenty-five thousandths of an inch. Since the action of the spark jumping the gap eventually transfers some of the metal of the electrodes away, they must be regapped occasionally to return them to their original specifications. Spark plugs are accurately constructed to allow just the right amount of heat transfer to the coolant so that the porcelain insulator will not be too cool and allow the unburned carbon particles to form a deposit and short or 'foul' the electrodes. They must also prevent too much heat from being retained which would cause the porcelain insulator to blister or crack. The accurate determination of this fact is known as selecting the proper 'heat range.' Spark plugs should be of the heat range that the manufacturer of the vehicle recommends in his specifications. To re-adjust the spark plug gap, a round wire type feeler gauge should be used to eliminate inaccuracies which would result from a flat feeler gauge. When adjusting the gap, it is important to move only the outer electrode. Moving the inner or center electrode may cause cracking of the porcelain insulator.

MAGNETO IGNITION

The magneto is a compact device for generating electrical power for spark ignition by means of electromagnetic induction. It serves as an excellent means of ignition when dependability and compactness are of prime consideration. Whereas a battery source utilizes a primary circuit, circuit breakers, condensors, coil, and distributor connected as individual units by a wiring arrangement in the battery ignition system, the magneto contains all of these elements within its housing to provide a properly timed spark at the spark plugs of the engine. Although magnetos are most common in aircraft engines, we find them in use today on tank engines and many types of tractor engines.

It has been found that an electric current will be produced in a wire if the wire is moved across a magnetic field between the poles of a magnet. This principle is employed when the winding of the armature is rotated between the poles of a horseshoe magnet. The current thus produced is allowed to flow around the core of the armature in a primary winding. This, in turn, creates a magnet of even greater strength and when the current flowing in the primary reaches a maximum, it is interrupted by the breaker points, thus causing a hasty collapse of the magnetic field (similar to the breaking of the primary circuit in the battery ignition system). High voltage is produced in the secondary winding in the armature and is led to a distributor rotor by means of a carbon brush or a collector ring. The rotor is geared to the magneto armature shaft and thereby distributes the high tension spark to the wires in the magneto blocks which are connected to the spark plugs in their order of firing.

Again, a multi-lobed cam is utilized to operate the breaker points, causing the primary field to collapse each time it reaches its maximum. A condensor plays the same role as it did in the battery ignition primary circuit, with the

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exception that it now is operating in an A.C. circuit in which the strength of the primary circuit depends upon the speed at which the magnetos are operated. It is because of the weak primary circuit at low speed that we must supply an auxiliary source of high tension current when starting a magneto-equipped engine; a booster coil.

Two general types of magnetos are in present use today; one in which the permanent magnets are stationary and the winding revolves, the other in which the permanent magnets revolve and the winding is stationary.

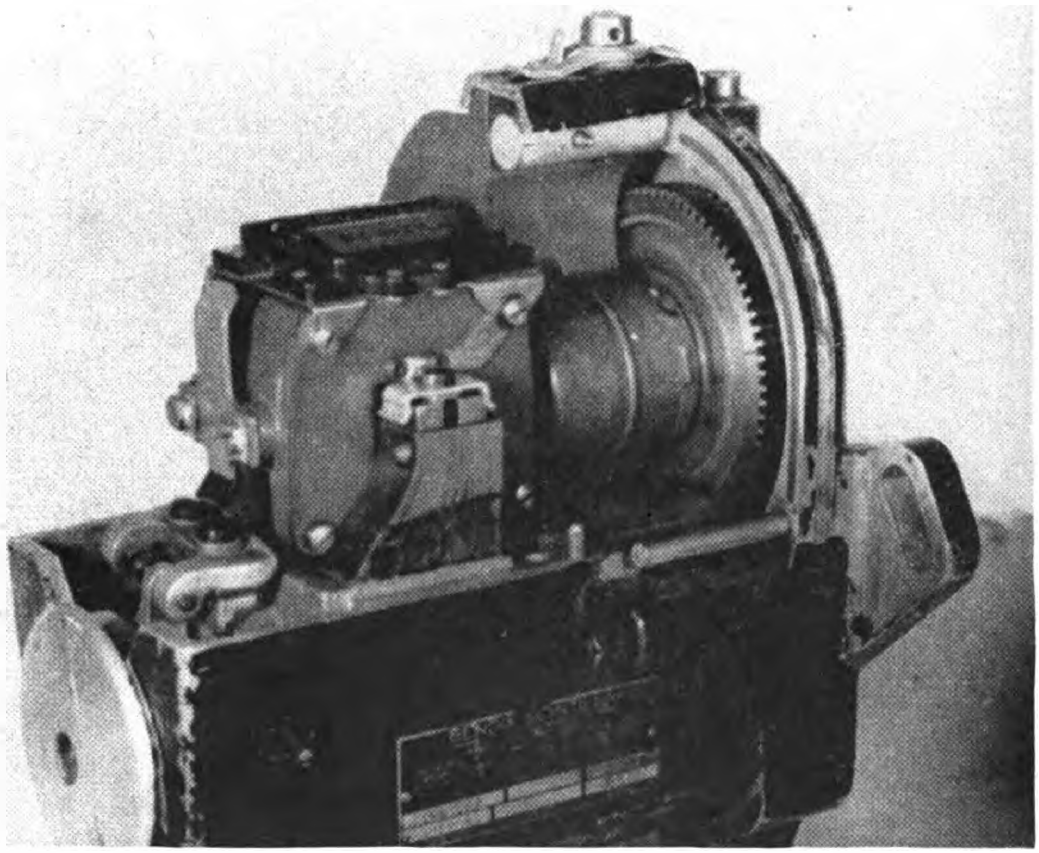

Figure 29. Inductor Magneto With Rotating Magnet.

The type magneto employing the stationary magnets of the horseshoe type is sometimes referred to as the armature wound type. The horseshoe magnet usually forms the frame for the magneto. Soft iron pole pieces are attached to the poles of the steel magnet. The inner ends of these pole pieces are circular and project far enough inward so that there will be very little air gap or clearance between the pole pieces and the rotating armature. Since the magneto is usually attached to steel or cast iron, a 'boss' of nonmagnetic material is placed under the ends of the magnet to prevent the magnetic field between the poles from being diverted by the metal on which the magneto is mounted.

The retention of magnetism by steel is a very curious and interesting property. It is found that a much stronger magnet is obtained, weight for weight, by putting two or more magnets together than by using a single large magnet. To accumulate the magnetism of separate magnets, all the north poles are placed together and all the south poles together. (An easy way to tell if like poles are together when placing the magnets on a magneto is to place the magnets so that adjacent poles of the individual magnets repel each other). The advantage of a permanent magnet in a magneto is that the magnetic field is of a high intensity at very slow magneto speeds so that a good spark is produced. At the same time,

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the magnetic field does not increase with speed, so that excessive voltage will not be produced at the high speeds and burn out the winding.

The revolving magnet type of magneto, sometimes called the inductor type, employs the same principles except that the magnets in this case are revolving and the primary and secondary windings and the breaker points are stationary.

Many of the troubles which occur in magneto ignition systems are similar to those found in battery ignition systems. Dirty or incorrectly spaced breaker points or weak or shorted condensors can be detected by the means outlined in battery ignition. The permanent magnets may, over a long period of time, lose their magnetism due to heat and vibration. They can be readily recharged by placing them on a strong electromagnet and subjecting them to stronger magnetic lines of force.

ENGINE COOLING SYSTEMS

The temperature produced by the burning fuel in an internal combustion engine often reaches 2000 to 4500 degrees depending upon whether the engine is gasoline or diesel. The hot gases come in contact with the pistons, cylinder walls, valves, and cylinder head, all of which absorb heat. If this absorbed heat is not dissipated, the valves will burn and warp and the lubricant will burn causing seized pistons and bearings and scored cylinder walls. The excessive temperatures would also cause undue expansion of the fuel charges, creating a lean mixture which would result in a loss of power and additional heat-forming tendencies. Surfaces of the combustion chamber would become red hot, causing preignition. In most engines, about 35 per cent of the total heat in the fuel must be dissipated by the cooling system.

The two general systems of cooling now in common use and practical for a wide range of operating conditions are: *Air cooling,* sometimes referred to as direct cooling in which the engine is cooled by direct flow of air over the cylinder surface, and *liquid cooling,* in which the engine is cooled by circulating liquid, usually water, through jackets surrounding the cylinders. In liquid cooling, the liquid is subsequently cooled by circulating it through a radiator where its heat passes off into a current of air before being recirculated through the cylinder jacket.

Modifications of the liquid cooling system include steam cooling and sealed cooling. In the steam-cooling system, hot water is passed from the engine to a lower radiator tank, whence it returns to the engine; steam forming in the lower tank is condensed in the radiator. The sealed system is used in some liquid-cooled aircraft engines with ethylene glycol, which boils at 330°F., as a coolant. Engines using this system can run at higher temperatures than water-cooled engines and small lighter radiators can be used, offering less wind resistance.

LIQUID COOLING

Liquid cooling is accomplished by keeping the cooling medium in circulating contact with the metal surfaces to be cooled. This is accomplished by placing a jacket around the cylinder walls, head, and valve seats through which a liquid can be circulated. Water jackets are cast integrally with the cylinders, welded to the cylinders, or mechanically attached. The jacket includes an opening for cool water (or coolant) to enter and one for hot water to escape. The hot water outlet must be at the highest point in the jacket in order to prevent the formation of steam pockets.

Pipes connect the openings in the water jacket to the radiator. The pipe from the hot water outlet slopes upward to the top of the radiator with a minimum of curves and twists to form no restriction to flow. In order to prevent injury to the system from vibration, shock, and twisting strains between the radiator and the engine, the rigidity of the pipes is relieved by short lengths of rubber-hose.

Radiators cool the hot water leaving the engine jacket so that the same water may be reused for cooling the engines. When the water has been cooled it is recirculated through the jackets and repeats the cycle. All radiators for motor vehicles consist of two tanks between which is a core forming the radiating element. The core, of tubular construction, is made of copper or brass. It divides the water into thin columns or ribbons, thereby exposing a large radiating sur-

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face area to the air for more efficient cooling. While going through the core, the water gives up heat by transferring it through the metal conductors of the radiator core to the cool air. The air flow through the core is maintained by a fan which is usually driven by a V-belt from the front end of the engine crankshaft.

An Overflow Pipe is placed in the top of the radiator to maintain atmospheric pressure in the radiator. If the overflow pipe becomes clogged, the presence of any steam generated is liable to rupture the thin walls of the radiator core. In large cooling systems, an expansion or surge tank is added to the system to relieve any excessive pressure that might be built up by the formation of steam or expansion of the coolant.

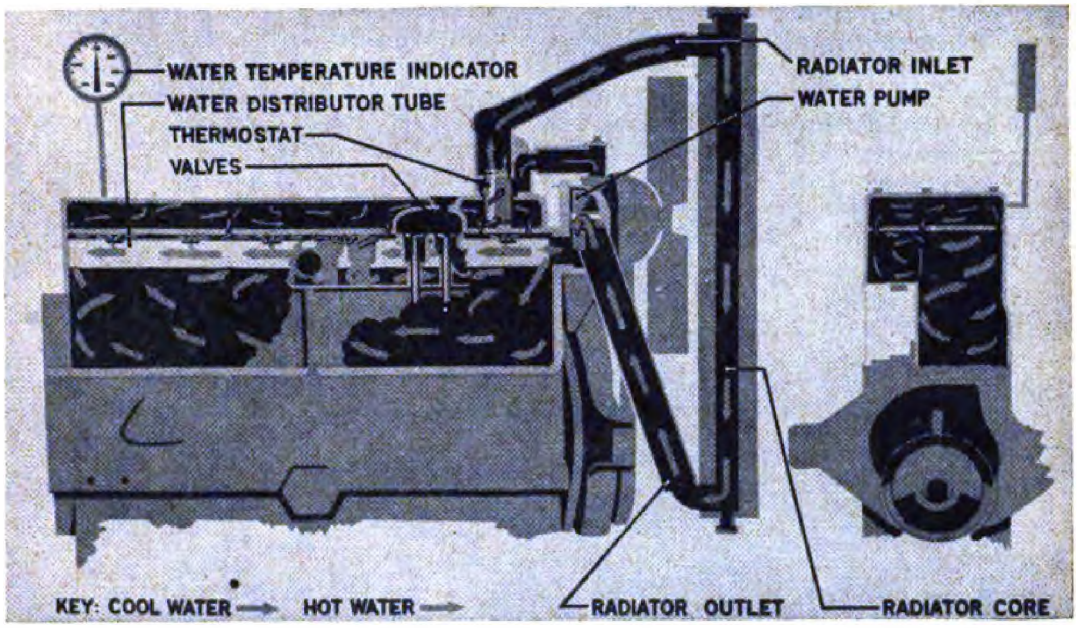

Figure 30. Circulation of Cooling Liquid and Parts of Cooling System of Water-Cooled Engine.

Means of sending the coolant through the radiator has developed from the days of the 'thermosyphon' process to the present force circulation system that incorporates special devices for improved temperature control.

The Thermosyphon system remains a part of the present means of circulation but no longer performs the task alone. This system works by gravity, cold water being heavier than hot water. As the water in the jacket becomes heated, it rises and is displaced by cold water, causing a continual, slow flow, which is no longer sufficient for present day requirements.

Pump or Forced Circulation resembles the thermosyphon system with the addition of a pump to speed the circulation of the water. The pump is driven by the engine and permits the cooling job to be done by smaller radiators, smaller piping, and less coolant. The pump in most common practice is the contrifugal type and permits circulation of dirt and foreign matter without a stoppage. Because the pump operates as soon as the engine starts, a longer time is required to warm-up the engine and it is possible to overcool the engine under light load.

A Thermostat has been placed in the line to overcome this defect in cooling. It is basically a heat-operated valve placed in the return line of the system to shut off the flow of water to the radiator when the engine drops below an efficient operating temperature. Another device to insure proper operating temperatures is a manual or automatic shutter to restrict or block the flow of air through the radiator core. Recent design trends show the use of an oil temperature regulator in the system as a means of regulating temperatures of oil or water, (through operation of a thermostat) through a small heat-exchanger. The

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ideal temperature for a water-cooled engine is generally just below the boiling point of water (212 degrees F.), but a safety factor must be added, bringing operating temperatures down to 170 to 185 degrees. The temperature of the cooling system is indicated on a control panel dial connected to a thermocouple or expansion bulb placed in the top of the cylinder head or block.

MAINTENANCE

The cooling system of the modern engine, when new and clean, usually has a cooling capacity in excess of that required for normal operation, but the efficiency of the system is substantially lowered by deposits in the jacket and radiator. The deposits (dirt, oil, grease, rust, and scale) occur during normal operation, and overheating will result if these deposits are not removed. Dirt and scale can be eliminated by using clear, soft water whenever possible. Oil and grease deposits are eliminated by proper lubrication of the water pump and proper seals between the jacket and working parts. Rust can be prevented by keeping the system full and using a rust inhibitor. Draining and cleaning accompanied by flushing with a cleaning agent and reverse flushing gun, cleaning air passages in the radiator, checking for leaks in the systems, and being particularly careful to have clean systems and using proper anti-freeze solutions during cold weather operation are all items of routine maintenance. Particular phases of cold weather operation will be discussed under separate heading in this book.

AIR COOLING

In cooling an engine directly with air, the cylinders and cylinder heads are provided with fins or ribs which offer a larger area for dissipation of heat. A current of air is forced over the fins by a fan or blower, thereby carrying the heat away. Cowling and baffles are used to direct the flow of air uniformly to all portions of the cylinders.

By making the cooling fins of metals having a high heat conductivity, the efficiency of the air-cooling system is increased. Aluminum, copper, and brass are used as much as possible. Most common are the cast aluminum heads of air-cooled radial and horizontally opposed engines.

Air-cooled engines were seldom found in automotive powerplants until the advent of air-cooled radial tank engines, previously discussed. In tanks, the fan or blower, to replace the aircraft propeller and the movement of the engine through a stream of cool air, has been built integrally with the flywheel. It is claimed that the present fans absorb no more power than the liquid cooling systems to keep the engines at proper operating temperatures. However, a weakness lies in the fact that at low speeds under heavy load conditions the cooling capacity is seriously cut down when it should be highest.

Air cooling eliminates the complicated 'plumbing' of high output liquid cooled engines, *i.e.*, water pump, radiators, and all piping and hose connections. Also eliminated is the problem of coolant supply and its freezing tendencies in cold weather operation. With proper design and control of temperature, air-cooling permits higher operating temperatures and consequently, higher thermal efficiency; however, the weight-saving construction of air-cooled engines is generally incorporated into the *high output side* so that operating efficiency is of lesser importance in actual practice.

ENGINE LUBRICATION SYSTEM

The primary purpose of engine lubrication is to prevent metal-to-metal contact between moving parts as the friction accompanying such contact would result in a loss of power, rapid wear of mating surfaces, and a temperature rise that might cause close-fitting parts to expand to the extent that seizure and failure of the parts would occur. The action of the lubricant is to coat each metal surface with a thin clinging film. Between the two films, other layers of lubricants slide along over each other, replacing the high friction of metal-to-metal contact by the low internal fluid friction of the oil. Composition, characteristics, and limitations of lubricating oils will be discussed in detail in another section.

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Lubrication systems in general are divided into two classifications according to the manner in which the reserve oil, or oil that is not being circulated through the engine, is stored. The most common is the 'wet sump' type of lubrication, in which the oil is carried in an oil pan as part of the engine itself. The moving throws of the crankshaft dip into this reserve to pick up part of the oil needed for lubrication. In engines where the cylinders are horizontal or inclining downward from the axis of the engine, the "dry sump' lubrication system is employed since no oil can be actually stored in the engine itself without running down into the lower cylinders. The 'dry sump' system employs an external storage tank for the lubricant from which the oil is pumped to and throughout the engine. Oil in the engine collects in a small sump located at the lowest part of the engine and is pumped by a 'scavenger' pump back to the external storage tank, passing through a cooler and filter on the way.

Referring to the 'wet sump' system as used commonly in automotive engines, all the vital working parts that are in, or open into, the crankcase are lubricated by the oil carried in the crankcase which is circulated under pressure or splashed mechanically on the contacting surfaces. The systems commonly used are: Splash, Force (pressure) Feed, Combination Splash and Force Feed, and Full Force Feed.

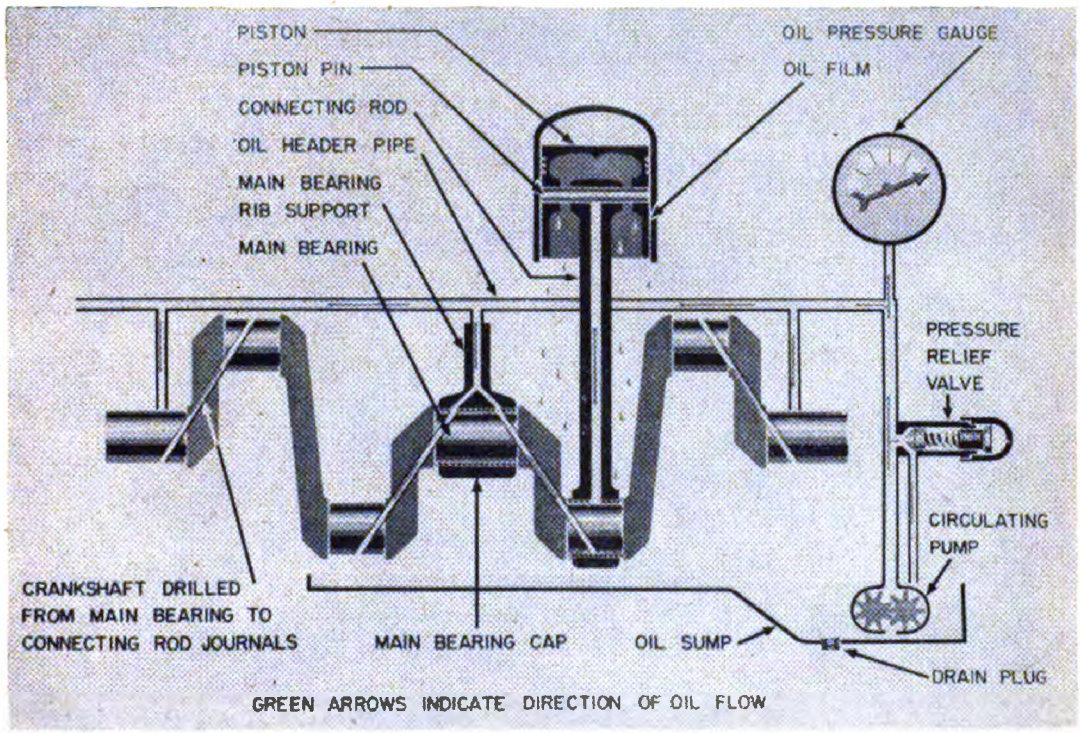

Figure 31. Full-Force Feed Lubricating System.

Splash System. The splash system was the first system employed in the internal combustion engines and was satisfactory until the advent of the present high speed, high output engine. In this system, the oil is carried in troughs under the connecting rod throws within the oil pan itself. As the crankshaft rotates, projections or dippers on the lower ends of the connecting rods swing down through the oil during the lower portion of each stroke, forcing oil up into the connecting rod bearing and splashing it throughout the internal parts of the engine. Troughs are placed in the upper part of the crankcase, cast integrally with the upper half, to catch a portion of the oil and direct its flow to the main bearings.

Combination Splash and Force Feed System. The combination splash and force feed system is still in practical use in medium-sized engines. An oil-circulating

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pump picks up the oil from the oil pan or reservoir and sends it under pressure through an oil gallery in the crankcase to the main bearings. Oil pipes in each separate oil trough may direct a stream of oil against the dipper on the lower end of the connecting rod. Piston pins, cylinder walls, timing gears or chains, valve operating mechanisms, and sometimes camshafts depend upon the splashed oil for their lubrication.

Force Feed System. The force feed system incorporates another step toward the positive lubrication of specific engine parts. The oil pump sends the oil through an oil gallery to the main bearings of the crankshaft, but in addition, the crankshaft contains drilled passageways through which the oil can flow under pressure to lubricate the connecting rod bearings on the crankshaft throws. Oil also flows under pressure to the camshaft and overhead rocker arm bearings (in 'I'-head or valve-in-head engines). The cylinder walls and piston pins are lubricated by splash, the oil being thrown off the crankshaft and connecting rods.

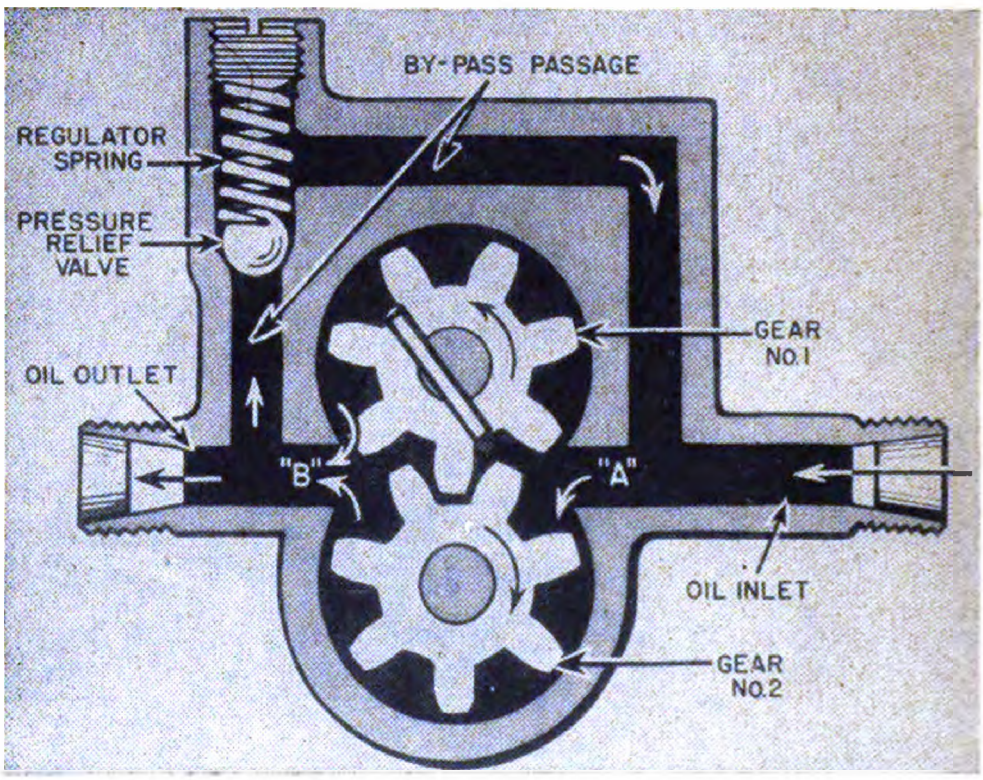

Figure 32. Gear Type Oil Pump With Cover Removed, Showing Oil Passage and Pressure Relief Valve.

Full Force Feed System. The full force feed system embodies the latest developments in lubrication systems and meets the demands of present engine operating conditions. In this system, the flow of oil under pressure to the gallery, crankshaft bearing, and connecting rod bearings is continued through rifle-drilled connecting rods to the piston pins. Camshaft and rocker arm bearings are also lubricated under pressure. The oil spray from around the piston pin lubricates the pistons and cylinder walls. Included in modern design trends are oil passageways in the engine block leading to hydraulic valve lifters (when used), oil filters, and oil temperature regulators mounted integrally with the block itself.

Oil Pumps. Oil circulating pumps are critical items in the present form of pressure feed system. They are generally arranged to be driven from the camshaft on the same shaft that drives the distributor. Oil pumps are of three general types: plunger, vane, and gear, of which the latter is almost the universal

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standard at present. All, with the exception of the plunger type, are positive displacement pumps and have a pressure relief valve incorporated into the system to prevent the pressure developed in the oil lines from exceeding a predetermined standard.

The plunger type pump, used as an oil circulator in splash systems, is operated by a cam from the camshaft similar to the fuel pump. As the plunger is forced outward by a spring, oil is drawn into the cylinder and a ball check valve closes after it. As the plunger is forced back into the body of the pump by cam action, the charge of oil is pumped out of the cylinder past a spring-loaded check which stops the flow back into the body on the following intake stroke. The vane type positive displacement pump has an impellor containing spring loaded vanes mounted off the axis of the pump body, its rotation giving the vanes an eccentric effect. As the impellor turns, the vanes are forced outward by the springs which hold them in contact with the pump body at all times. Oil-drawn in after one of the vanes through the entrance, is trapped by the vane ahead. As the vane is rotated to the opposite side of the pump, the space between the impellor and body becomes smaller, forcing the trapped oil out into the oil lines.

The gear type pump consists of two meshing gears with power provided to one of them through a shaft. Oil is drawn in, and follows the outer circumference of the teeth to the outlet side. A very close fit between the gear teeth and top, bottom, and sides of the pump body prevents oil from escaping from the outside teeth.

Oil Filters. Oil filters recently have become one of the more highly developed parts of the lubrication system because of the many operations of military engines under adverse conditions of open terrain and desert. The unit removes from the oil stream particles of dirt, sand, and metal that are picked up by the engine and prevents them from circulating to minimize the wear of moving parts. The filters generally are connected in the oil circuit so as to handle part of the circulating oil at all times. They are incorporated with a bypass and a spring loaded valve (particularly if designed to handle most or all of the lubricant), in order that stoppage of the filter due to accumulation of dirt will not choke off the lubricating system. The filtering element consists of a screen and a filtering material that retain impurities as the oil is forced through. Among the materials in use are cotton, steel wool, and fullers earth, in various combinations that are replaced when dirty. Disc filters of the Cuno type, rapidly gaining in prominence, are equipped with a wiper that can be either manually or hydraulically controlled to keep the discs clean, a drain being provided at the base of the unit through which the accumulation of dirt, can be removed.

Among other necessary accessories of the engine lubrication system are: oil temperature regulators—which are, in operation, heat exchangers as connected with the engine cooling system, designed to maintain the engine oil temperature approximately 70 degrees above the coolant temperature; oil pressure gages—which indicate the functioning of the oil pump (pressure gage readings will sometimes indicate stoppages in the system or high viscosity oil but *do not indicate the quantity of the oil in the engine);* oil level gages—usually of the 'bayonet' type to indicate the oil level in the crankcase; oil temperature gages—generally found on heavy duty engines; oil strainers—filtering elements which generally float on the surface of the oil in the reservoir and serve as the inlet to the oil pump; crankcase ventilators—to permit water and gasoline vapors to escape and also to prevent pressure inside the engine to build up to the extent where the lubrication system to the bearings would fail.

Regardless of the capacity of present day filtering elements, no system has yet been divised to remove water and gasoline vapors that have condensed in the lubricating oil. Since oil, therefore, can become seriously contaminated by water and gasoline in addition to its own oxidation, the oil must be changed at regular intervals. Contamination is caused by such dissimilar conditions as temperature ranges, load conditions, and atmosphere that no fixed rule can govern the frequency of changes; however, the recommendations of the manufacturer of the vehicle provide sufficient safety for all except the most extreme operating conditions.

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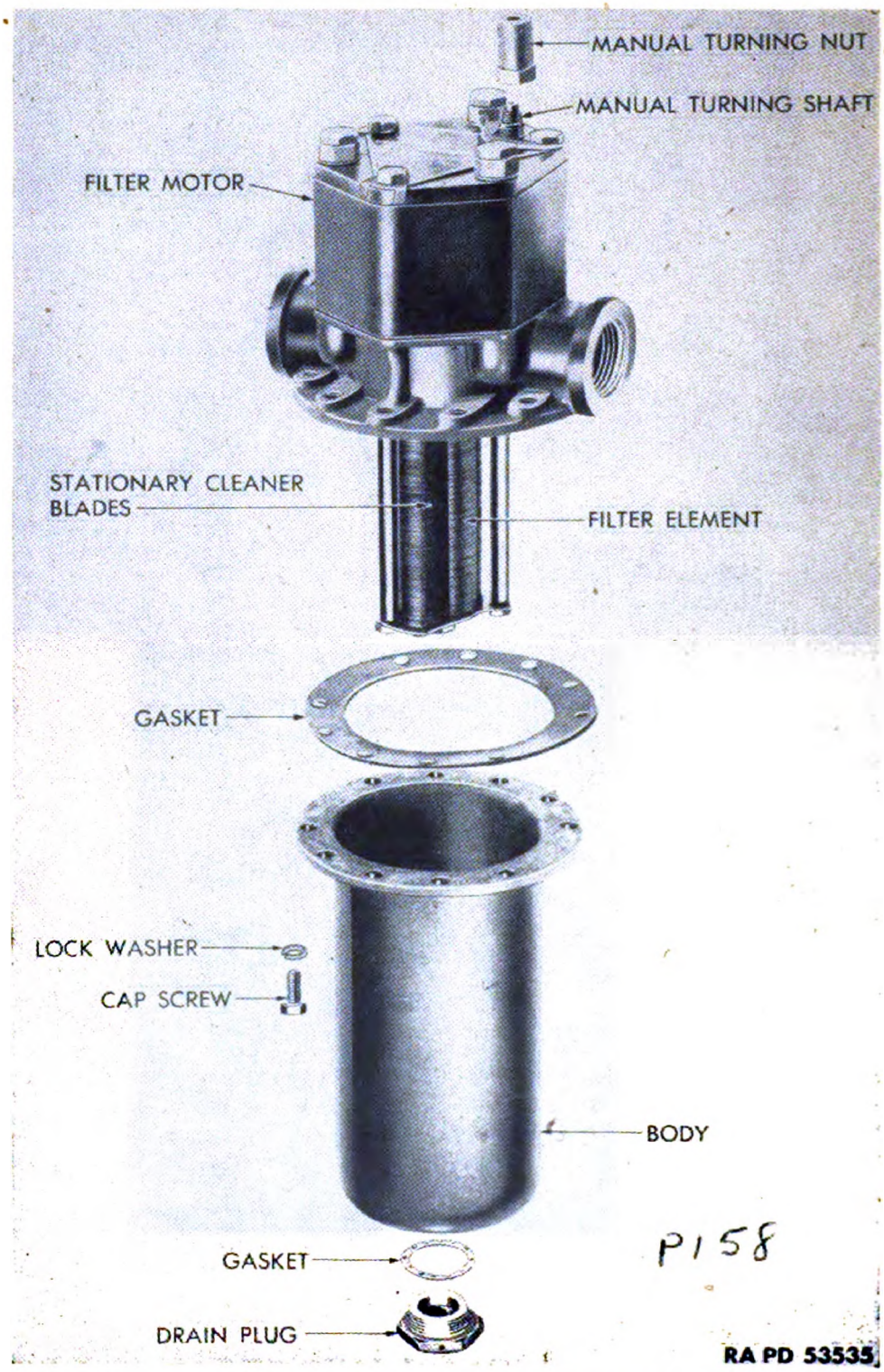

Figure 33. Engine Oil Filter Disassembled.

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ENGINE RECONDITIONING EQUIPMENT

The engines which power our military vehicles are subjected to much abuse through normal tactical operations. Many automotive officers have the mistaken idea that replacement of piston rings is all that is necessary to restore peak engine performance.

Piston rings have a limited range for the purpose they serve and all related parts have a direct bearing upon their life. To properly explain the need for special reconditioning equipment we must consider an engine which has worn beyond the allowable tolerances designated by the manufacturer.

Cylinder blocks worn in excess of a designated tolerance must be bored to true up the walls. Due to the thrust exerted by the piston on the sides of the cylinder walls during engine operation, normal wear tends to make the cylinder slightly funnel-shaped at the top. This condition is commonly known as taper. Engines used in wheeled vehicles have an allowable tolerance of .002 inch taper and .002 inch out of round when finished new. Wear in a cylinder exceeding .010 inch much be corrected by reboring and installing oversize pistons.

A special tool known as a cylinder boring bar is employed to correct and recondition cylinders. Many types of boring bars are being used throughout the Armed Forces, each doing a splendid job. The portable tool will bore a cylinder within .001 inch (one thousandth of an inch) of perfection. An explanation of the shop set-up used in cylinder block re-boring operations is given in Chapter 7.

Honing of cylinders may be necessary in extreme cases. This necessitates highly skilled personnel and considerable time. The hone, or cylinder grinder, is most commonly used to polish cylinders after they have been bored.

The most commonly used valve in present day engines is known as the 'poppet' type. It has an angular face which contacts an angular seat. These two surfaces are held together by a valve spring and form a gas tight seal. The angular face and seat is preferred because the valve upon closing will seek a common center, seating tightly. Valve seat width governs the valve life in that a narrow seat will not permit a rapid rate of heat transfer when the face and seat make contact. Burning of the valve is the net result. On the other hand, a valve seat that is too wide will become pitted due to small deposits of carbon lodging on the seat surface. When both surfaces are pitted, a leak results and valves must be reconditioned.

To properly recondition poppet valves a sufficient amount of margin must remain at the head of the valve to keep it from burning during operation. Each time that a valve is refaced, part of the margin is removed, thereby limiting reconditioning work as well as valve life. When the valves are refaced they should be free of any pits or scratches.

The rate of wear on valve stems is very low in most instances. Valve guides, although replaceable, last a long time. When reconditioning, clearance between valve stem and guide should be checked. *Note:* Worn intake valve guides will introduce a high rate of oil consumption.

Valve seats are ground with a valve seat grinder. This tool will do a very precise job. The operator must remember to remove just enough of the valve seat metal to clean it up and no more, particularly in an engine which does not use a valve seat insert.

ENGINE PERFORMANCE

When an engine is installed and operated in a vehicle it is impracticable to accurately determine the performance of that particular engine and the amount of power being developed. The power output depends on several factors such as; throttle opening, speed of the engine, spark advance, engine temperature, efficiency of the transmission gearing, rolling resistance, and others.

The most accurate method of studying the performance of the engine itself under controlled conditions is to place it on a test stand where the power developed may be accurately measured and the effects of several variable factors carefully determined. This method, however, does not fully duplicate the factors of a vehicle, particularly its moving through the cooling air. However, it is

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the basis for the horsepower ratings that are given engines before installations in one particular type of vehicle.

The usual method in testing engines is to couple them to an electric dynamometer which is, essentially, a variable speed D.C. motor that may readily be converted into a generator. The field of the dynamometer is supported in ball bearings which allow it to rotate freely and exert a torque through the armature on a balance or scale by means of a lever arm that is equal to engine torque. The dynamometer may be used as a motor in starting the engine and determining friction horsepower (that power required to drive the moving parts within the engine itself). Because of its high capacity to absorb power and its versatility, this means of engine testing has almost entirely superceded the old prony brake and water pump method of loading.

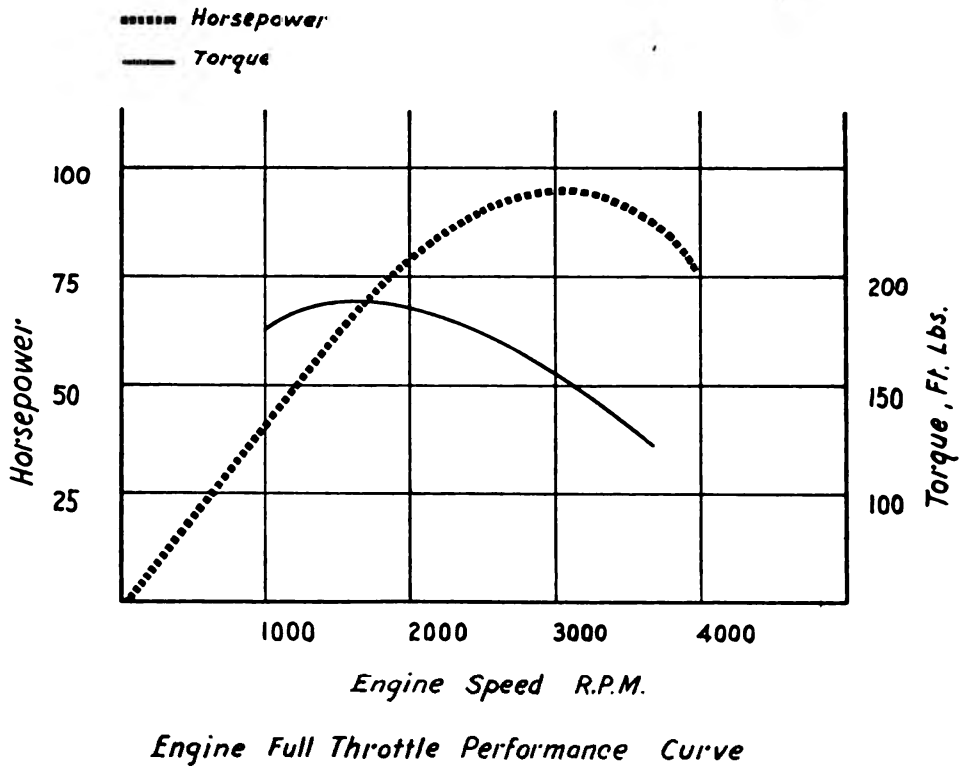

Figure 34. Chart Showing Engine Full Throttle Performance Curve.

One of the newer testing stands, particularly for use with aircraft engines, is the Torque Stand. The engine is operated, using a propeller as load, in a sealed cell with all controls in a separate compartment. The torque reaction from the propellor is recorded by instruments and the temperature and pressure conditions on the many working parts can be read by thermocouples in the control booth. From data obtained in these tests, curves of engine performance are computed and plotted, in most instances against the speed of the engine. These curves show horsepower outputs, torque developed, and fuel consumption, all at varying loads and varying throttle positions. The horsepower output of the engine, depending upon its volumetric and thermal efficiency, reaches a peak at a particular speed, depending upon the basic design. It is this peak output at full throttle from which the engine rating is determined. It is specified as ..... Horsepower at ..... R.P.M. The engine will develop its maximum torque at a lower speed, the torque capacity varying with valve timing and the relation of the length of the connecting rod to the crankshaft throw.

In addition to the engine tests conducted on test stands or cells, research engineers have set up a program of exhaustive endurance tests for automotive engines in which the engine operates under normal conditions in a vehicle over hundreds of hours of constant running. During this time the engine is subjected

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to abnormal punishment in an effort to bring out its weaknesses. Change in design and more exhaustive tests will follow. This differs from acceptance tests in which each individual engine is tested over a comparatively short period, covering all conditions of loads and conditions before being put into actual service.

Despite changes in design of parts, fundamental consideration of engines in general will always benefit persons involved in their use. Knowledge of the fundamentals of engine operation enables one to understand any variations in its functioning.

CLUTCHES

A 'clutch' enables the connection or disconnection of two rotating units when either one or both are stationary or in motion. Through the use of a clutch, a vehicle may be smoothly accelerated through several speeds, may be held idle with the engine running, or may be stopped rapidly without stalling the engine.

The clutch itself is not wholly connected to either of the two rotating units upon which it acts. Part of the clutch is connected to one rotating unit, the engine flywheel; the other part is connected to the second rotating unit, a shaft of the transmission. The part connected to the flywheel is the 'driving member' and the part connected to the transmission shaft is the 'driven member'. To activate the clutch for its different functions, linkage is provided.

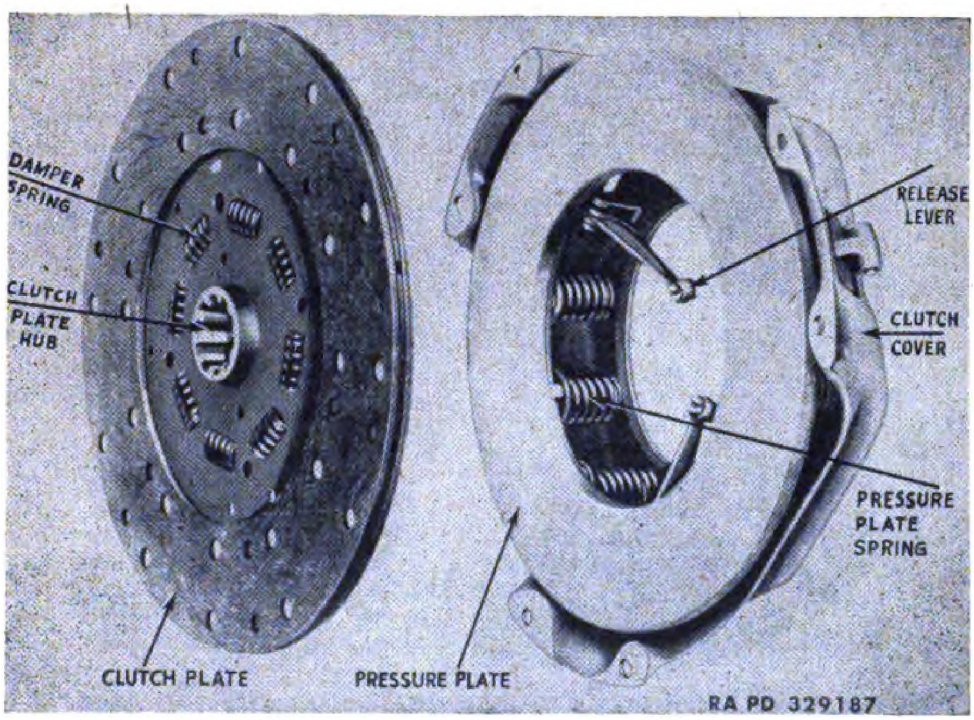

Figure 35. Clutch Disc and Pressure Plate.

All vehicles do not have the same type of clutch, although all but a few operate by friction. The friction surfaces may either be wet or dry, in which cases the former would be a 'wet' clutch and the latter a 'dry' clutch.

Depending upon the torque which the clutch must transmit, it may have a single plate or several discs. These plates in the one case and discs in the other constitute the driven member which is splined to a clutch shaft integral with the main drive gear of the transmission. The driven member may move axially in either direction depending upon the function which the clutch is performing. The construction of the driven member is a combination of a metal plate with asbestos or cork friction surfaces around the outside. Connected to the metal plate through damper springs is the clutch hub which is splined to mesh with the clutch shaft splines.

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The driving member is bolted to the flywheel and offers a smooth surface for engagement with the friction surface of the driven member. It is composed of a clutch cover, a pressure plate, and one or more springs acting against the pressure plate and release levers. The flywheel and pressure plate are both made of cast iron to facilitate cooling. The pressure plate affords another smooth surface for the engagement with the driven member. The clutch springs act against the pressure plate to keep the driven member firmly pressed between the flywheel and the pressure plate. The release levers provide a means for moving the pressure plate back against the pressure of the clutch springs, thus releasing the driven member or clutch disc from the torque of the driving member. A diaphragm spring may be substituted for the clutch springs and release levers and will perform the operations of both. A connection is made between the release levers and the pressure plate through lugs. When the release levers are depressed, they draw the pressure plate from the clutch disc. A throw-out bearing provides a means for transmitting the action of the operating linkage to the release levers. As long as no pressure is applied to the inner ends of the release levers, the clutch springs hold the pressure plate firmly against the clutch disc, and in turn the clutch disc is tightly clamped between the flywheel and pressure plate. The torque from the engine is then transmitted from the flywheel to the clutch cover to the pressure plate, which has lugs inserted into slots in the clutch cover. Torque flows from driving member to driven member by the friction between the flywheel, clutch disc, and pressure plate. Since the clutch disc is splined to the clutch shaft through the splines of the clutch disc hub, the torque is then transmitted to the transmission. Upon initial engagement of the pressure plate, clutch disc, and flywheel, the pressure plate presses the clutch disc into contact with the flywheel. The driving members are rotating but the driven members are stationary. A shock develops in the driven member by the sudden engagement of the clutch. Damper springs, connecting the friction surface of the clutch disc and clutch disc hub allow slight movement of the friction surfaces without movement of the clutch disc hub. When the initial engagement shock has been absorbed, the clutch disc will slip slightly between the pressure plate and flywheel until driving and driven members finally have synchronized their speed. The action of clutch engagement is similar to a person's hand attempting to slide a heavy object along a table through friction between the hand and the object. With the addition of pressure the slippage decreases and the object starts to move. Finally, with enough hand pressure against the object, it will move at the same speed as the hand.

To disengage the driving from the driven member, depress the foot pedal. This action moves the operating linkage which forces the throw-out bearing against the inner ends of the release levers. The pivot action of the release levers in the clutch cover draws the pressure plate back from the clutch disc. The rotation of the flywheel will throw the clutch disc full away from any driving member, and the driven member will then cease to rotate. Release of pressure on the throw-out bearing will allow the pressure plate to force the clutch disc into contact with the flywheel, and the clutch will again be engaged.

The clutch employing a diaphragm spring rather than clutch springs and release fingers operates on the same principle. The spring is dished like the bottom of an oil can. Pressure against the inner section will cause the outer edge to pivot around rings attached to the clutch cover. The movement of the outer edge of the diaphragm spring will draw the pressure plate away from the clutch disc, thereby releasing or disengaging the clutch. When pressure is taken away from the diaphragm spring, the inner section moves out and the circumferential section pivots and forces the pressure plate against the clutch disc.

For vehicles whose engines transmit a greater than average amount of torque, several discs and plates must be used to provide a greater friction area to reduce heat due to slippage. The same principle of operation as the single disc clutch is used in the 'multi-disc' clutch. Rather than have one pressure plate, several pressure plates are attached to the clutch cover slots or pins with a clutch disc between each two pressure plates. When the throw-out bearing exerts pressure against the release levers, they will pivot and draw back one pressure plate which is attached to all the others. The rear pressure plate's movement will

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take the tension of the clutch springs from the remaining pressure plates and allow the clutch discs to separate.

To further cool the clutch assembly, the aforementioned wet type clutch may be used. Its construction is similar to a dry clutch with the exception of minor details. There are driving and driven members. The driving member includes the flywheel, the clutch cover, and the pressure plate which are all similar to the dry clutch except that the clutch cover is sealed to the flywheel and clutch shaft to prevent leakage of the fluid. The driven member or clutch disc is constructed of a metal plate with metal hub (splined for engagement), and friction surfaces. These friction surfaces are made of a large number of cork plugs inserted through the metal plate of the clutch disc. (Cork plugs do not swell and cause the clutch to grab as would an asbestos friction lining.) The operation of a wet clutch is the same as that of a dry clutch except that the throw-out bearing is inside the clutch cover rather than outside and is forced against the release levers on disengagement by means of a sleeve attached to the operating linkage. The actual engagement and disengagement of a wet clutch is the same as that of a dry clutch.

A 'dog' or 'positive' clutch is used to connect a gear to a shaft by positive engagement. This type of clutch is found inside the transmission and its function will be discussed under transmissions. Its construction consists of a sleeve splined internally to match the splines of the shaft, the ends of which may be cut to form 'dogs' or square teeth. The circumference may have teeth on it to be engaged with the internal teeth on another gear.

TRANSMISSIONS

The torque developed by an engine will vary according to engine speed and load; at low engine speeds there is very little torque developed. The purpose of the transmission is to provide a gear reduction which allows the engine to turn over rapidly while moving the vehicle slowly, thereby furnishing high torque for starts and hills. A means for reversing the direction of rotation of the drive shaft is also provided by the transmission. If the transmission is put into neutral, the vehicle may be held stationary with the engine running.

An understanding of gear ratio must be obtained if the theory of the transmission is to be grasped. A gear reduction means a reduction of rotational velocity of the driven shaft with respect to the driving shaft. The torque delivered by the driven shaft is inversely proportional to its speed. Take for example the mechanism of a mechanical ice cream freezer. A handle is connected to a shaft which has a small gear on it. This small gear is meshed with the teeth of a large gear attached to the ice cream container. One revolution of the handle may turn the container one quarter of a turn; there is a gear ratio of four to one because it takes four revolutions of the driving member to move the driven member through one revolution. The greater the difference between the two revolutions of the driving gear, the greater will be the gear ratio; but if the driving gear rotates a fewer number of revolutions than the driven gear, the reverse situation arises. There is now an 'overdrive' rather than a gear reduction. The sprockets of a bicycle are good examples of an overdrive. The driving sprocket is large and the driven sprocket is small. If the drive sprocket turns one revolution to the driven sprocket's three revolutions, the gear ratio is 'one to three.' If the case exists in which both driving and driven gear are the same size, both will rotate at the same speed. The gear ratio is then 'one to one.'

Some transmissions may have three different gear ratios, the smallest being one to one or direct drive. This transmission is said to be a 'three speed' transmission. A five speed transmission will usually have one gear ratio an overdrive. All transmissions have some means of providing a high gear ratio for starting and a low gear ratio for traveling. All transmissions, however, do not incorporate the same method of obtaining these different gear ratios. The classification of a transmission is according to the number of forward speeds it provides, the manner in which the driver selects these different speeds, the manner in which the gears are engaged, and the types of gears used.

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Gears in a transmission may be any one of three types. A 'spur' gear is one which has straight teeth cut on the circumference of the gear blank, the teeth being parallel to the axis of the blank. This type of gear is used in the sliding spur type of transmission. A 'helical' gear is one which has straight teeth cut on the blank at an angle to the axis of the blank. This type of gear has to be in constant mesh with the gear it is driving due to this angular construction. A third type of gear is most often used for very heavy operation. It is called a 'herringbone gear.' The teeth are cut in a "V" shape around the circumference of the gear blank. A transmission using this type of gear is also a constant mesh type.

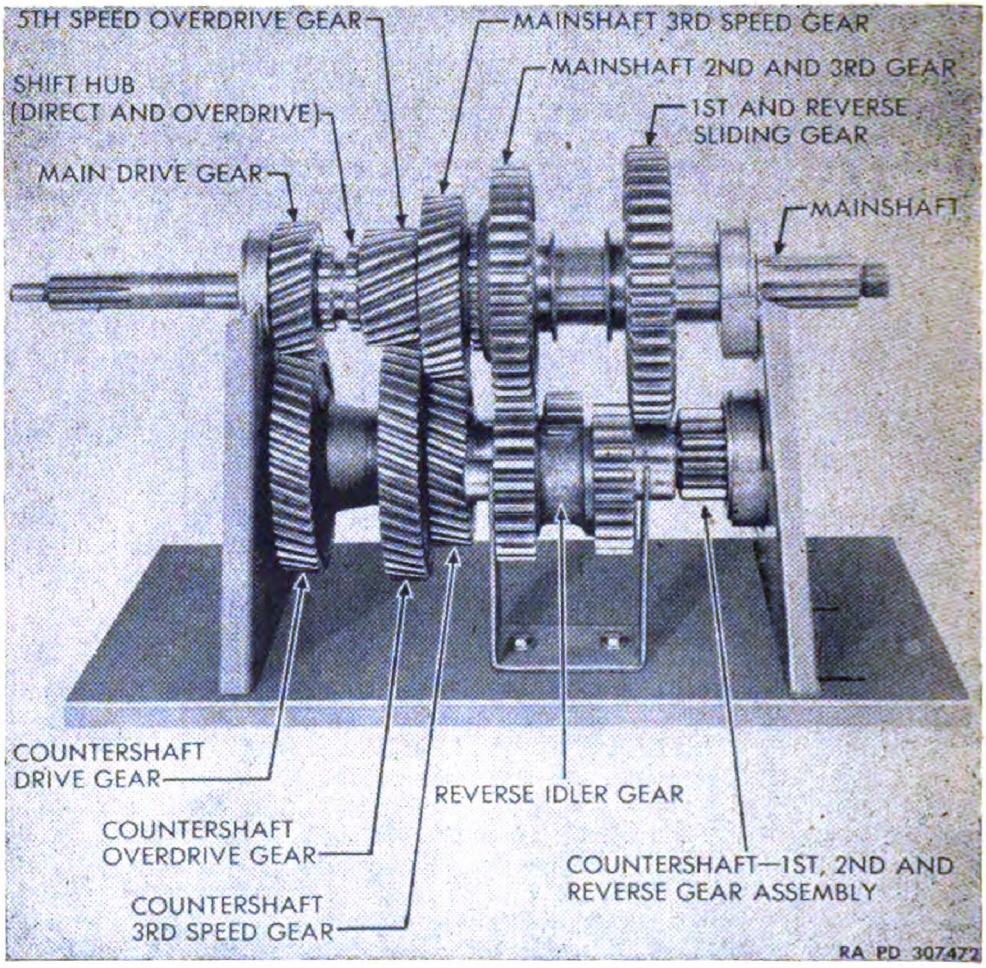

Figure 36. Transmission Gears in Neutral Position.

Transmissions may have one of the three types of gears, or they may have a combination. The type or types of gears used in a transmission will determine the method of selection of the different speeds. A 'progressive' type transmission is one which must be shifted through all speeds to obtain the highest speed. A 'selective' type transmission is one which allows the selection of any gear ratio without first proceeding through one or two of the other gear ratios. In the selective type, the chosen gear ratio is selected by sliding one spur gear into mesh with another spur gear, or the use of one gear as a dog clutch to connect another gear to the output shaft. As long as there is no restriction on the sequence of speeds, the transmission is of the selective type. One which uses sliding spur gears exclusively for speed selection is a sliding spur transmission.

In a constant mesh transmission it is possible to have all gears in mesh at the

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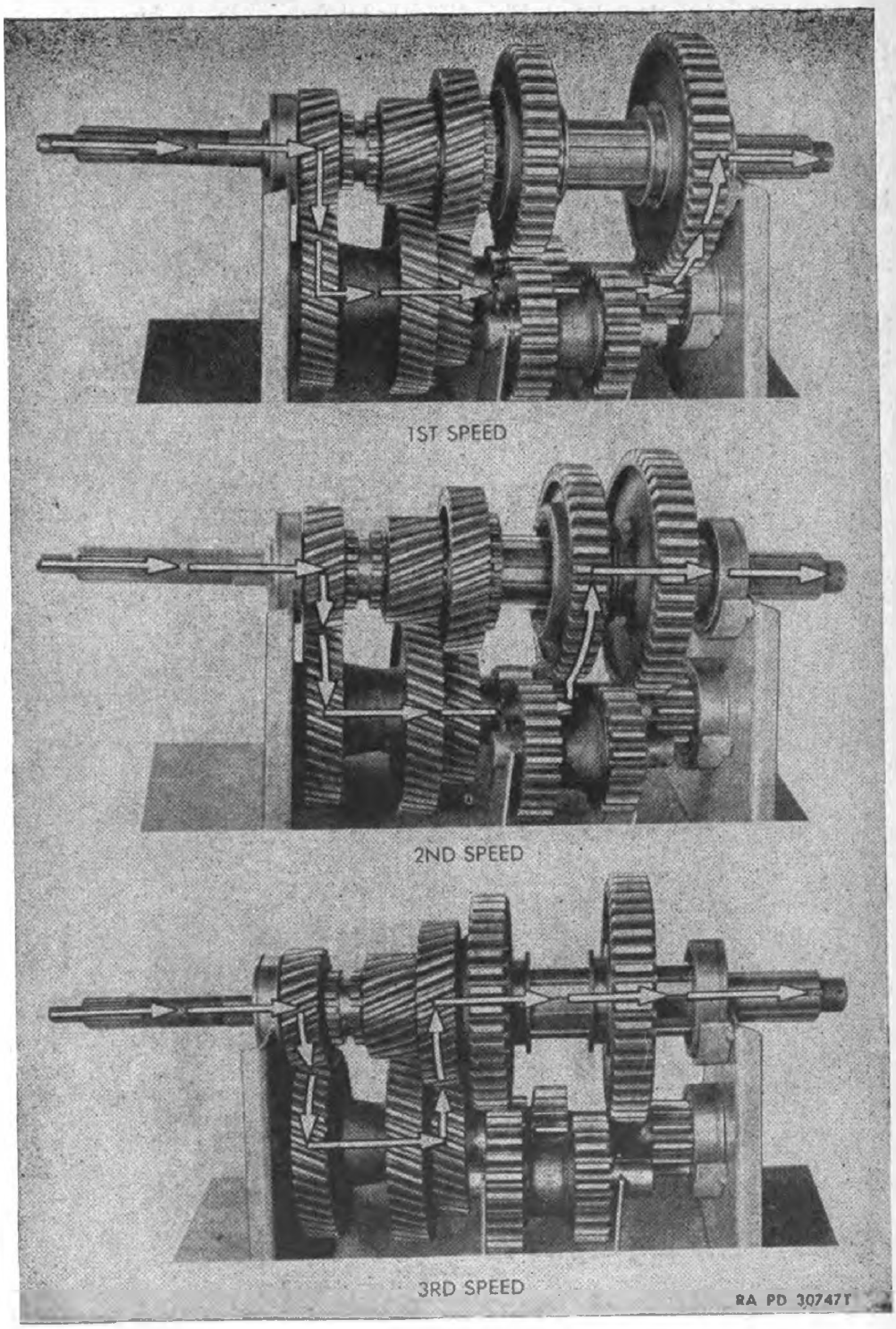

Figure 37. Operation of Transmission Gears—1st, 2nd, 3rd.

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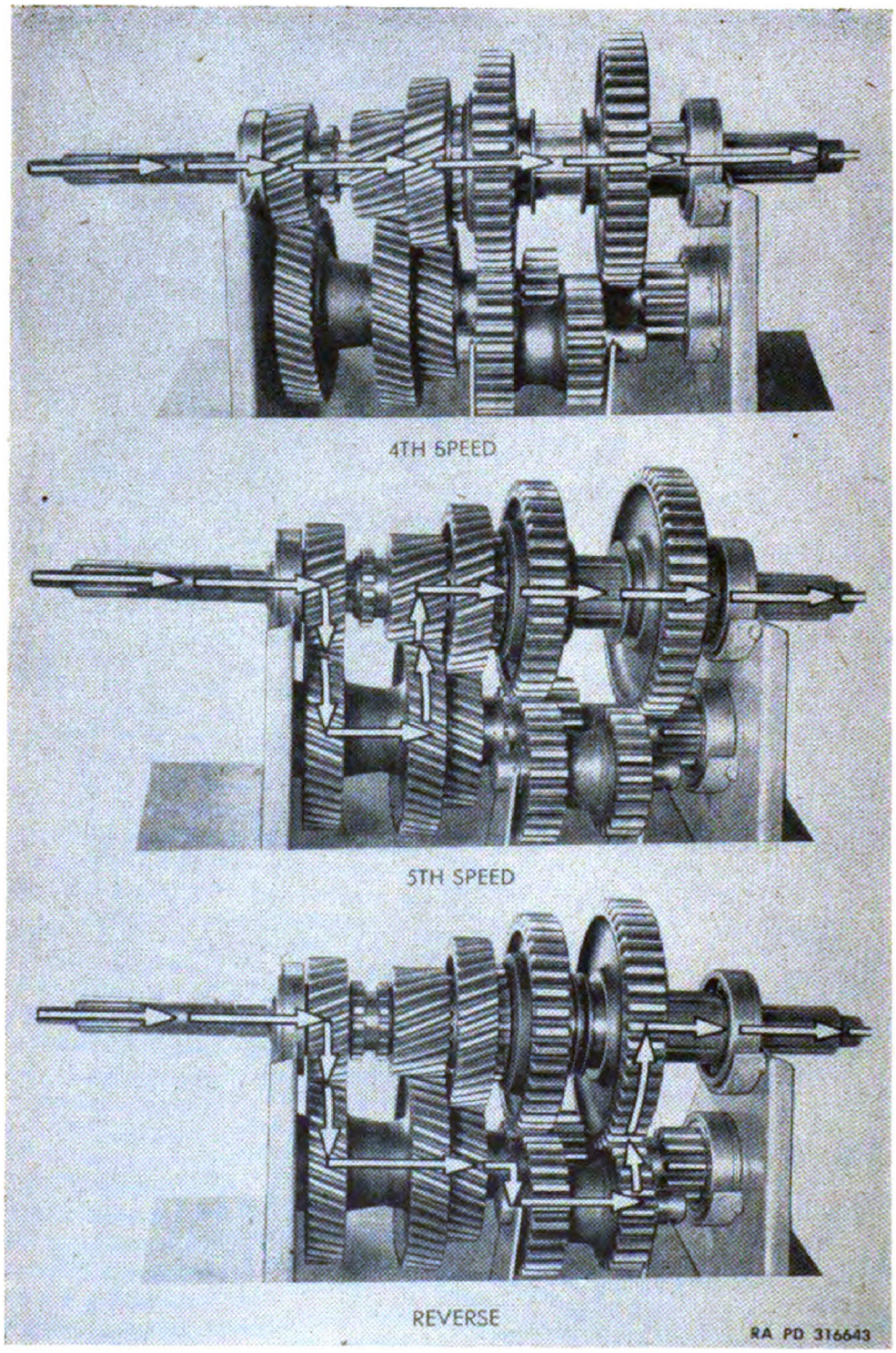

Figure 38. Operation of Transmission Gears—4th, 5th and Reserve.

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same time. The driven gears are mounted on bearings on the output shaft and do not actually drive until a sliding dog clutch engages a certain gear with the shaft. A 'syncromesh' unit is often used with a constant mesh transmission to syncronize the speeds of driving gear and driven shaft before positive connection between the two is made. The unit itself merely consists of a sleeve splined inside and out with a bronze cone at one end. Another sleeve, splined internally to the first sleeve, is held to the first sleeve by a spring loaded ball between the two. There are teeth on the side of the gear to be connected which will fit in the internal splines of the outer sleeve. When the outer sleeve is moved over to the gear, the bronze cone on the inner sleeve connects with a mating cone on the gear. This connection of the two cones causes the gear to gain the speed of the shaft connected to the synchromesh unit. The outer sleeve is moved a small amount more, and the teeth of the gear are engaged with the splines of the outer sleeve. The shaft connected to the sleeve is then driven by the gear through the synchromesh unit.

All transmissions have certain fundamental components. These are; the case which houses the gears and shafts, the control cover which houses the shifter mechanism, and the various gears and shafts. The shafts in the case, in order of the flow of power, are; the clutch shaft or drive end shaft, the counter shaft, and the main shaft.

The clutch shaft is located at the upper front of the case. It has a main drive gear either keyed or forged to it which drives the counter shaft at all times. The main drive gear is splined internally to allow entrance of a dog clutch and is also bored to allow another shaft to ride in it. It is supported by a pilot bearing in the flywheel and also by a bearing in the case. The counter shaft is located at the bottom of the case and is supported at both ends by bearings in the transmission case. The gears on the countershaft are either integral with the shaft or connected so that they all rotate together. The main shaft is located directly above the counter shaft, and is supported by a transmission case bearing at the rear and by a roller bearing inside the main drive gear. The gears on this shaft are either splined to the shaft in the case of a sliding spur, or are mounted on bearings on the shaft as in the case of the constant mesh type. The gear used to put the transmission into reverse may either be sliding or constant mesh. It is located beside and above the counter shaft.

When speed selection is necessary it is accomplished through the use of the operating mechanism in the control cover. The gear shift lever in the cab enters the top of the control cover and contacts a shift lug which is clamped to a shifter rail. The shifter rail is merely a bar with a fork attached to it. This fork, the shifter fork, is the unit which moves a gear or dog clutch into mesh. One shifter rail holds one fork and can be made to engage two different speeds by moving forward or backward. These shifter rails are located in the control cover just above the transmission main shaft. To shift the transmission into gear, move the gear shift lever into contact with the first speed shift lug—backward or forward depending on what gear ratio is desired.

In the case of first speed, the large gear at the rear end of the main shaft is moved into engagement with the small gear at the rear of the counter shaft. The torque will then flow from the main drive gear to the counter shaft drive gear, along the counter shaft to the first speed gear, and up to the low speed gear on the main shaft. This gear is splined to the main shaft, and therefore, transfers the torque to the main shaft. There is a gear reduction between the main drive gear and the counter shaft drive gear; there is also a gear reduction between the countershaft first speed gear and the main shaft low speed gear. The gear ratio is the product of both gear reductions. All other speeds of the transmission may be selected by moving the gear shift lever to the position corresponding to the desired speed. To obtain a lower gear reduction and an increase in speed, another selection is made.

It will be noted that first speed and second speed gears are of the sliding spur type. By sliding the second speed gear on the main shaft into mesh with the second speed gear on the counter shaft the desired gear ratio is obtained. Torque flows from the main drive gear to the counter shaft drive gear, along the counter

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shaft to the second speed gear and from there to the second speed gear of the main shaft. The second speed gear is splined to the main shaft and therefore transfers its torque to the main shaft.

Before a speed change can be accomplished, the gear shift lever must be moved to neutral. This action moves the driven gear out of mesh with the counter-shaft gear, thus leaving only the clutch shaft, counter shaft, and idler gear rotating.

The third speed gear on the main shaft is in constant mesh with the third speed gear on the counter shaft, both gears being helical gears. The third speed gear is on a bearing on the main shaft so that it must be connected to the main shaft by a dog clutch before it will drive the main shaft. By moving the second speed main shaft gear forward until its internal splines mesh with the dog clutch on the side of the third speed main shaft gear, the third speed of the transmission is accomplished. The flow of torque can then be traced from the main drive gear to the counter shaft drive gear and along the counter shaft to the third speed gear. The third speed main shaft gear carries the torque from the counter shaft to the second speed main shaft gear, which is now being used as a sliding dog clutch, and then to the main shaft.

All three of the speeds thus far have given a gear reduction so that the main shaft rotates slower than the clutch shaft. For normal driving most transmissions are shifted into the direct drive which allows the clutch shaft and the main shaft to be directly connected. This connection is obtained by moving the shift hub into mesh with the main drive gear's internal splines. The shift hub is splined to the main shaft. The torque then flows straight through the transmission from clutch shaft to main shaft, and consequently the gear ratio is one to one.

Transmissions on light or medium trucks having five forward speeds will usually have an overdrive for the fifth speed. To engage the overdrive gear with the main shaft, move the shift hub to the rear until it meshes with the internal splines of the overdrive gear. Flow of torque will then be from the main drive gear to the counter shaft drive gear, and along the counter shaft to the fifth speed gear. The main shaft overdrive gear transfers the torque from the counter shaft overdrive gear to the shift hub, which in turn carries the torque to the main shaft.

Reverse is another function which the transmission is capable of providing. A reverse idler gear is meshed with a reverse idler drive gear on the counter shaft. To engage the reverse speed, the first speed gear on the main shaft is meshed with the reverse idler gear. The torque goes from the main drive gear to the counter shaft drive gear, and along the countershaft to the reverse idler drive gear. It then is transferred to the first speed main shaft gear through the reverse idler. The main shaft is now in reverse.

Some vehicles have accessories such as winches, pumps, etc., which are driven through a power take-off from the transmission. This power take-off has one or two speeds forward and a reverse, depending on the duty it must perform. The selection of rotational speeds and direction of rotation of the output shaft is regulated by a shifter lever located in the cab. The shifter lever moves a sliding spur gear into mesh with the desired gear for speed and direction of rotation. The principle involved is the same as a transmission. The power take-off is bolted to the side of the transmission on which the reverse idler is located. An intermediate gear of the power take-off is in constant mesh with the reverse idler gear of the transmission. The speed of the transmission main shaft does not affect the speed of the power take-off drive shaft. Since the reverse idler gear obtains its torque from the counter shaft, the transmission main shaft may be in neutral, forward, or reverse rotations without affecting the rotation of the power take-off drive shaft. If a vehicle such as a half-ton pick-up truck becomes stuck in a swamp, the front winch may be used to pull it out. By engaging the power take-off in the forward speed, the winch will take in cable and draw the vehicle from the mire. Of course, the end of the cable must be attached to some anchor.

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AUXILIARY TRANSMISSIONS

If a vehicle is very large and its duty is that of hauling tremendous loads, further gear reduction must be provided for starting and for slow speeds. An 'auxiliary' transmission is added behind the main transmission and is driven by the transmission main shaft. The auxiliary transmission will have from two to four or more speeds depending on the greatest gear reduction needed. A separate gear shift lever is provided. This type transmission is the same as a main transmission except that there is no necessity for its having a reverse as the main transmission provides for that. If the main transmission has four forward speeds and the auxiliary transmission has three speeds, the possible speeds forward are twelve. The combination of gear ratios selected will depend on the difficulty of getting the vehicle in motion. The greater the torque needed at the wheels, the greater will be the gear reduction. As the torque need decreases, the auxiliary transmission and then the main transmission may be shifted up to direct drive.

HYDRAULIC DRIVES

The first function of a hydraulic type connection between the engine and the remainder of the power train is to act as a clutch. There are types, however, that act as both clutch and transmission and will automatically select the torque ratio between the engine and driving members within its predetermined limitations. For this reason we will break down the hydraulic drives into two parts and discuss each separately, using as examples; first, the straight fluid coupling, whose function is that of a clutch only, and second, the torque converter which acts as both a clutch and a transmission.

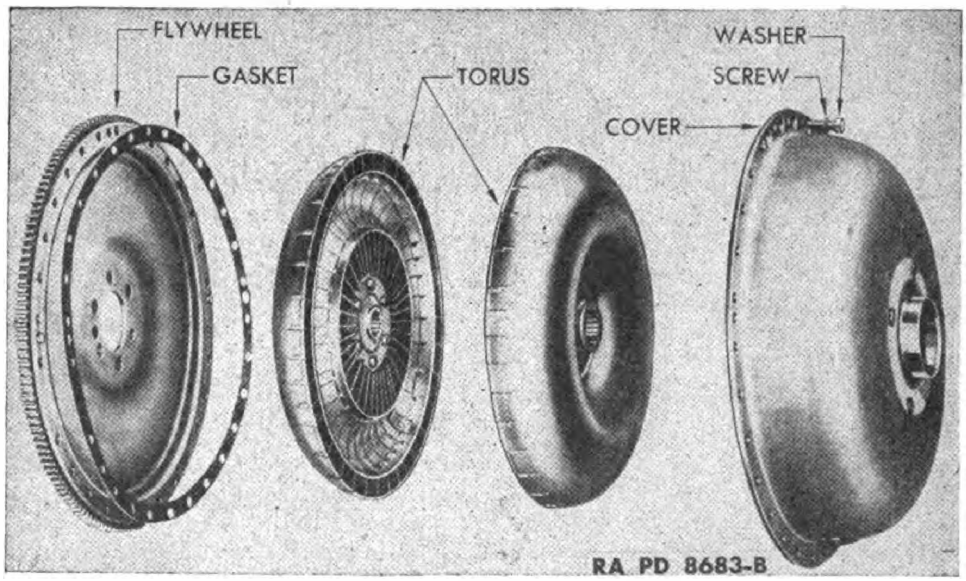

Figure 39. Fluid Coupling Disassembled.

Fluid Couplings. As this unit is used to replace the conventional friction type clutch discussed previously in this section, its characteristics must compare favorably with that of the friction clutch. It must be remembered that this unit is not expected to multiply torque, so it is always used in conjunction with some type of gear box. Sometime a friction type clutch is employed with the unit to facilitate shifting of gears while the vehicle is in motion.

The fluid coupling consists of three major parts: the drive member which is attached to the engine shaft, the driven member attached to the output shaft, and a housing or case filled with a fluid which surrounds the two members.

The drive and driven members are sometimes referred to as torus members, and will be so referred to in the remainder of this discussion. The drive torus

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and the driven torus are identical to each other, therefore either torus may serve as a drive or driven member.

In operation the engine causes the drive torus to rotate. Rotation of the torus creates centrifugal forces in the fluid contained in this member and because of the pressure differential created between the center and the periphery of the member, the fluid flows radially outward toward the periphery. The vanes incorporated in the members give a positive rotation to the fluid and the baffle directs the flow of the fluid. Once the fluid reaches the periphery of the drive member it is under considerable pressure and is projected from the drive torus to the driven torus, striking the vanes and causing it to rotate or at least to attempt to rotate. Here the kinetic energy of the fluid is absorbed, the fluid loses rotational velocity, and the centrifugal forces are decreased. Guided by the baffle, it is forced to move from the periphery of the driven torus to the center of this member, and due to the low pressure at the center of the drive torus it is carried from the driven side to the center of the drive torus to again begin its cycle of circulation. In figure 39 will be found a detail picture of the oil flow in the unit. Referring to the vector diagram in figure 40, it will

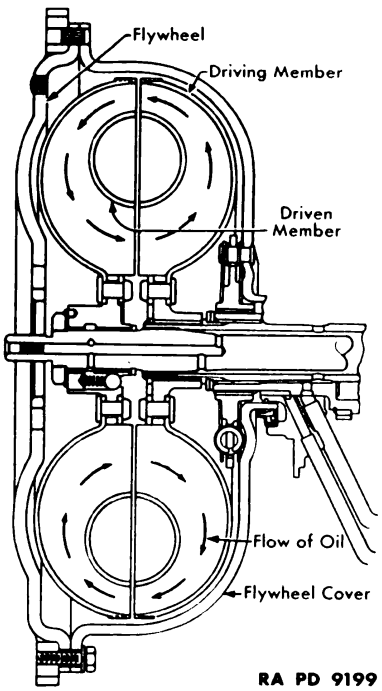

Figure 40. Fluid Coupling, Schematic Cross Section.

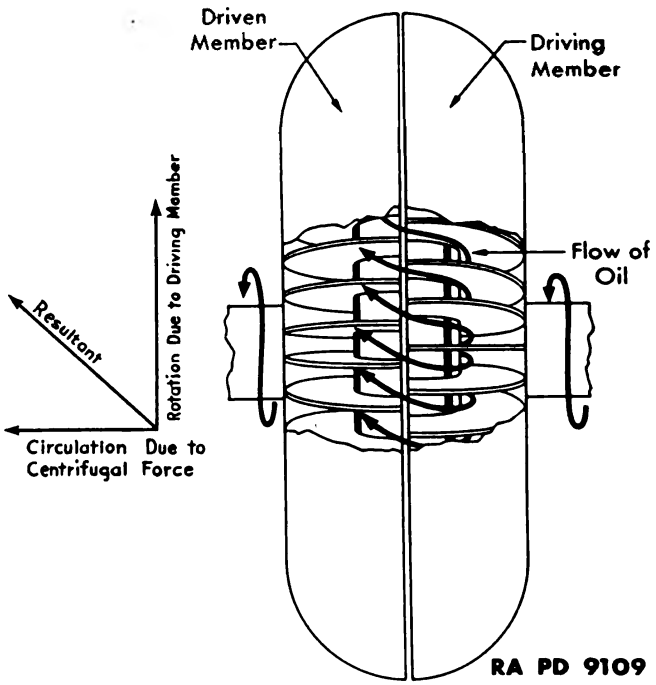

Figure 41. Fluid Coupling, Schematic View.

be noted that fluid must rotate with the driving member; thus one vector is the rotation of the fluid. As the fluid is rotated the centrifugal forces created cause it to be thrown outward from the driving torus, giving a second vector at 90° to the direction of rotation. The third vector is the plotted resultant giving the angle and direction in which the fluid tends to strike the driven member, driving it in the same direction as the drive member. From the vector diagram it can be seen that there must be a circulation of fluid from the drive torus to the driven torus in order to transmit power. As the vehicle moves forward the load on the driven torus decreases and its speed increases. This causes centrifugal forces to be set up in the fluid of this member which will oppose the circulation of fluid from the drive torus. Hence, if both were traveling at the same rate of speed there would be no circulation of fluid, and no power would be transmitted through the unit. At high speeds, however, a small speed differential circulates more fluid than a large differential at low speeds because the centrifugal force varies as the square of the angular velocity of the member.

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The slip or energy loss between the drive and driven torus will range from 100 per cent at idle speeds when the rotation is low and centrifugal forces imparted are negligible, to 1 or 2 per cent at high speeds where the load on the output shaft is small. Knowing that there must be a slippage in order to transmit power, provision must be made to take care of thermal expansion of the fluid because the energy lost by any slippage will appear in the oil as heat. Provisions in some types of fluid couplings are made by leaving a void in the fluid housing, and in others as illustrated in figure 42. An external pump causes fluid to be circulated through the coupling back to a cooler or heat exchanger, thereby providing a positive change-over and cooling the fluid.

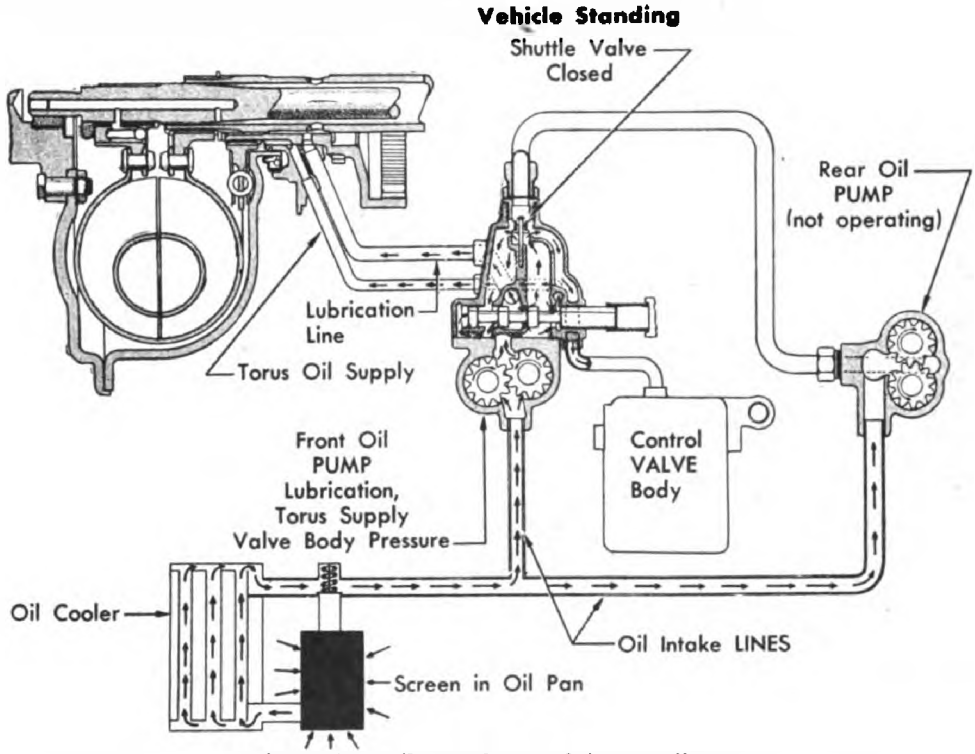

Figure 42. Oil Supply to Fluid Coupling.

Difficulty experienced with fluid couplings in cold weather is due to the thickened fluid which will not circulate readily. The fluid will 'shear', causing immobility for a few minutes until the coupling is warmed up to operating temperature.

The Torque Converter. The unit consists of four major parts: a centrifugal pump which is driven by the engine, a co-axial three-stage turbine which is attached to the output shaft, and a hydraulic chamber to which is attached the fourth part or reactor blades.

The purpose of the torque converter is to act as both a clutch and a transmission and thereby apply the engine horsepower to the drive members smoothly and in an indefinitely variable torque-speed ratio. The desired ratio is automatically determined solely by the load imposed upon the output shaft within known limitations.

The torque converter is physically limited to a torque output of from one to about five times the input torque. The normal working speed of the output shaft is from zero to almost two-thirds input speed. Any increase in torque or speed above the normal operating range of the converter may be obtained by using a gear box between the converter and the drive members. The selective gear box and final drive ratios are designed to give the torque converter a peak efficiency of about 80 percent over a broad operating range.

In operation, the pump is driven by the engine. Due to the centrifugal forces, the fluid is thrown out toward the pump periphery, absorbing kinetic energy at the same time and thereby imposing the corresponding load on the engine or

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driving member. As the fluid strikes the turbine blades it attempts to rotate the output shaft. If the load on the output shaft is great, little or no rotation will result and the fluid will rebound from these blades, reversing its direction of flow. In this operation only part of the energy of the fluid is spent. This action could be likened to the throwing of a ball against a wall. The ball strikes the wall with a great force and rebounds because the wall did not move. The stationary wall causes the ball to reverse its direction of flight and at the same time a push is exerted against the wall as rebound takes place; the energy stored in the ball is only partially spent. Similarly, as only a part of the energy has been expended in passing through the first set of turbine blades, it would seem to be good practice to make provision for utilizing the remainder. A careful study of figures 44 and 45 will show that the fluid rotation has been reversed just as the ball movement has been reversed in rebounding. Due to the shape of the hydraulic chamber, however, the fluid is forced to flow through a set

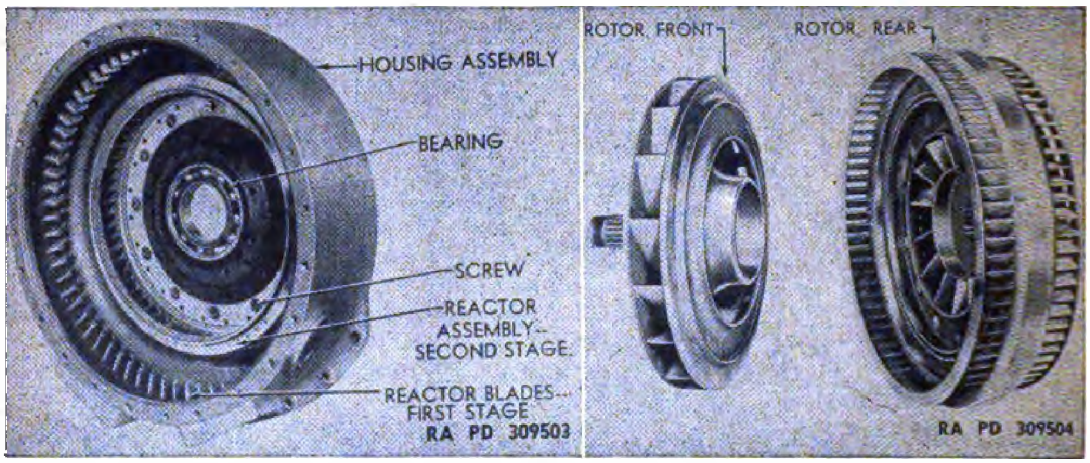

Figure 43. Torque Converter.

of reactor blades, which are securely attached to the inner wall of the chamber, and reverse its direction of rotation back to the original direction. In other words, the fluid rebounds again, but this time instead of being forced outward, it is forced downward through a second set of turbine blades where it again attempts to rotate the output shaft in the same direction at the input shaft is turning. Again we can liken the fluid to the rubber ball which, when rebounding, is traveling in a direction away from the wall, the remaining energy wasted unless the rebound direction could be reversed. This can be done by having the ball rebound from a parallel wall, travel toward the first wall in the original direction, and exert a second push against it. Back to the fluid. After passing through the second set of turbine blades, more of the energy has been utilized and the rotation is again reversed. More of the energy is spent, so the fluid is forced inward toward the center of the chamber through a second set of reactor blades and finally to the third and last set of turbine blades on the output shaft. Here the remaining energy in the fluid is spent and is conducted by this third set of turbine blades in toward the center of the centrifugal pump where the fluid started its cycle.

On the other hand, however, if the load on the output shaft is not very great the blades will be rotated and the greater part of the energy in the fluid will be pent at this set of blades, with no reversal of the fluid direction taking place. It would simulate a ball thrown against a moveable object. As the ball strikes the object, the energy stored in the ball would be absorbed in moving the object and the ball would not rebound or change direction. Similarly, as the fluid is forced to flow through the remainder of the blades, there would be no further push exerted on the output shaft. Multiplication of input torque depends upon the number of times the direction of oil flow is reversed by the driven rotor blades before its energy is spent and upon the completeness of reversal. Reversal

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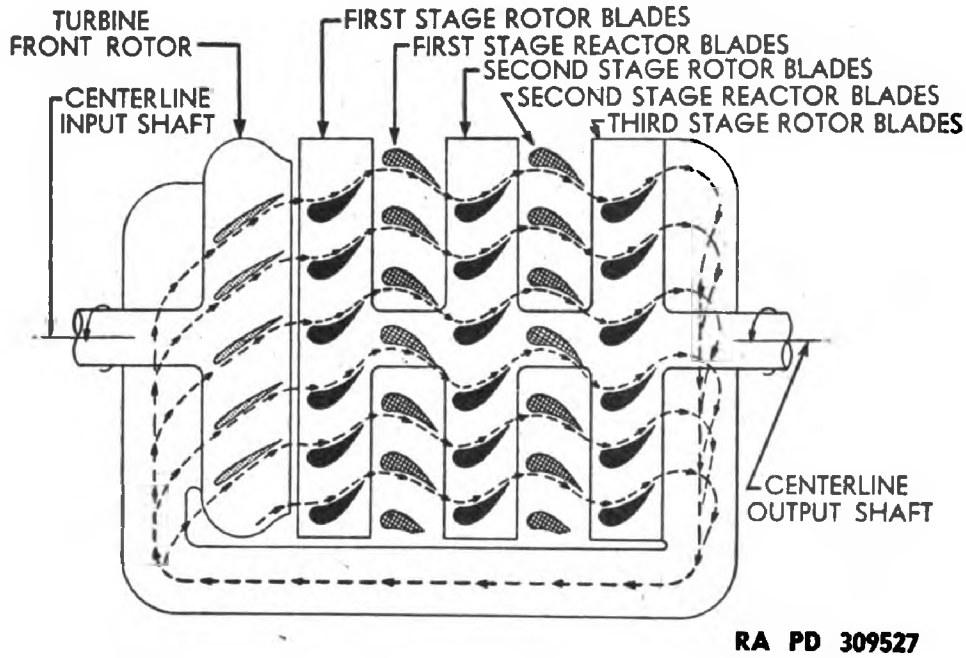

Figure 44. Schematic Illustration of Oil Flow and Turbine Action.

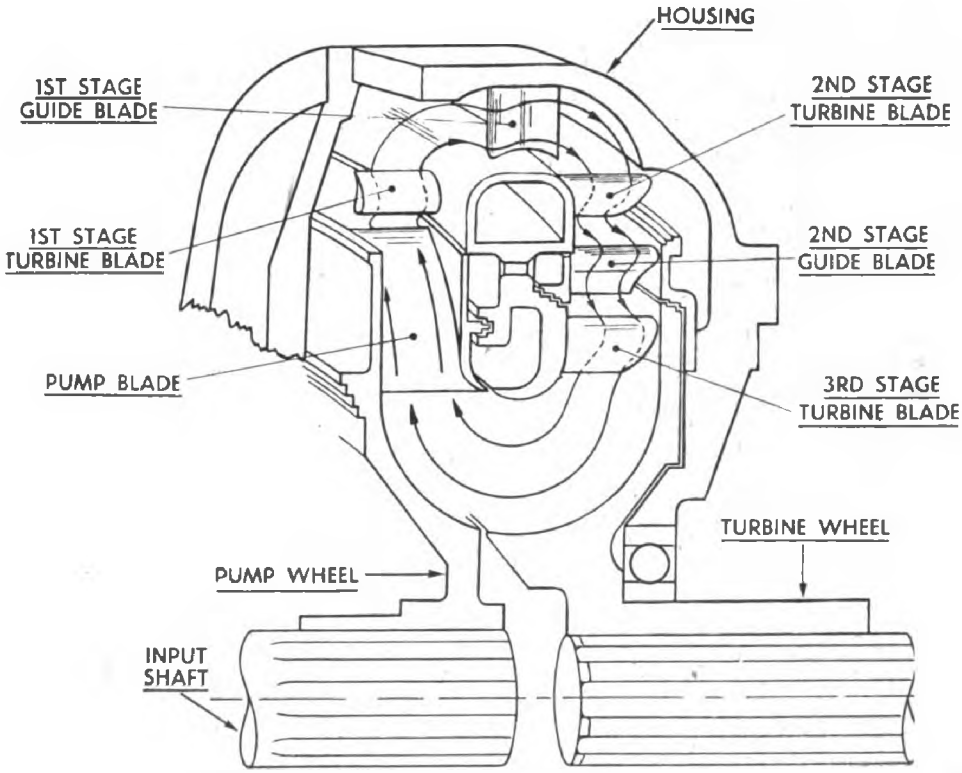

Figure 45. Torque Converter-Principle of Operation.

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of flow is complete only when the turbine or rotor blades are stationary, as shown in figure 45. If the rotor blades move with the oil, the torque decreases accordingly. Therefore, the multiplication of torque is at its maximum when the driven rotor is stationary, or when starting a motionless vehicle. It is at a minimum when the rotating speed of the driven shaft is approximately the same as that of the driving rotor, or when the vehicle is fully in motion. Maximum multiplication of torque is approximately 4.8 to 1.

Throughout the cycle of operation it must be remembered that power or energy cannot be multiplied. Consequently, if the torque is increased, the speed is correspondingly reduced. The nautral losses incurred in circulating the fluid due to the internal friction of the fluid itself and the friction of the reactor blades also contribute to the loss in efficiency of the unit. These losses are, however, more than overshadowed by the fact that an automatic torque ratio between the engine and drive members is maintained throughout the speed range of the vehicle with the engine at a constant throttle setting.

From the foregoing, it will be noted that maximum torque at the output shaft is obtained when the vehicle is stationary and the torque decreases as the vehicle speed increases. The efficiency of the unit increases to a point of slightly over 80 per cent when the output shaft speed reaches a point of ½ to ⅔ engine speed and then efficiency drops off, so that if vehicle speeds of greater ranges are desired, a selective transmission must be incorporated, or a sacrifice of efficiency and overheating will result.

Due to the temperature rise of the fluid during normal operation, a means for cooling the fluid as well as an expansion tank to accommodate its volumetric increase due to expansion must be provided.

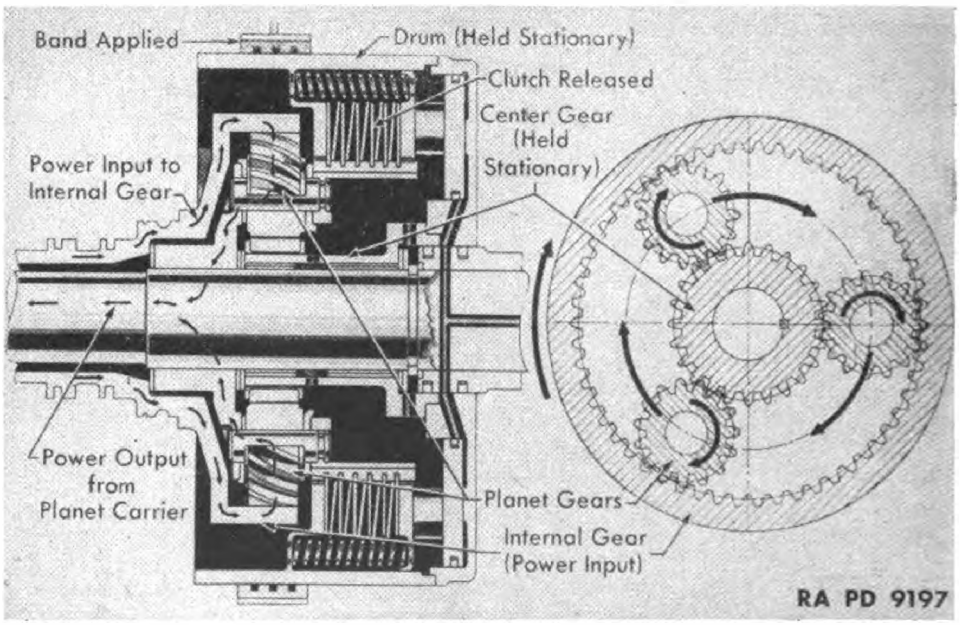

Figure 46. Planetary Unit in Reduction.

Heat generated within the converter is directly proportional to its loss in efficiency; since it is operated normally above 70 per cent efficiency, cooling radiators capable of dissipating 30 per cent of the maximum engine horsepower must be provided. Circulation of fluid through the radiator is obtained by utilizing the pressure differential across the converter pump.

One of the great advantages of the torque converter is that it does not work in reverse unless a special engaging type of rigid clutch is used between input and output shaft, as found on some high speed tractors. Hence, the engine can not be stalled. On a hill, if the stall point is reached, the vehicle may be safely backed down by manipulation of the throttle to control its rate of descent.

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Here again, this unit does not operate very well when cold because of the thickened fluid which does not circulate readily For this reason a very thin fluid is used ranging from an SAE 10 engine oil to a straight diesel fuel. Engine oil must be used when the fluid in the converter is also circulated through a gear box for lubricating purposes.

Planetary Gears. Gear trains which are often referred to as planetary are in reality epicyclic trains. An epicyclic gear train may be described as a combination of gears in which some of the gears have a motion composed of rotation about an axis in the revolution of that axis.

The planetary gear train is composed of three major parts: a center or sun gear, an arm or carrier to which are attached the planet pinions which are in mesh with the sun gear, and an internal gear surrounding the gear train and in mesh with the pinions at a point diametrically opposite the sun gear. The planet pinions that are mounted on the carrier are capable of independent rotation on their axis.

It will also be noted that all three shafts that are used, *i.e.*, sun gear shaft, planet carrier shaft, and internal gear shaft, have a common axis. This makes the unit very compact. There are several combinations possible. The unit with all gears constantly remaining in mesh makes the unit strong and especially adaptable to use in automatic type transmissions.

In operation the planetary unit has three shafts as compared with the two of the conventional transmissions. The shafts of the planetary unit are: an input shaft, an output shaft, and a reactionary shaft. The gear ratio selected will determine which shaft will be input, output, or reactionary. The reactionary shaft will have to be held stationary. The usual method is to attach to the reactionary shaft a brake drum surrounded by a brake band which can be either mechanically or hydraulically operated. With the planetary unit it is possible to obtain the following reactions:

1. Neutral (Power to input, no power on output).
2. Reduction (Low torque input, high torque output).
3. Overdrive (High torque input, low torque output).
4. Coupling (Torque on input and output equal).
5. Reverse (either reduction or overdrive).

In utilizing the possibilities of the planetary unit it is generally constructed so that two or more combinations may be obtained. In order to explain the actions of the gear train, all possible combinations will be reviewed.

Neutral. This reaction is possible when the reactionary shaft is left free to rotate. It will be found that the power put in the input shaft will cause the shaft with the least resistance to move. As the output shaft will be connected to a load, it will tend to remain stationary while causing the reactionary shaft which has no load to rotate in reverse to the input shaft. There will be no power to the output shaft.

Reduction. Reduction is possible only when the planet carrier shaft is the output shaft and either the sun gear or the internal gear is the input shaft, depending on the reduction desired. If the internal gear is the input shaft and the planet carrier shaft is the output shaft, then the sun gear will be the reactionary shaft and will be held stationary by the action of the brake band. As the internal gear revolves, the pinions will be forced to rotate on their axis. As the sun gear cannot move, the pinions, as they rotate, will walk around the stationary sun gear. (See figure 46.) To figure the speed of the output shaft in the case of reduction, the following formula is used:

$$\text{R.P.M. of output shaft} = \text{R.P.M. of input shaft} \left(\frac{\text{Dia. of Input Gear}}{\text{Dia. of Input Gear} + \text{Dia. of Reactionary Gear}} \right)$$

If the input and reactionary shafts are changed about, the sun gear revolves and the pinions would be forced to rotate on their axis and walk around the stationary internal gear. They will carry the planet carrier shaft in the same direction as the sun gear was revolving, but at a reduced rate of speed. In this reduction the same formula would apply.

Overdrive. Overdrive will result if the input shaft is the planet carrier and

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the output shaft is either the sun gear or the internal gear. It is just the opposite of reduction.

If the planet carrier is the input shaft and the internal gear is the output shaft, the sun gear will be the reactionary shaft and will be held stationary. As the planet carrier is revolved once it would tend to move the internal gear through one revolution. However, the pinions must walk around the stationary sun gear so they are forced to rotate on their axis in such a direction as to add to the speed of the internal gear, giving a higher speed output than input. Speed of the output shaft may be determined as follows:

$$\text{R.P.M. of output shaft} = \text{R.P.M. of input shaft} \left(\frac{\text{Diameter of output gear}}{\text{Diameter of Reactionary gear}} \right)$$

In the case of the sun gear shaft being the output and the internal gear being the reactionary shaft, the reaction would be the same except that a greater overdrive would result. The same formula would apply.

Coupling. If two of the shafts in the planetary unit are locked together so that they must travel at the same rate of speed, the remaining shaft must travel at the same speed. There can be no independent movement of the pinions and they act as a lock between the sun gear and the internal gear, thereby producing a coupling or direct drive. To lock two shafts together, a clutch is placed between them. This clutch may either be mechanically or hydraulically operated.

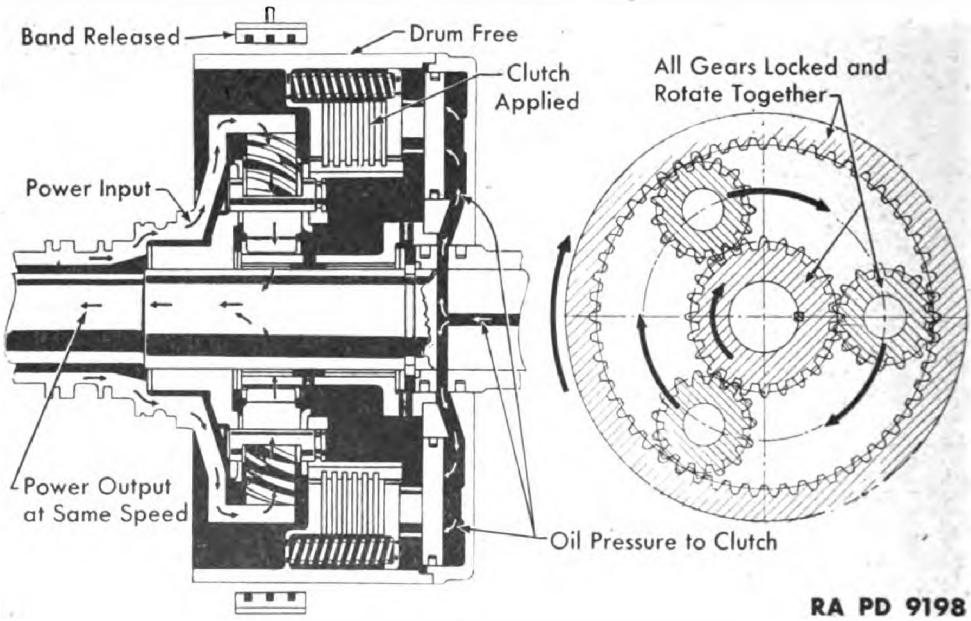

Figure 47. Planetary Unit in Direct Drive.

From the foregoing it can be readily seen that one of these units may be utilized as a two speed transmission. The unit would have a brake band and a clutch. When both the clutch and the band are released, 'neutral' would result. If the band were applied and the clutch were released, it would be in reduction. Then, with the clutch applied and the band released, a coupling would result.

In some transmissions the planetary unit is used as an overdrive. In normal range the unit would act as a coupling, *i.e.*, with clutch applied and band released. When overdrive is desired, the clutch is released and the band applied. It must be kept in mind that application of the band can give both reduction or overdrive, depending upon whether the planet carrier shaft is the input or output shaft. The clutch can only give a coupling.

Reverse. The last possible combination of the planetary gear train is reverse. If the planet carrier shaft is the reactionary shaft, then either the sun gear or the internal gear could be the input shaft, depending upon what speed-torque

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ratio is desired. As the planet carrier shaft can not move, the pinions are forced to act as idlers between the sun gear and the internal gear, causing a reversal of direction. To determine the speed of the output shaft the following formula is used:

$$\text{R.P.M. of output shaft} = \text{R.P.M. of input shaft} \left(\frac{\text{Dia. of input gear}}{\text{Dia. of output gear}}\right)$$

From the above formula it can be seen that if the sun gear is the input shaft and the internal gear is the output shaft, a reduction in reverse will result. If changed about so that the internal gear is the input shaft and the sun gear is the output shaft, an overdrive in reverse will result.

PLANETARY TRANSMISSIONS

In use today in automotive power transmission systems are various types of gear boxes some of which employ the use of planetary gear trains. At present, in military combat vehicles there are only two transmissions of this type. They are the Hydra-matic and the Torq-matic. As these are the only two in use in military vehicles, they will be the only ones discussed in this book. It should not be assumed however, that they are the only planetary transmissions.

The Hydra-matic Transmissions. The term Hydra-matic is a trade name meaning Hydraulic-Automatic gear box. This transmission is automatic in the selection of gear ratios, thus relieving the driver of this responsibility.

In order to analyze the operation of the transmission, the gear train only will first be considered, with no thought being given to hydraulic control.

The gear train consists of three planetary units: front, rear, and reverse, which when used in combination will give four speeds forward and one in reverse. The fluid coupling is used as an automatic clutch (refer to fluid coupling) thus eliminating the need for a foot operated clutch, and the clutch pedal. In order to improve the operational characteristics of the fluid coupling, *i.e.*, to eliminate its tendency to creep when the transmission is in gear and the engine idling, a planetary unit is placed between the engine and fluid coupling. This unit is capable of a reduction of 1.44:1 and also direct drive or coupling. The placement of the planetary in such a position reduces the speed of the driving torus so that creep is eliminated and allows the engine to speed up and develop more power before it is subjected to a load. The second or rear planetary is placed between the coupling and the output shaft and has a reduction of 2.26:1. It is also capable of direct drive. Placing the unit in this position reduces the load on the driven torus thereby tending to reduce the loss due to slippage when the driven torus is under load.

In reference to figure 48, it will be noted that the apparent placement of the coupling is between the engine and the two planetary units, however, the fluid coupling functions between the two in the following manner:

Neutral. The power from the engine flywheel flows around the fluid coupling through a flywheel cover (which is bolted to the flywheel) to the front planetary internal gear. The output shaft of this unit is the planet carrier shaft attached to the drive torus. The sun gear, which in this case is the reactionary, is attached to a brake drum controlled by a band. When the unit is in neutral this band is released, so that the power flows to the sun gear which is not under load and is free to rotate. The engine power is thereby absorbed without transmitting it to the fluid coupling, and the vehicle remains stationary regardless of engine speed. Likewise the rear planetary is in neutral as the band is released.

First Gear. In first gear the power flows by the same route from the engine to the front planetary. This time, however, the band is applied and the sun gear is held stationary so that the engine power is transmitted to the drive torus with a reduction of 1.44:1. If the engine is idling, the vehicle will not move even though it is in first gear, because the power transmitted across the fluid coupling will not be great enough to overcome the load imposed by the vehicle. As the power is increased across the fluid coupling, it will cause the driven torus to turn and the driven shaft drives the sun gears of the rear planetary (compound). The planet carrier shaft here again is the output shaft and as the

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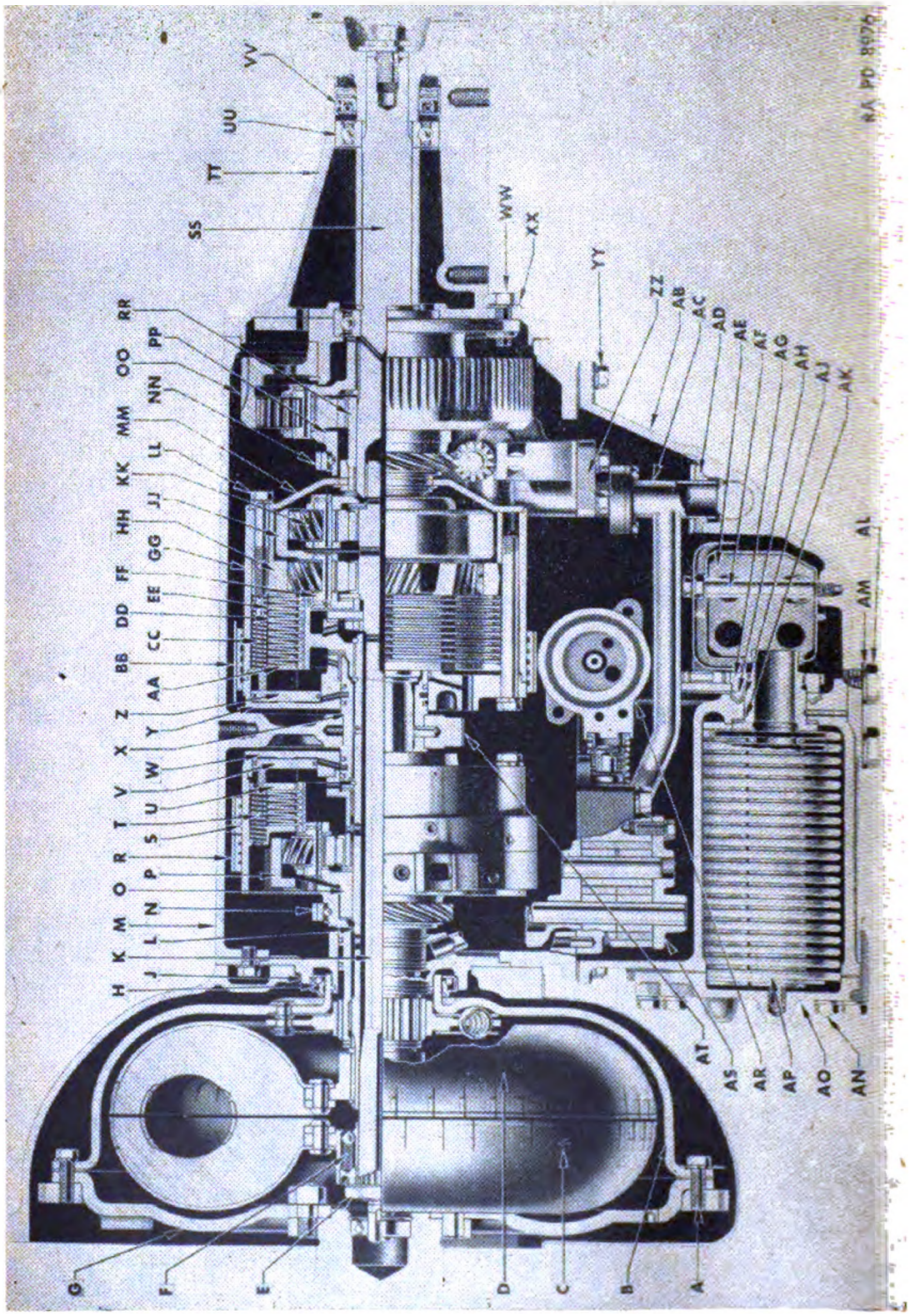

Figure 48. Hydra-matic Transmissions, Cross Section.

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internal gear is the reactionary shaft, it is held stationary by a band. The power from the sun gears is transmitted through a reduction of 2.26:1 to the output shaft, giving a total reduction in 1st gear of 1.44 x 2.26 = 3.26:1. The reverse planetary in all forward speeds is in neutral.

Second Gear. The power flow to the front unit is identical to 1st gear except that this time the front band is released and the clutch between the sun gear and the planet carrier shaft in the front unit is applied, giving a coupling. Therefore, the power from the engine is transmitted without reduction to the fluid

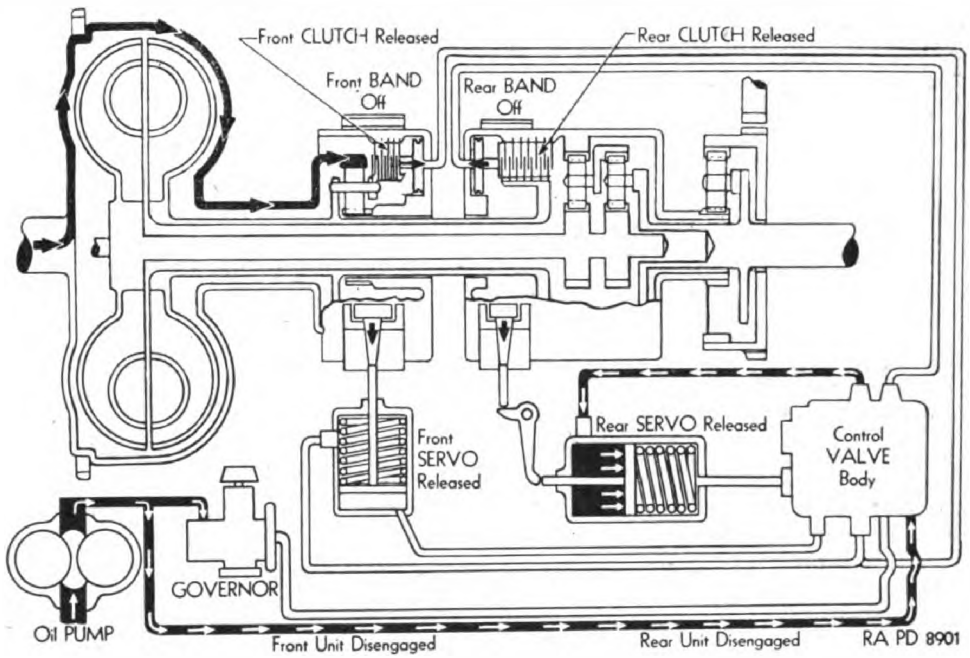

Figure 49. Transmission in Neutral.

coupling. The clutch of the front unit is hydraulically applied and spring loaded for release. From the fluid coupling the power is transmitted through the rear planetary unit, which is still in reduction (band applied), to the output shaft, giving a total reduction in the transmission of 1 x 2.26 = 2.26 or 2.26:1 in second gear.

Third Gear. Here the front band is applied and the clutch released, so that the engine power is transmitted to the fluid coupling through a 1.44:1 reduction. The rear band is released and the rear clutch is applied. In this case careful study of figure 52 will reveal that the rear clutch is not between the two shafts of the rear planetary, but that this clutch actually engages the other end (opposite the fluid coupling) of the front planetary output shaft to the rear unit internal gear so that some of the engine power is transmitted through the front unit direct to the rear unit internal gear. The remainder of the power goes

Legend for Figure 48 (See Preceding Page)

A—Screw
B—Cover, Assembly
C—Torus, Assembly
D—Torus, Assembly
E—Nut
F—Spring
G—Flywheel, Assembly
H—Seal, Assembly
J—Cover, Assembly
K—Shaft, Assembly
L—Shaft, Assembly
M—Case, Assembly
N—Gear
O—Carrier, Assembly
P—Gear, Assembly
R—Band, Assembly
S—Drum, Assembly
T—Spring
U—Plate
V—Piston
W—Drum, Assembly
X—Sleeve, Assembly
Y—Drum, Assembly
Z—Piston
AA—Plate
BB—Band, Assembly
CC—Spring
DD—Plate
EE—Plate
FF—Pin
GG—Drum, Assembly
HH—Gear, Assembly
JJ—Carrier, Assembly
KK—Pinion
LL—Screw
MM—Flange
NN—Gear
OO—Gear
PP—Carrier, Assembly
RR—Gear, Assembly
SS—Shaft, Assembly
TT—Retainer
UU—Bearing, Assembly
VV—Seal, Assembly
WW—Screw
XX—Washer
YY—Screw
ZZ—Pump, Assembly
AB—Pan
AC—Pipe, Assembly
AD—Seal
AE—Screen, Assembly
AF—Bolt
AG—Nut
AH—Ring
AJ—Seal
AK—Gasket
AL—Plug
AM—Gasket
AN—Screw
AO—Cover
AP—Cooler, Assembly
AR—Servo, Assembly
AS—Servo and Oil Pump Assembly
AT—Cap, Assembly

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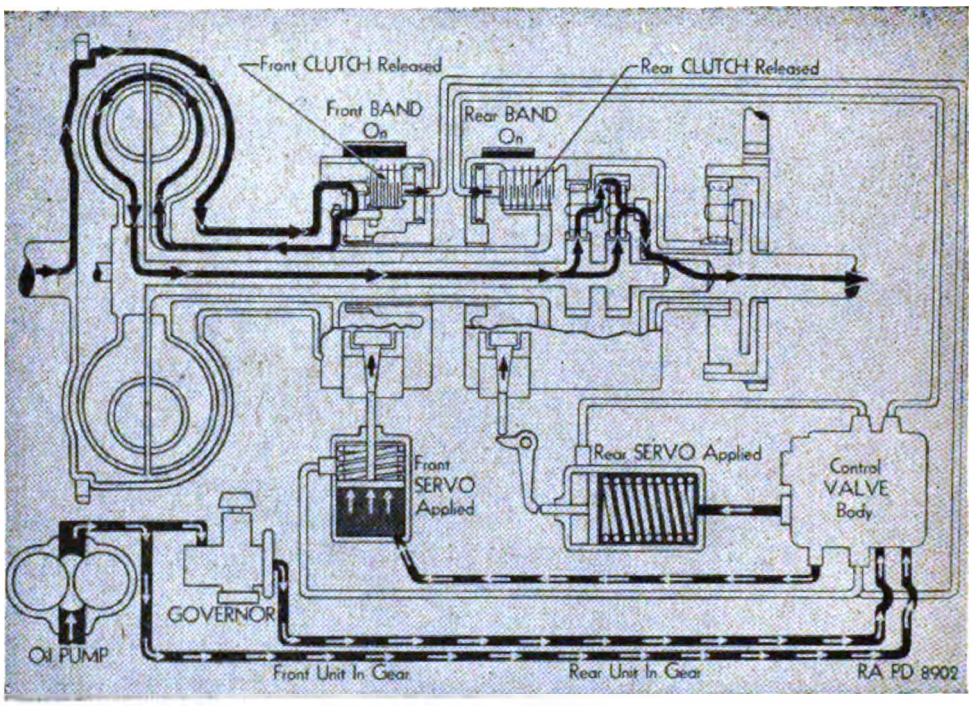

Figure 50. Transmission in First Gear.

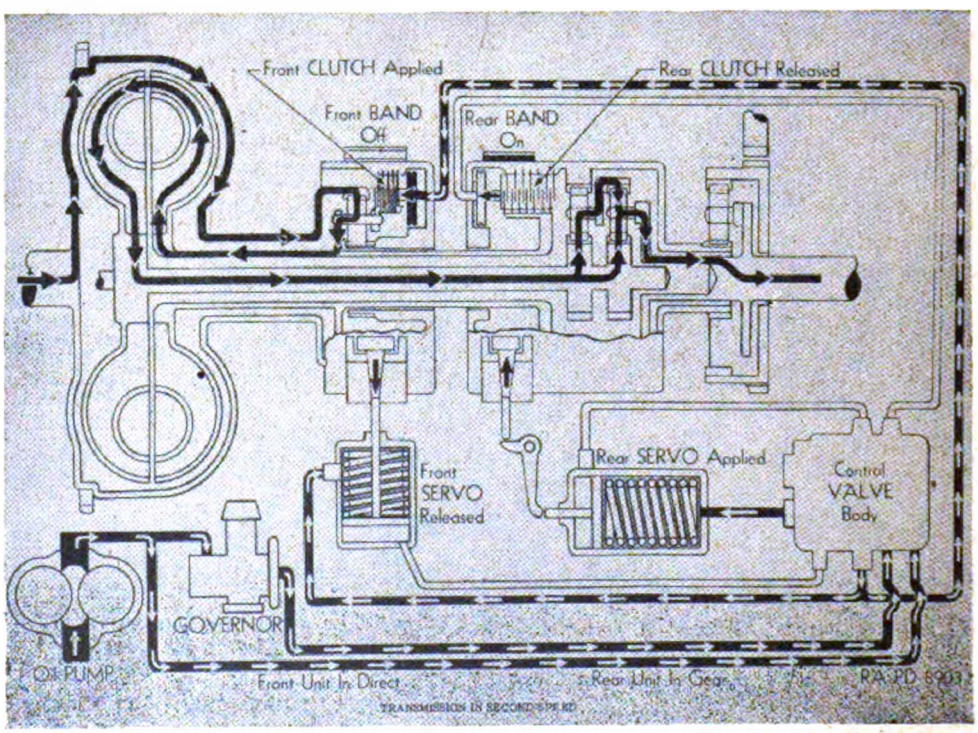

Figure 51. Transmission in Second Speed.

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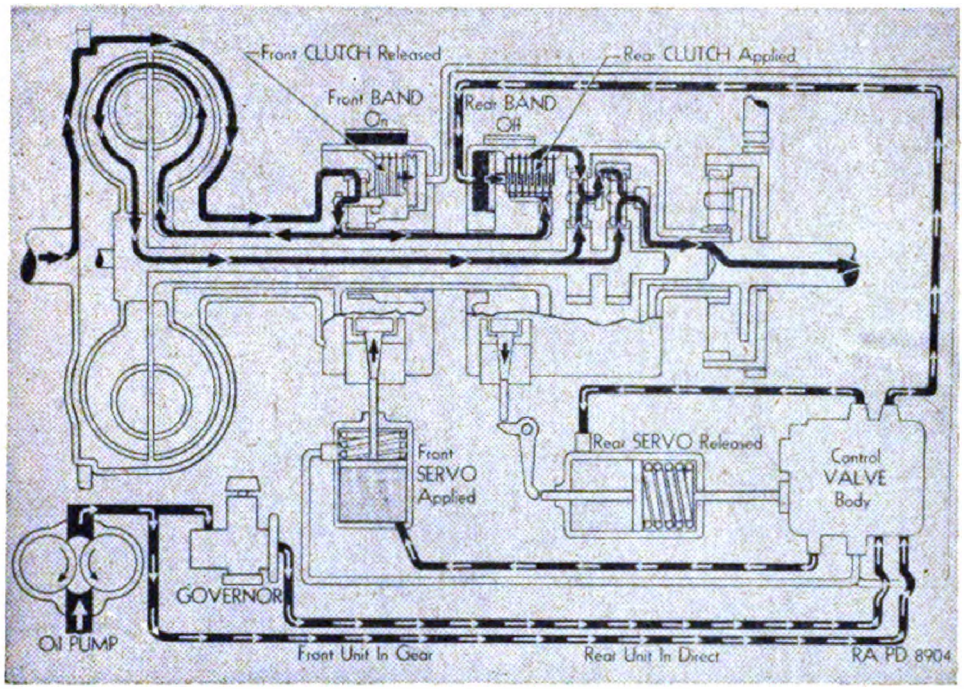

Figure 52. Transmission in Third Speed.

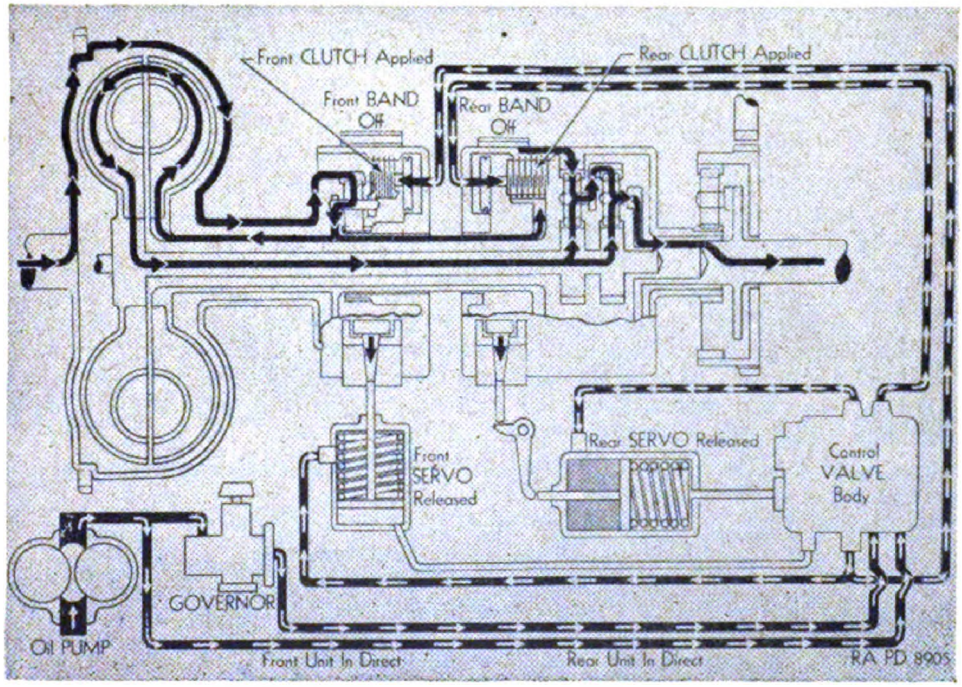

Figure 53. Transmission in Fourth Speed.

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through the front planetary, through the fluid coupling to the rear unit sun gears, and then from both the sun gears and internal gear to the output shaft. This arrangement makes it possible to by-pass the fluid coupling with about 60 per cent of the power. The loss due to slippage is reduced, but, by having part of the power pass through the coupling, a certain amount of flexibility of the power train is retained. The reduction in third gear discounting any slippage is 1.44 x 1 = 1.44:1.

Fourth Gear. Power flow in fourth gear is identical to that in third gear with the exception that the front unit is again in direct drive rather than reduction. The reduction in third gear, discounting any slippage, is 1 x 1 = 1 or 1:1.

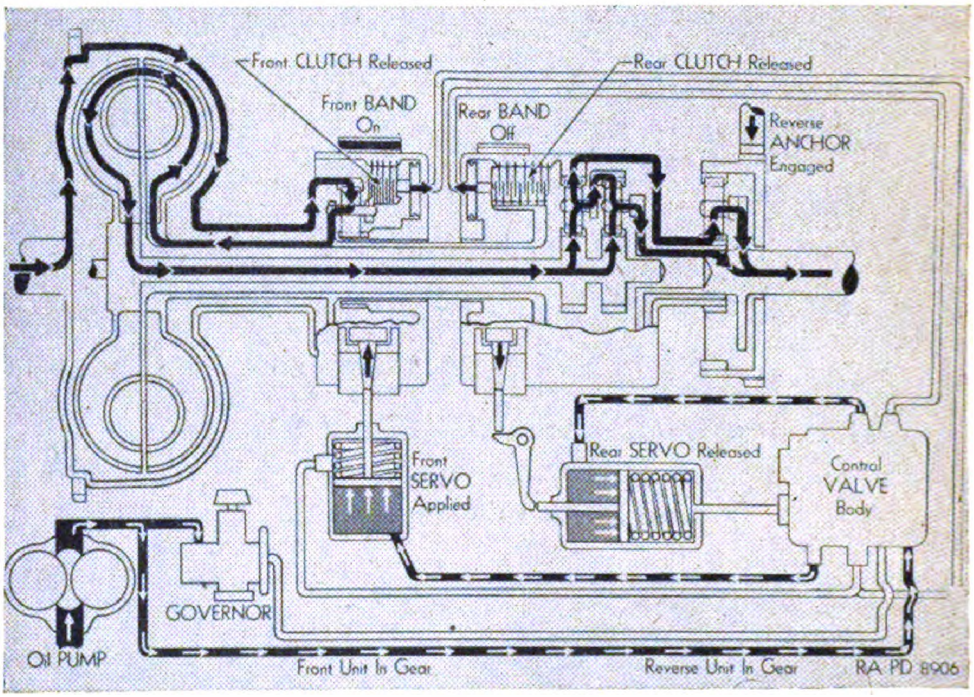

Figure 54. Transmission in Reverse Speed.

Reverse. In reverse, power flows to the fluid coupling through a 1.44:1 reduction in the front planetary and then from the coupling to the rear planetary unit which is in neutral (band and clutch released). This causes the rear unit reactionary gear (internal gear) to rotate in reverse to the input shaft. It will be noted in figure 54 that the internal gear of the rear unit is attached directly to the sun gear of the reverse planetary. The reverse planetary internal gear is held stationary by a mechanical latch (anchor), so that the lower output is from the sun gear (which is rotating opposite to the engine) to the planet carrier. The planet carrier is attached to the output shaft causing this shaft to rotate in reverse also. The reduction in reverse is 3.77:—1.

Figure 55 is a chart showing application of bands and clutches in all speed ranges:

Speed Ranges	Front Planetary Band	Front Planetary Clutch	Rear Planetary Band	Rear Planetary Clutch	Reverse Planetary Anchor	Ratio
Neutral	..	..	..	..	..	..
1st Speed	X	..	X	..	..	3.26:1.0
2nd Speed	..	X	X	..	..	2.26:1.0
3rd Speed	X	..	..	X	..	1.44:1.0
4th Speed	..	X	..	X	..	1.0 :1.0
Reverse	X	..	..	..	X	3.77:—1.0

X = Applied
.. = Off

Figure 55. Application of Bands and Clutches in All Speed Ranges.

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HYDRAULIC CONTROL OF THE HYDRA-MATIC TRANSMISSION

The changing of gear ratios, either in upshifting or downshifting, is the function of the hydraulic control system. It is basically a system of valves carefully balanced to provide a precise relationship between the momentum of the vehicle and the performance demands of the driver as expressed by the pressure on the accelerator. The hydraulic control system consists of two interconnected oil pumps, an oil pressure regulator valve mechanism, a centrifugal governor,

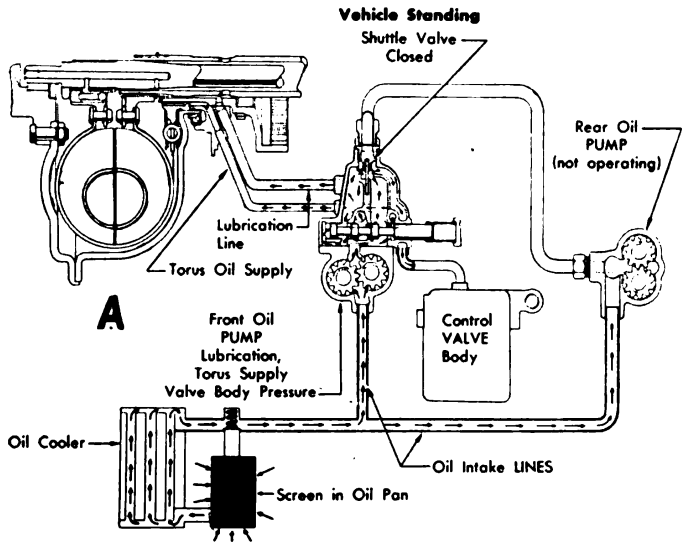

DIAGRAM OF OIL PUMPS

Figure 56A. Diagram of Oil Pump, Vehicle Standing.

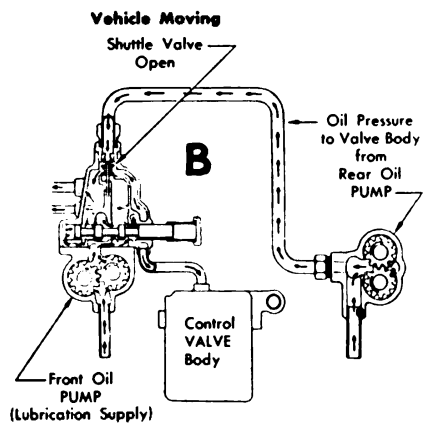

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Figure 56B. Diagram of Oil Pump, Vehicle Standing.

a control valve body containing regulator and shift valves, and the necessary connecting passages. Also included in the system are: a front servo to apply and release the front unit band, a rear servo to apply and release the rear unit band, and front and rear clutches which cause the front and rear units to become couplings as previously discussed.

Oil Pumps. The front oil pump, which is driven by the engine, begins to build up a pressure in the hydraulic system as the engine is started. When this pressure exceeds a predetermined amount, the regulator valve is moved off its

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seat, allowing oil to flow to the fluid coupling and the lubrication system. As the vehicle moves forward, the rear pump, which is driven by the transmission output shaft, begins to operate and builds up pressure. When this pressure exceeds that of the front pump, a shuttle valve connecting the output of the rear pump to the front pump opens, allowing the pressure from the rear pump to flow into the hydraulic control system. It also shuts off the pressure from the front pump to the control system. The front pump, however, continues to apply oil pressure to the fluid coupling and the lubricating system.

Governor. The governor, which is mounted on the rear oil pump drive shaft and therefore operates only when the vehicle is moving, is of the compound type; that is, it has two valves of different operating characteristics through which metered oil pressures flow to the valve body. When the vehicle is standing or moving very slowly, oil pressure from the regulator keeps the valves closed. As th evehicle speed increases, centrifugal force moves the governor weights outward against the pressure from the regulator. This pressure is metered out past the valves in proportion to the centrifugal force applied to the valves. A study of figure 57 will show that the two valves are attached to different size weights. Therefore, the pressures metered out by the valves will be different at a given R.P.M. The pressure from the large weight will be higher than that from the small weight. The high pressure is known as G-1 and the low pressure as G-2. The governor has the ability to modulate the

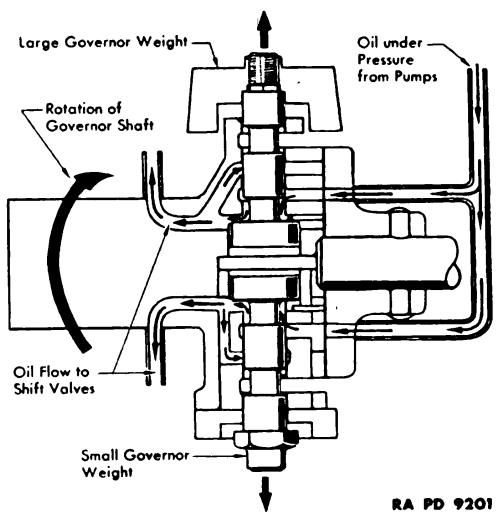

Figure 57. Cross Section of Governor.

pressure from the regulator from zero to the given pressure, depending upon the velocity of the governor. This pressure is directed to the shift valves in the valve body. This unit is sometimes referred to as the 'brain box.' The valve body contains a manual control valve which is operated by the driver. This valve directs the flow of oil for 'Dr. Range,' 'Lo Range,' and neutral (three shifter valves which are operated by the governor in accordance with the vehicle momentum). The valves are kept in the closed position by shift valve springs and three regulator plugs which oppose the shift valves' opening through pressure on the accelerator. A throttle valve is incorporated in the valve body which is capable of changing the foot pressure on the accelerator to an equivalent hydraulic pressure directed to the regulator plugs.

The Front Servo. This unit controls the front unit band. It consists of a piston rod to which is attached two pistons, each piston contained in a separate cylinder. A weak retracting spring keeps the servo released when no oil pressure is applied to the unit. When the unit is applied, oil pressure is directed against the applying side of one piston only. To release the servo it is not necessary to release the applying pressure, because the same pressure is applied to the release side of both pistons giving a greater force to the release side.

The Rear Servo. This servo controls the rear band. It consists of two pistons

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attached to the same piston rod, and each contained in separate cylinders. The servo is applied by means of a heavy apply spring. No oil pressure is necessary for application. To cause release of the unit, oil pressure is directed to the release side of both pistons thereby overcoming the spring tension.

Front and Rear Unit Clutches. The function of these units has been previously discussed under gear train. The clutches are of the multiple plate wet type. Springs between the pressure plate and the driving surface keep the clutches disengaged when not in use. To apply the clutch, oil pressure is directed behind each of the six pistons in the clutch cover. This pressure causes the pressure plate to move toward the driving and driven plates, thereby engaging the clutch. Exhausting this pressure causes clutch release through the action of the release springs.

Oil Flow, Neutral. When the vehicle is standing and the engine is not running, the front band is released and the rear band is applied regardless of the position of the control lever. When the engine is running and the control lever is in the neutral position, the front pump delivers pressure to the manual control valve which directs it to the rear servo, thereby releasing it. The front band is kept released by the action of the light retracting spring. The manual control valve blocks any flow of oil to the governor so that even if the vehicle were rolling the governor would not be able to move the shift valves. The oil pressure from the regulator, besides being delivered to the manual control valve, is also allowed to flow to the shifter valves which are in the closed position. This blocks any further flow.

High Range, First Speed. When the manual control valve is positioned to 'Dr.' it allows oil pressure to flow to the apply side of the front servo, applying the front band. At the same time, the oil pressure is cut off from the rear servo and the pressure which was there in neutral is exhausted so the spring applies the rear band. The vehicle is now ready to move out in first gear as the accelerator is pressed. Also at this time, the manual control valve allows delivery of pressure to the governor. Pressure from the regulator is delivered to the throttle valve so that, in turn, pressure is delivered to the spring side of the shifter valves to help keep them in the closed position.

Shifting from First to Second. This shift is accomplished by moving the 1-2 shift valve which is held in the closed position by the weakest spring of the three shifter valves. As the vehicle gains momentum the governor pressure increases. Only G-1 pressure is applied to the 1-2 shifter valve giving the greatest possible opening force to this valve. Opposing the opening of the valve (beside the spring), is the pressure from the throttle valve, which increases as the throttle is opened. When the vehicle gains sufficient momentum the governor pressure will overcome the spring and throttle pressure and will open the shifter valve. When the shifter valve is opened the pressure from the regulator is directed to the release side of the two front servo pistons, releasing the front servo. At the same time the pressure is directed to the front clutch applying this unit. This shifts the transmission from 1st to 2nd speed.

If the throttle is opened wide the transmission will stay in first gear longer because greater momentum of the vehicle must be gained before the governor will be able to overcome the increased throttle pressure, which is applied in opposition to governor pressure.

Shifting from Second to Third. As the vehicle spee dincreases in second, the governor pressure increases. At this time time G-1 and G-2 are both acting against the 2-3 shift valve which is held in the closed position by stronger spring and stronger throttle pressure than the 1-2 shift valve. When the governor pressure increases to a point where the 2-3 shift valve is opened, pressure from the regulator is directed to the release side of both rear servo pistons, releasing the rear band, and at the same time applying the rear clutch. However, the 1-2 shift valve is still held open and this would cause the transmission to be in fourth gear unless the front unit is again placed in reduction. This is accomplished by having the pressure from the 2-3 valve directed to the double transition valve which, when opened, blocks the pressure from the 1-2 valve to the front servo and front clutch and at the same time opens an exhaust port at the closed 3-4 shifter valve, causing the front servo to apply the front band as the front

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clutch is released. This causes the transmission to shift from 2nd to 3rd speed. Here again the wider the throttle is opened the higher speed the vehicle must attain before the governor pressure can overcome the increased throttle pressure.

Shifting from Third to Fourth. As the speed of the vehicle increases in third gear, the governor pressure G-1 and G-2 becomes great enough to open the 3-4 shift valve against the greatest spring pressure and throttle pressure of the three shift valves. When the 3-4 shift valve opens, the exhaust port used in the 2-3 shift is closed and the pressure from the regulator is directed by the former exhaust passage to the release side of the front servo, releasing the band as the clutch is applied. This shifts the transmission from third to fourth. Likewise, the greater throttle opening the greater speed the vehicle must attain to have the shift take place.

Downshifting. When vehicle speed decreases, the governor pressure decreases to a point where it can no longer hold the shift valves open against the spring pressure. On throttle pressure, the shift valves move to the closed position, one at a time, in proper sequence because of the different spring tensions and throttle pressures, causing the transmission to downshift to first gear. The vehicle may be stopped in first gear because of the action of the fluid coupling. In order to have the transmission shift from first gear to neutral the control lever must be moved to the neutral position from 'Dr.'

When the driver wishes to downshift from fourth to third for greater acceleration, he presses the accelerator all the way down. The throttle valve in the valve body opens a separate oil passage from the regulator to the 3-4 valve in opposition to the governor, causing the 3-4 to close and the transmission downshifts to third gear, providing that the speed of the vehicle is not so great that the force from the governor pressure will hold off the regulator pressure.

Low Range. Moving the manual control lever into the 'Lo' position applies additional pressure against the 1-2 regulator plug, making it necessary to attain greater vehicle speed in first gear before the valve will move and cause a shift into second gear. Also, regulator pressure is applied to the 2-3 valve in opposition to the governor. The vehicle can never attain a high enough speed to have the governor overcome this pressure; therefore, the 2-3 shifter valve can not be opened and the transmission never shifts into third gear.

Reverse. With the manual control valve in the 'reverse' position, the oil flow is directed to the apply side of the front servo, applying the front band. Also, oil pressure is directed to the release side of the rear servo, releasing the rear band. The movement of the control lever to reverse engages the reverse anchor through mechanical linkage. Governor pressure is completely cut off. Without governor pressure, the transmission will remain in reverse until the control lever is moved.

THE TORQMATIC TRANSMISSION

The second type of planetary transmission in use in military combat vehicles is known as the Torqmatic transmission. This type of transmission employs the use of the torque converter and, for additional torque-speed ratios between the engine and final drive members, a planetary type gear box is used. The unit is manually controlled and hydraulically operated. The planetary gear train in use is of the compound type, and the operator may, through the positioning of a control lever which actuates two selector valves, direct the flow of oil through the hydraulic system, effecting gear changes for neutral, first, second, third, and reverse gears. In all the following descriptions, the converter or input end is known as the front.

The torque converter has been previously discussed in this section so the description of the torqmatic will begin with the gear train. It must be held in mind during the discussion, however, that the power from the engine flows first through the converter, which acts as a clutch, thereby eliminating the need for a clutch pedal to be operated by the driver. The torque converter is also capable of acting as a transmission as it is able to multiply the torque of the engine automatically within certain predetermined limits, depending entirely upon the load imposed on the converter output shaft. The limits are a maximum of about 4.8:1 at stall speed of the output shaft to a minimum of about 1::1 at 0.7 revolu-

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tions of the output shaft to one revolution of the input shaft. In the discussion of the gear train the ratios quoted will be that of the gear train only, disregarding the variable that the torque converter oan supply in addition to the gear train.

The Planetary Gear Train. Power from the converter is delivered to a compound planetary gear train (fig. 59), which is the combination of two simple planetary gear trains arranged in this case so as to provide three speeds forward, one reverse, and a neutral. The low or first speed forward is direct drive; second, third, and reverse are overdrives.

The input shaft of the unit is integral with the planet carrier which contains three pinions in mesh with a sun gear and the internal gear. The internal gear is attached to a brake drum controlled by a surrounding brake band. The aforementioned units comprise the first half of the compound-planetary transmission. The second half of the unit consists of a sun gear which is attached directly to the first sun gear, the planet carrier with its pinions in mesh with the sun gear, the carrier being attached directly to the front internal gear and brake drum. The second internal gear is attached, like the first, to a brake drum controlled by a second brake band. The output shaft of the gear is not integral with any part of the gear train, but is so positioned that, by the use of two clutches, it can be attached to the sun gear shaft or the second internal gear. The inner clutch, (fig. 59), attaches the output shaft to the sun gear shaft and the outer clutch attaches the output shaft to the second internal gear. Both clutches are hydraulically applied and spring released.

Hydraulic Control and Power Flow. Oil pressure used to operate the clutches and bands is delivered by a front and rear pump. Its flow is controlled by two valves in the valve body, which are manually operated by one control lever. The manual control lever changes the position of the valves, which open and close the ports as required to direct the oil, at a pressure of approximately 100 pounds per square inch, in to the proper passages for actuating the bands and clutches. Clutches and servo bands are applied by oil pressure and released by spring pressure. The brake band servos normally operate as follows: oil pressure acting on the bottom side of the piston overcomes the spring pressure and applies the band. Releasing of the band is accomplished by admitting oil pressure to the top side of the piston. The oil pressure on both sides of the piston then balances and the release spring is free to move the piston and releases the band.

HYDRAULIC CONTROL AND POWER FLOW IN NEUTRAL

When the control lever is in the neutral position with the engine running, oil is directed from the front pump to both sides of the pistons of the servos, and the servo springs release the bands. Oil pressure is also directed against the piston of the inner clutch, thus engaging it. With the unit in neutral, power flows from the torque converter to the third speed or front planet carrier, and through the planet pinions to the internal gear, which, without the band being applied, is allowed to rotate, driving in turn the second speed or rear planet carrier and causing the pinions of this unit to rotate. The sun gears on the main shaft are under load because the inner clutch has the main shaft attached to the output shaft. Thus, the rotation of the pinions will cause the second speed or rear internal gear to rotate. The second speed or rear internal gear is not held by the band nor is it attached to the output shaft, so that when this drum rotates no power is transmitted to the output shaft.

HYDRAULIC CONTROL AND POWER FLOW IN FIRST GEAR

When the control lever is moved to first gear position, the oil pressure, as in neutral, is directed to both sides of the servo pistons allowing the servo springs to release the bands. Oil pressure is also directed to the piston of both the inner and outer clutches which are engaged. With both clutches engaged, the main shaft containing the sun gears is attached to the output shaft. The outer clutch also attaches the second speed or rear internal gear to the same output shaft, so that the sun gears and the second speed or rear internal gear are effectively locked together as one unit. If two of the units are locked together, as previously discussed in planetary gears, the planetary unit will act as a coupling and a direct drive through the gear train will be obtained.

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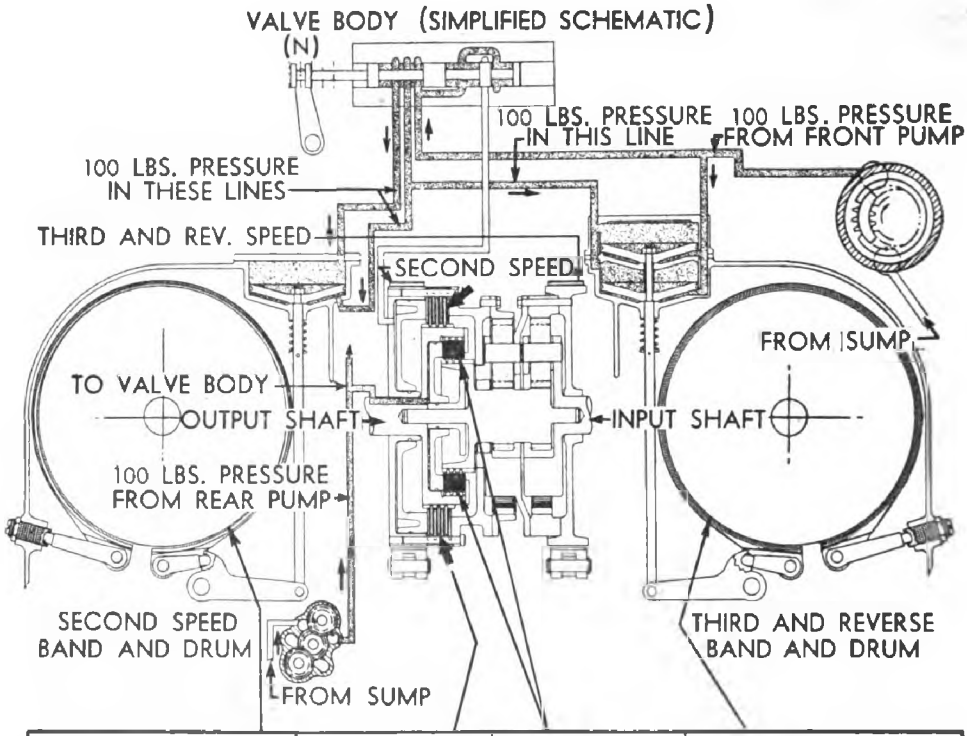

SECOND SPEED BAND	OUTER CLUTCH	INNER CLUTCH	THIRD REVERSE BAND
RELEASED	RELEASED	ENGAGED	RELEASED

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Figure 58. Hydraulic Control Lever in Neutral Position.

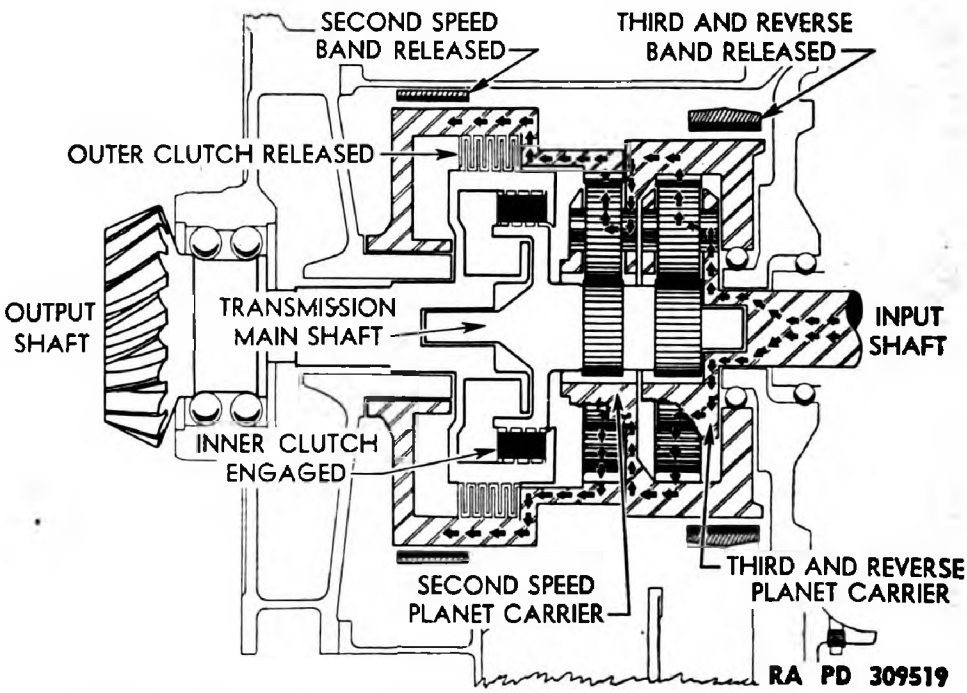

Figure 59. Power Flow With Hydraulic Control Lever in Neutral Position.

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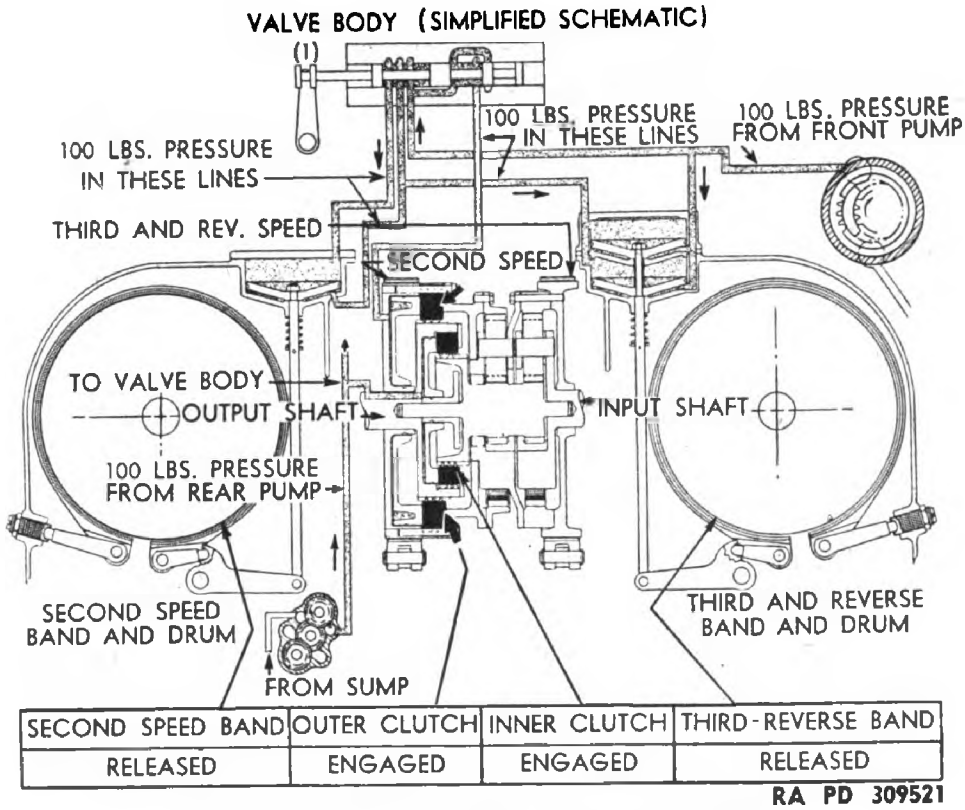

SECOND SPEED BAND	OUTER CLUTCH	INNER CLUTCH	THIRD-REVERSE BAND
RELEASED	ENGAGED	ENGAGED	RELEASED

Figure 60. Hydraulic Control Lever in Low Range.

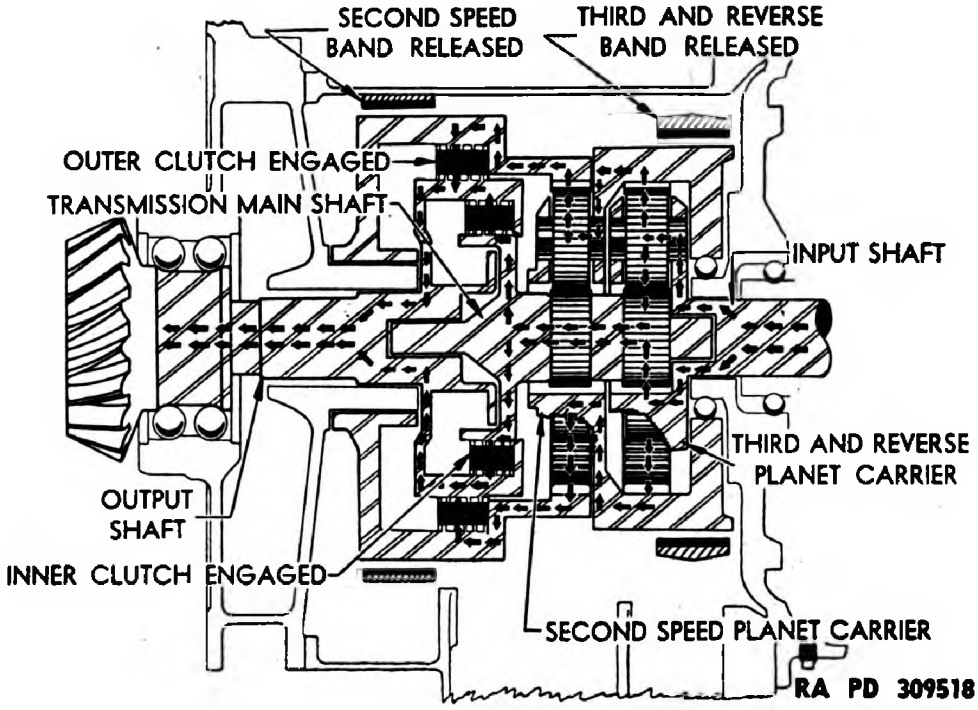

Figure 61. Power Flow With Hydraulic Control Lever in Low Range.

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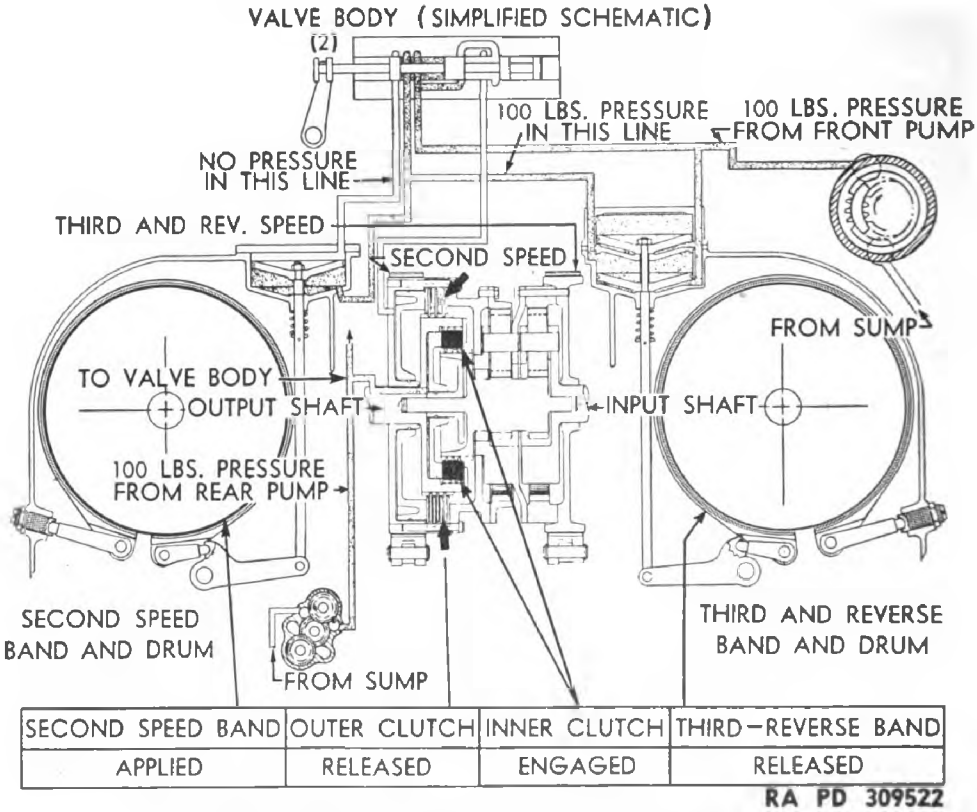

Figure 62. Hydraulic Control Lever in Intermediate Range.

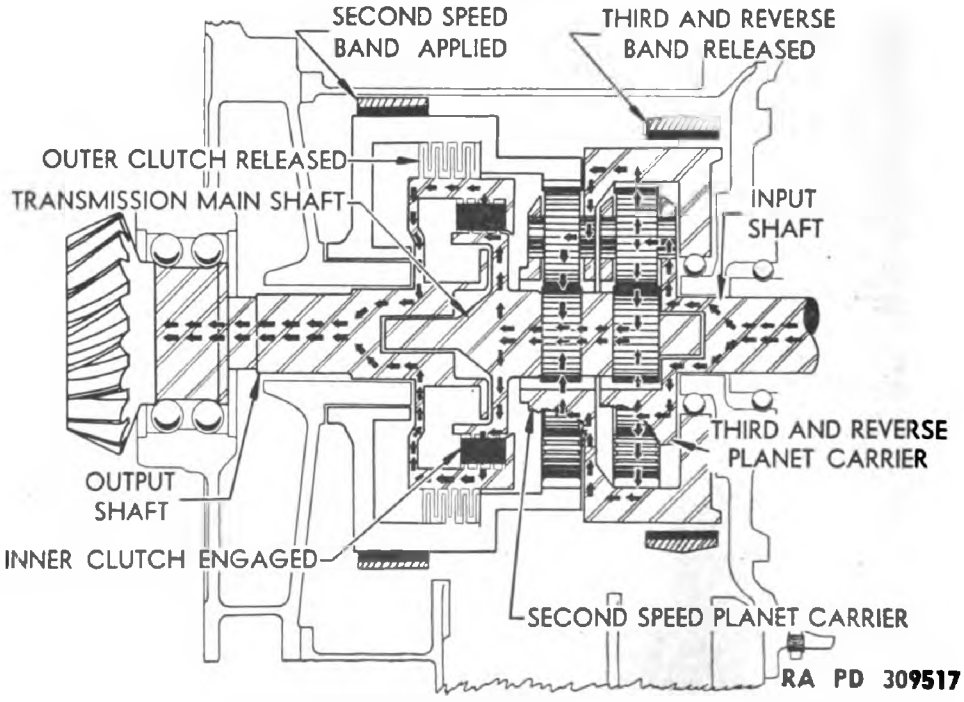

Figure 63. Power Flow in Intermediate Range (Second Speed).

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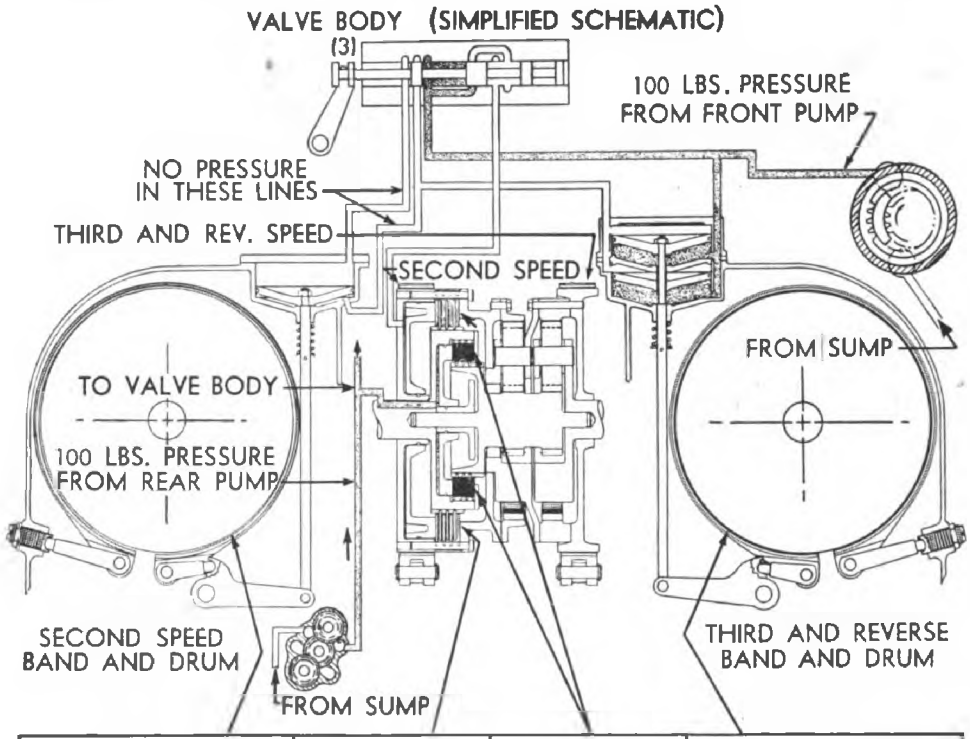
HYDRAULIC CONTROL AND POWER FLOW IN SECOND GEAR

With the control lever in second gear position, oil under pressure is directed to both sides of the third, reverse, or front servo piston allowing the servo spring to release the band. Oil under pressure is directed to the bottom side of the second speed or rear servo piston causing it to move upward against the action of the servo spring and apply the band. Oil pressure is directed to the piston of the inner clutch, engaging it. An oil passage is opened to release pressure from the outer clutch piston allowing the clutch spring to release this clutch. In second speed a compound action of the two planetary sets is used, resulting in an overdrive of 1.0:2.337. In second, the rear or second speed internal gear is held stationary by the action of the band. The front or third reverse internal gear is free to rotate. The main shaft or sun gear shaft is attached to the output shaft by the action of the inner clutch. The power from the converter is transmitted to the front or third reverse planet carrier pinions, which will be forced to walk around the third reverse internal gear if it is assumed to be stationary. This action would cause the third reverse or front sun gear to rotate. The speed at which this sun gear rotates is



SECOND SPEED BAND	OUTER CLUTCH	INNER CLUTCH	THIRD-REVERSE BAND
RELEASED	RELEASED	ENGAGED	APPLIED

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Figure 64. Hydraulic Control Lever in High Range.

dependent upon the speed of rotation of the third reverse or front planet pinions. The third reverse sun gear, however, is attached directly to the second speed sun gear so that this gear is also forced to rotate, and as the second speed or rear internal gear is held stationary by the band, this will cause the second speed or rear planet carrier to rotate. Attached to the second speed or rear planet carrier is the third reverse or front internal gear which rotates with the second speed or rear planet carrier. The rotation of the third reverse or front internal gear actually slows down the rotation of the third reverse or front planetary pinions and this effectively cuts down the speed of the main shaft so that through the compounding action of the gear train an overdrive of only 1.0:2.337 is obtained.

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HYDRAULIC CONTROL AND POWER FLOW IN THIRD GEAR

When the operating lever is in third speed position, oil pressure is released from the top and bottom sides of the second speed servo piston and the spring releases the front band, while the oil pressure is applied to the bottom side of the third reserve servo piston, causing the piston to move up against the action of the servo spring and apply the rear band. Oil pressure is still directed against the inner clutch keeping it engaged. In third speed only the front or third reverse half of the planetary unit is used, giving an overdrive of 1.0:4.105. The front or third reverse internal gear is held stationary by the band and the main shift or sun gears are attached by the inner clutch to the output shaft. The power from the converter is transmitted to the third reverse planetary carrier pinions which are forced to walk around the stationary internal gear. The rotation of the pinions will cause the sun gear on the mainshaft to rotate and drive

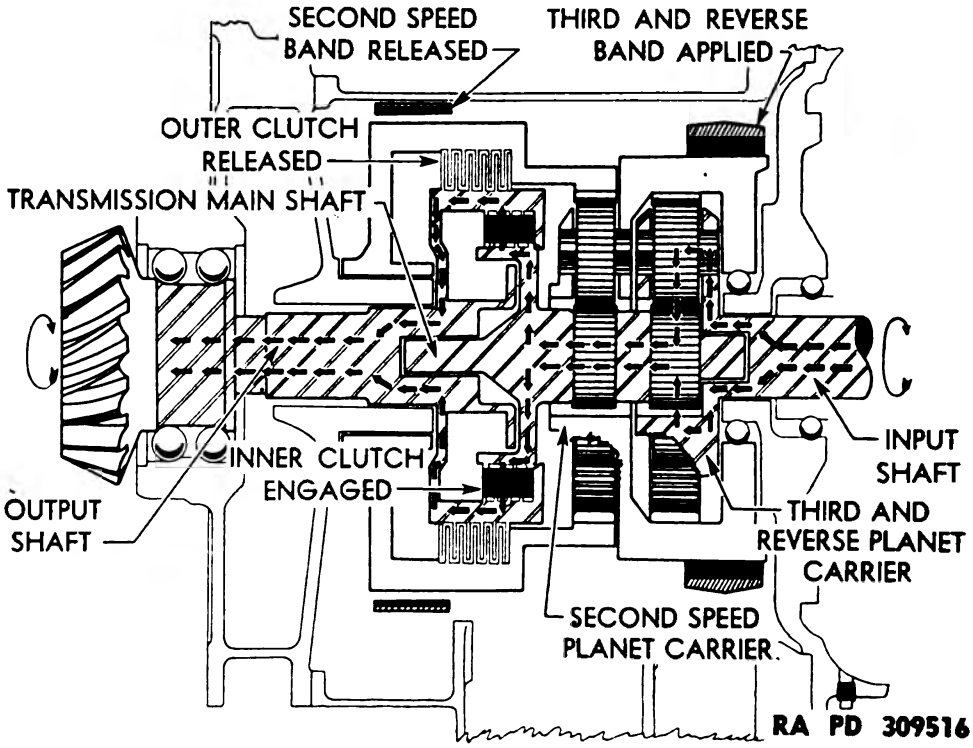

Figure 65. Power Flow With Hydraulic Control Lever in High Range.

the output shaft. The second speed planet carrier, which is attached to the third reverse internal gear, is stationary. This causes the pinions to act as an idler so that the rotation of the second speed sun gear driving these pinions causes the second speed internal gear to rotate in reverse. The second speed internal gear, however, is not attached to any shaft so no power is transmitted by this gear.

HYDRAULIC CONTROL AND POWER FLOW IN REVERSE

When the control lever is placed in reverse position, oil pressure is released from the top sides of the third reverse servo pistons while oil pressure is applied to the bottom sides of the piston to apply the front band against the action of the servo spring. Oil passages are opened to release the pressure from both sides of the second speed servo piston, allowing the spring to release the band. Oil pressure against the piston of the outer clutch causes the outer clutch to engage. The rear oil pump which rotates in reverse does not deliver oil pressure to the inner clutch; therefore, this clutch is released by spring pressure. In reverse, the compound planetary is used as two simple planetary trains. The

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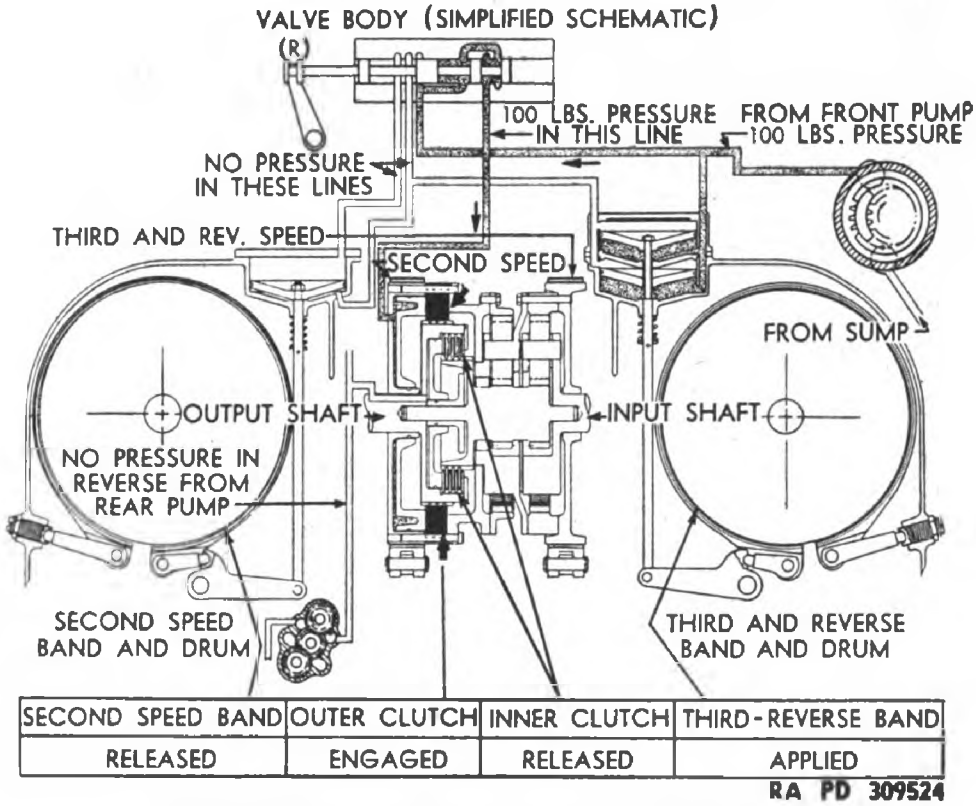

Figure 66. Hydraulic Control Lever in Reverse Position.

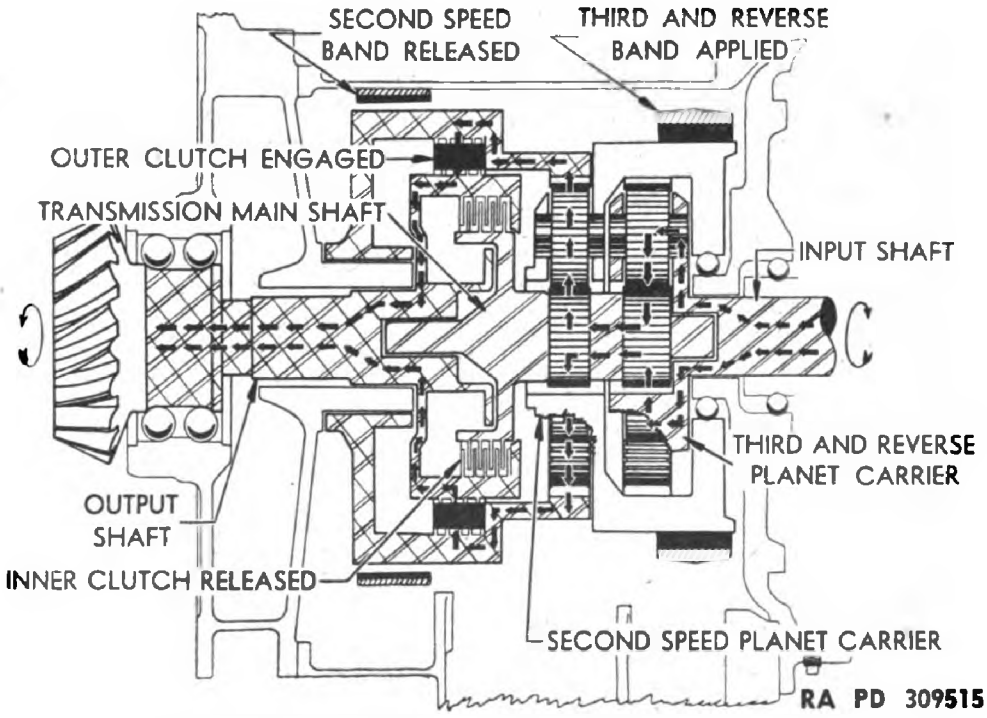

Figure 67. Power Flow With Hydraulic Control in Reverse Position.

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third reverse or front half is used as an overdrive and the second speed or rear half as the reversing and reduction unit, the total of which is an overdrive ratio of 1.0:1.322. In reverse, the third reverse band is applied to hold the third reverse internal gear stationary. The outer clutch is applied attaching the second speed internal gear to the output shaft, thus leaving the main shaft free to rotate without transmitting power to the output shaft. Power flows from the converter to the third reverse planetary pinions which are forced to walk around the stationary internal gear causing the sun gear to rotate, as in third gear. The second speed planetary carrier is held stationary by being connected to the third reverse internal gear so that the pinions are forced to act as idlers between the second speed sun gear and second speed internal year. This causes the second speed internal gear to rotate in reverse, carrying with it the output shaft which is connected to the second speed internal gear by the outer clutch. Below is a chart of the units showing the application of bands and clutches in all speeds.

Speed Range	Front or Third-Reverse Band	Rear or 2nd Speed Band	Inner Clutch	Outer Clutch	Ratios
Neutral	..	..	X	..	..
1st Gear	..	..	X	X	1.0:1.0
2nd Gear	..	X	X	..	1.0:2.337
3rd gear	X	..	X	..	1.0:4.105
Reverse	X	..	..	X	1.0:—1.322

X = Applied or engaged
.. = Disengaged or released

Figure 68. Application of Bands and Clutches.

TRANSFER CASES

When the need for more traction became strong, the front wheels were added to the driving members of a vehicle. The earliest type of transfer case had just one speed, but later models have two speeds. The construction of a transfer case is similar to that of a transmission. There is generally an input shaft, an idler shaft, and an output shaft for the front wheels which may be engaged at the will of the driver. The speeds of the transfer case are usually a low and a direct drive. The low speed gives the power train another gear reduction, while the direct drive allows the torque to travel through without change. The torque going to the rear wheels proceeds from a shaft on the same line with the input shaft.

The shaft leading to the front wheels is below the idler shaft which in turn is under the input shaft. The front wheel drive shaft is split in two so that the front wheels must be engaged by connecting the two halves of the shaft by a sliding internally splined sleeve. The position of this sleeve is controlled by a shifter lever located in the cab. Another sliding dog is splined to the input shaft and, by activation of a lever in the cab, may be used to tie the input and rear axle drive shafts together or to engage the input shaft to the idler which gives a gear reduction.

When the transfer case is in low, the torque flows from the input shaft to the idler shaft to the low speed gear and back to the output shaft. If the front wheels are engaged, the torque also flows from the idler shaft to the front axle drive shaft. When the transfer case is in high, the torque flows straight through the input and output shafts. The idler shaft also transmits the torque to the front wheels without reduction. If low speed is used the gear reduction at the propellor shaft is the product of the gear ratios of transmission and transfer case. The transfer case therefore acts not only as a unit to transfer torque to the front wheels but also as a unit giving further gear reduction. If an auxiliary transmission is incorporated however, the transfer case merely performs the function of engaging and disengaging the front wheels from the power train.

UNIVERSAL JOINTS AND PROPELLER SHAFTS

General. The motivating power of a vehicle having been delivered from the engine through the clutch, transmission, and transfer case, has started its flow to the wheels where it will cause the vehicle to operate. However, the power

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must flow through several more units of the power train before it can reach the wheels.

UNIVERSAL JOINTS

Conventional. Imagining a horizontal picture of the power train of a vehicle, it is readily seen that the axles are considerably lower than the frame of the vehicle on which are mounted the transmission and transfer case. In order to have the power transmitted from the height of the transfer case to the axle. it must be lowered from the horizontal line of the frame to the horizontal line of the axle, *i.e.*, the power must be transmitted through a line joining these two points. To accomplish this, a conventional universal joint is used. The universal joint (frequently referred to as a U-joint) is a flexible coupling which permits angular movement as well as rotary movement to be successfully transmitted. One yoke of this universal joint is bolted by means of a flange to one of the driving shafts extending from the transfer case, the other yoke is welded to the propellor shaft.

UNIVERSAL JOINTS

A conventional universal joint is fundamentally composed of three units; one cross pin and two yokes. The two yokes have their open portions facing each other and are opposed at 90°. The cross pin is inserted between the two yokes which makes the joint one complete flexible unit, allowing each yoke to move on its axis of the cross pin, as well as permitting the one yoke to rotate the other yoke. As a result this unit can transmit the revolving motion of the engine power through the necessary angle formed by the height of the transfer case down to the height of the axle; both heights being measured from the ground. The particular joint described is the Hookes' Coupling and is the unit upon which the current conventional universal joints have been developed. All the

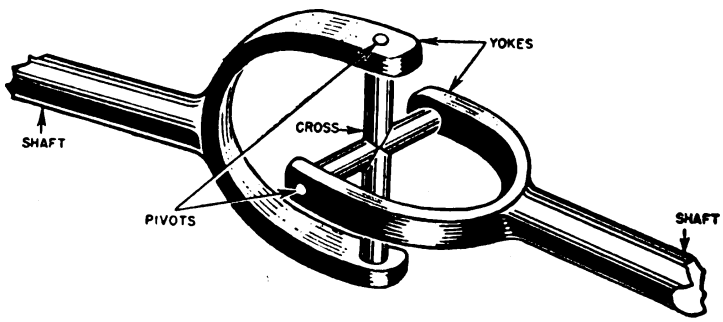

Figure 69. Hooke's Coupling.

popular universal joints have the same operating principal, and the few differences are due to slight ramifications in the particular design of various manufacturers. Each of the following types are adequate and are in current use: Cross and Two Yokes Type; Cross Pin Type; Ring and Trunnion Type; Split Ring Type; Split Ring and Pin; Sliding Ball and Trunnion Type.

In transmitting power through a conventional universal joint, *i.e.*, a flexible coupling, it has been found that a whipping condition developes in the shaft attached to the driven yoke. This condition exists only in the driven yoke and not the driving yoke of the conventional universal joint, and it is known as velocity fluctuation and occurs in one revolution or 360° of the driven yoke. To compensate for the undesirable action of the conventional joint, another conventional universal joint is mounted at the axle end of the propellor shaft. The last mentioned joint has its driven yoke turned 90° out of phase with the driven yoke of the joint flanged to the back of the transfer case shaft. As a result the two universal joints allow the tubular shaft, to which both universal joints are attached, to absorb the velocity fluctuation, and the whipping condition is alleviated.

Constant Velocity Joint (C.V.J.). Most army vehicles and some commercial

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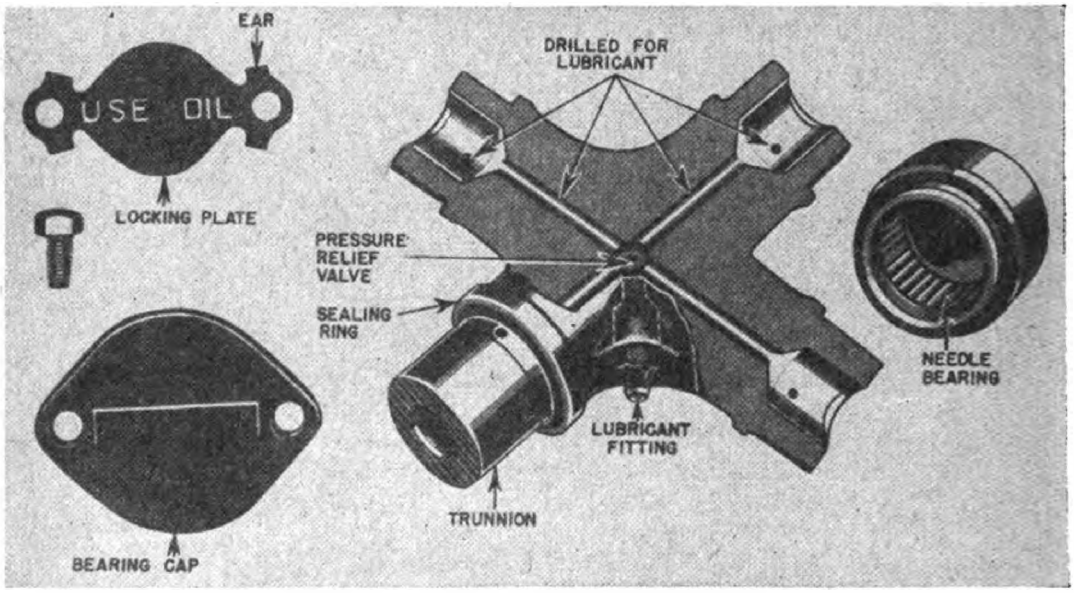

Figure 70. Universal Joint and Bearings.

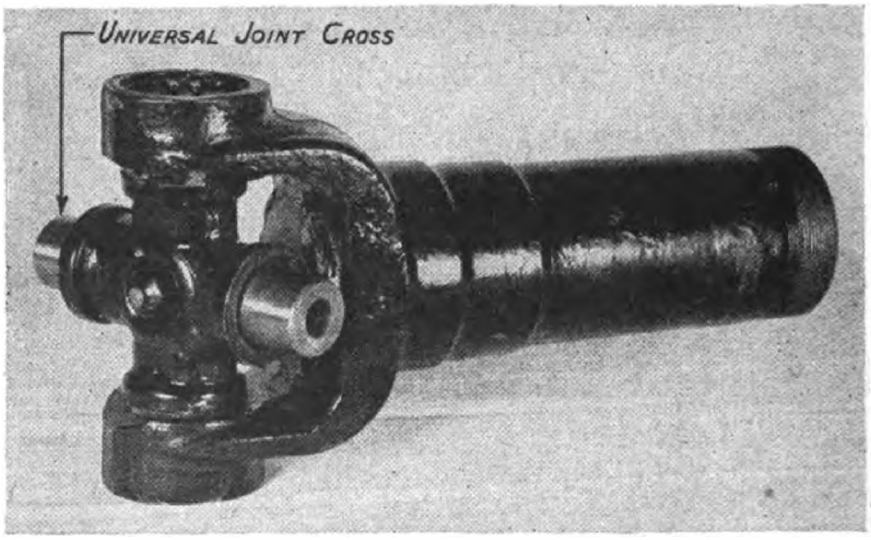

Figure 71. Assembled Cross Pin Universal Joint.

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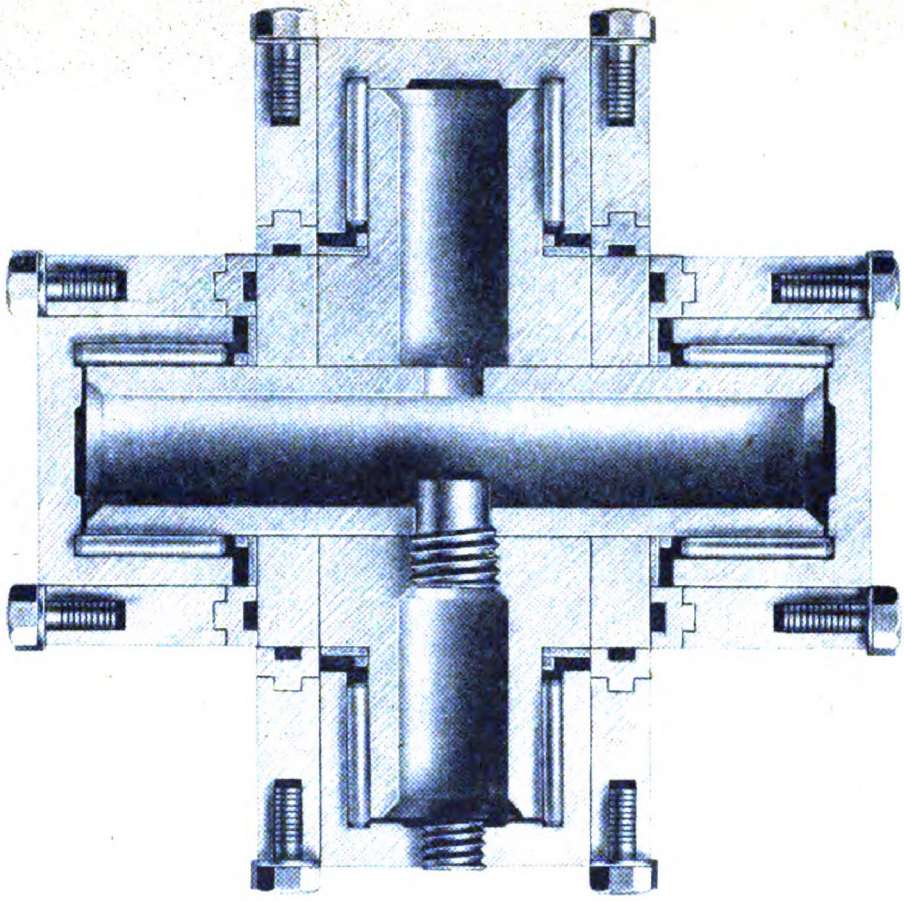

Figure 72. Cross Section of Cross Pin Universal Joint.

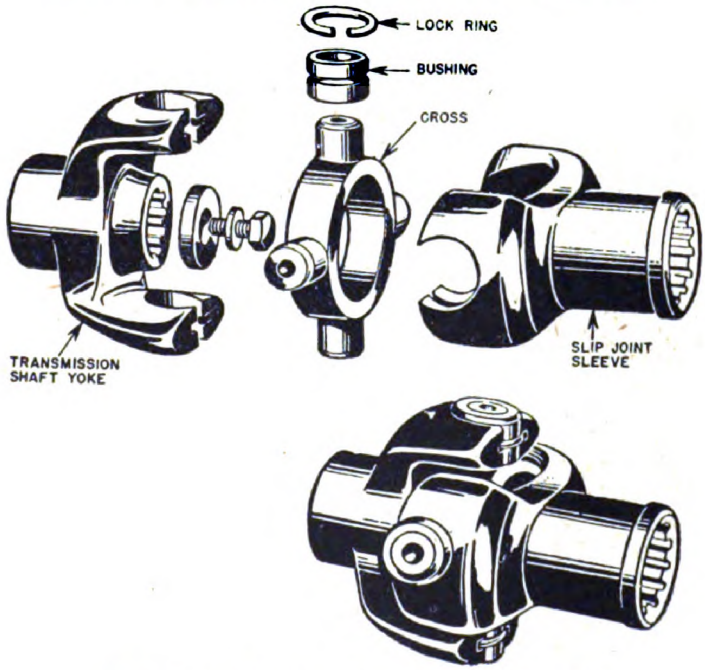

Figure 73. Ring and Trunnion Universal Joint.

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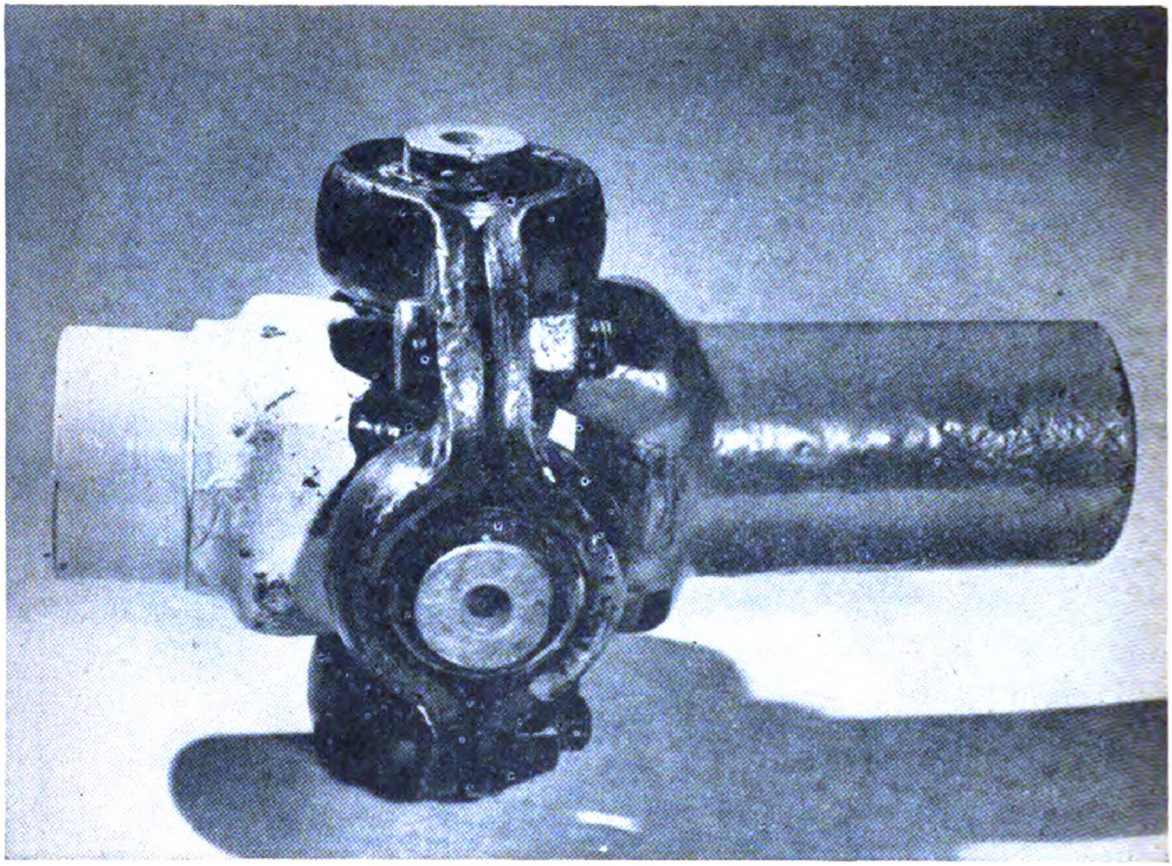

Figure 74. Split Ring Universal Joint.

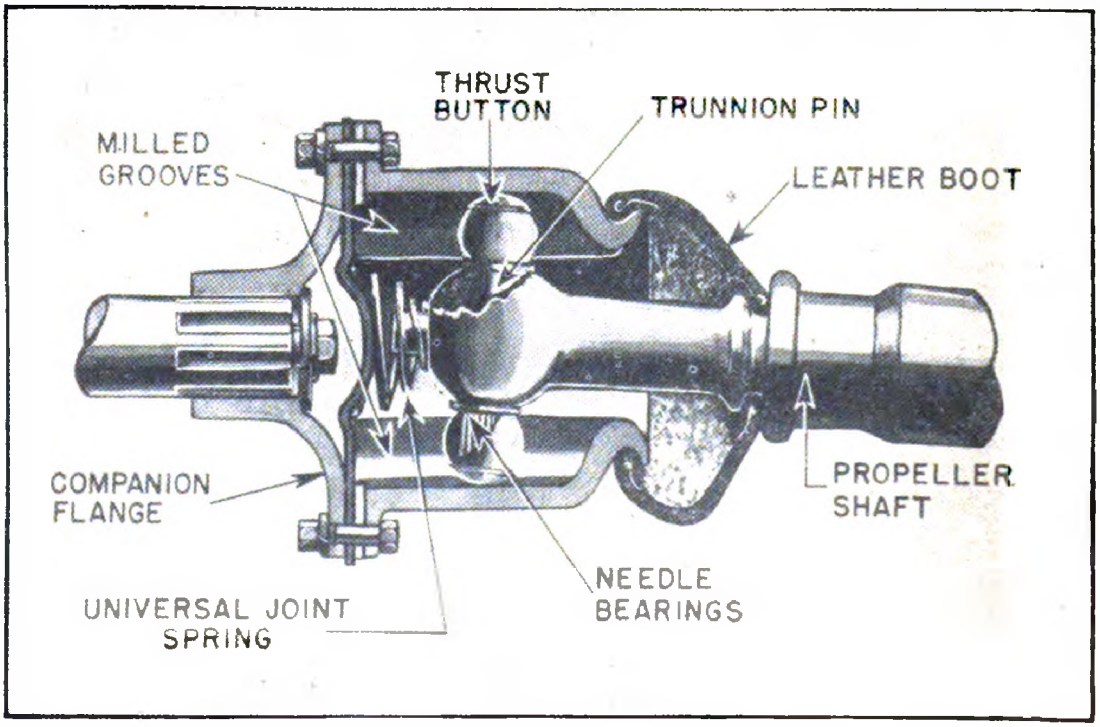

Figure 76. Sliding Ball and Trunnion Universal Joint.

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trucks use what is known as an activated front axle which performs the same task as the rear axle, *i.e.*, motivates the vehicle. In order to transmit the power to the front wheels it would be impossible to have a solid axle shaft as in the case of the rear axle, because it is necessary to allow for turning of the front wheels to control direction of the vehicle. Therefore, it becomes necessary to conduct power through a turning angle. We know that a conventional universal

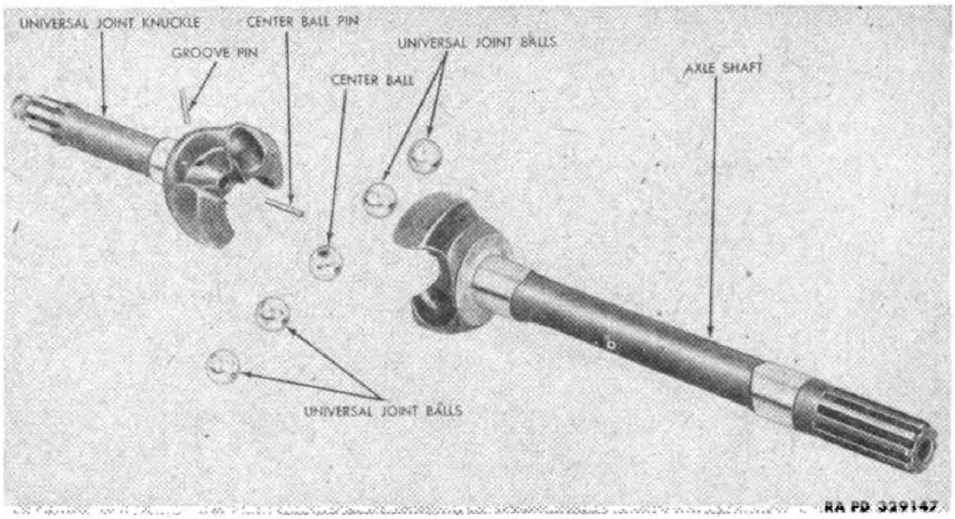

Figure 77. Front Axle Shaft Exploded View (Bendix).

joint will conduct rotary motion through an angle, but the conventional type does not permit a constant rate of revolutions per minute to be transmitted to the driven yoke of the joint. It can be readily understood that such a condition would be entirely impractical and is undesirable in the front wheels while the rear wheels continued to rotate at a constant number of revolutions per minute.

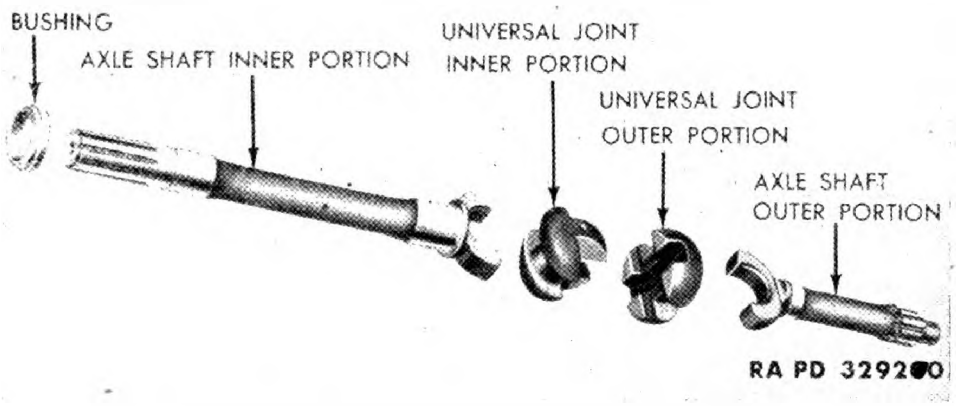

Figure 78. Front Axle Shaft Exploded View (Tracta).

In as much as the conventional universal joint is inadequate, a universal joint known as a Constant Velocity joint was developed and is in broad use. Actually there are four popular types; Bendix-Weiss, Rzeppa, Tracta, and Helical gear joint.

Each of the types to date has proven satisfactory. The Tracta is in limited use and the gear type is in use in the heavier vehicles, but the other two have had extensive application. The Bendix-Weiss and Rzeppa operate on the principal that their construction bisects the angle between the driving axle and the driven

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steering knuckle regardless of the angle of turn up to 30° maximum. In the conventional universal joint, at only four points during one complete revolution of the driving and driven yokes is the angle between driving and driven shafts bisected, and at that particular time both shafts rotate at the same rate of speed. With a constant velocity joint, there is no fluctuation, which is the desired characteristic.

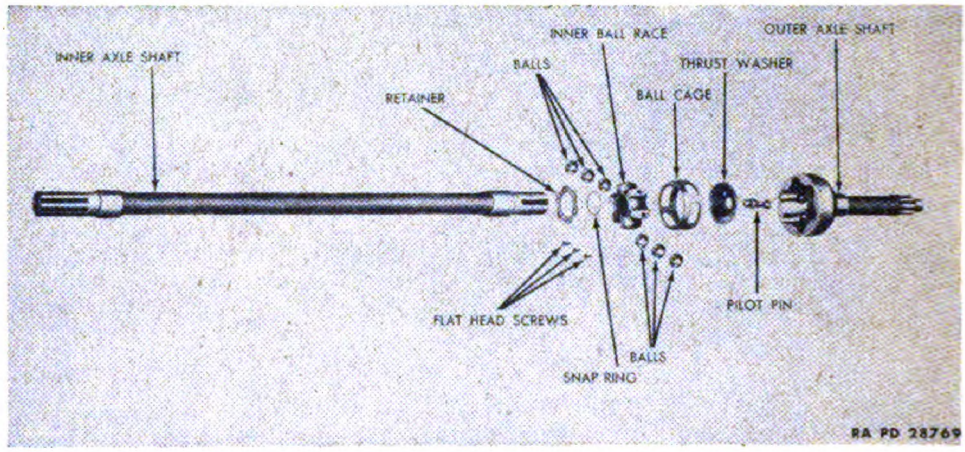

Figure 79. Front Axle Shaft Exploded View (Rzeppa).

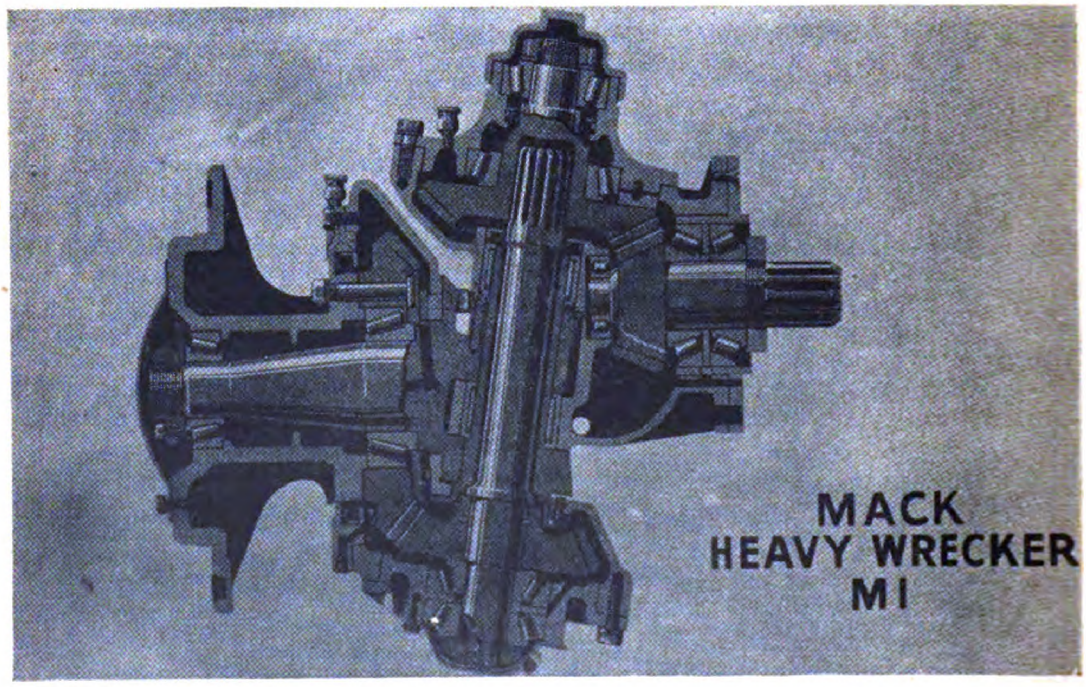

Figure 80. Helical Gear Steering for a Front-Wheel Drive.

Referring to figure 81, we can see why the angle between driving and driven units is bisected at all times. The driving member is stationary in terms of horizontial movement but we know that it can move in terms of the outer race which is moving through an arc at the top and bottom of the outer race. The movement between driving and driven yokes is permitted by the balls interposed between the two members just mentioned. Let us consider for a

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moment the action of a round pencil placed on a table with a ruler placed on top of the pencil. Should the ruler be moved to the right or left, the pencil travel is exactly half that of the ruler, regardless of the distance the ruler is moved. In this example there are three objects; the table top, the pencil, and the ruler, two of which are moveable members and the third stationary. In a like manner the inner race can be considered the stationary table top, the ball as the pencil, and the driven race as the ruler. The same relative motion between the pencil and ruler exists between the outer driven race and the balls in the C.V. joint. Whatever the degree of turn of the driven yoke, each ball moves

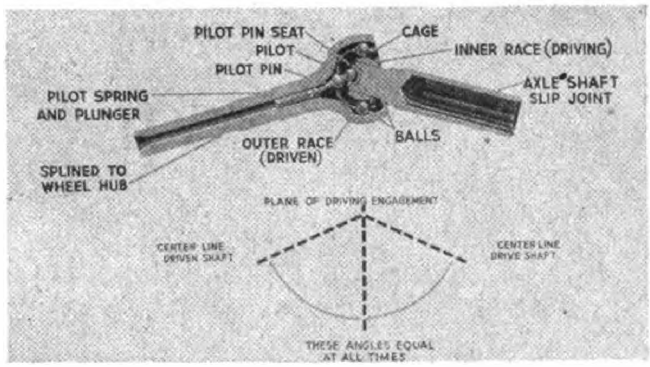

Figure 81. Rzeppa Type of Constant Velocity Universal Joint Assembled.

half the number of degrees when turning the vehicle left or right. When turning the vehicle 20° to the left the top ball moves 10° counter clockwise, the bottom ball moves also 10°, but clockwise. As a result the balls of the constant velocity universal joint are thereby positioned, from a top view, to bisect the angle formed as indicated in figure 81.

PROPELLER SHAFT AND SLIP JOINT

The power, having been transmitted through an angle, is next carried along the power train by a device known as a propeller or drive shaft. Propeller shafts are of the solid and tubular type, the latter being more common. The tubular shaft permits greater stress to be put through it than the solid shaft of the same weight.

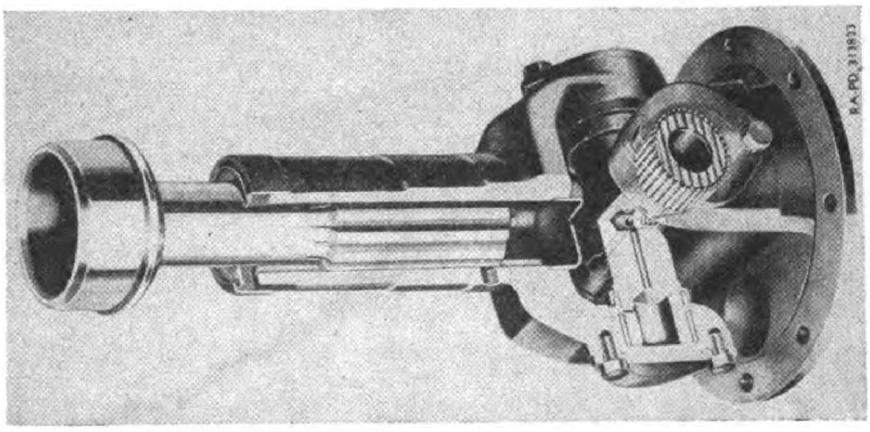

Figure 82. Universal Joint, Bearing Cap Type.

Because flexing of the springs causes the axle housing to move, it necessarily means that some provision must be made to allow the propeller shaft to contract and expand too. A device known as a 'slip joint' permits elongation and contraction of the propeller shaft. A slip joint consists of a male and female

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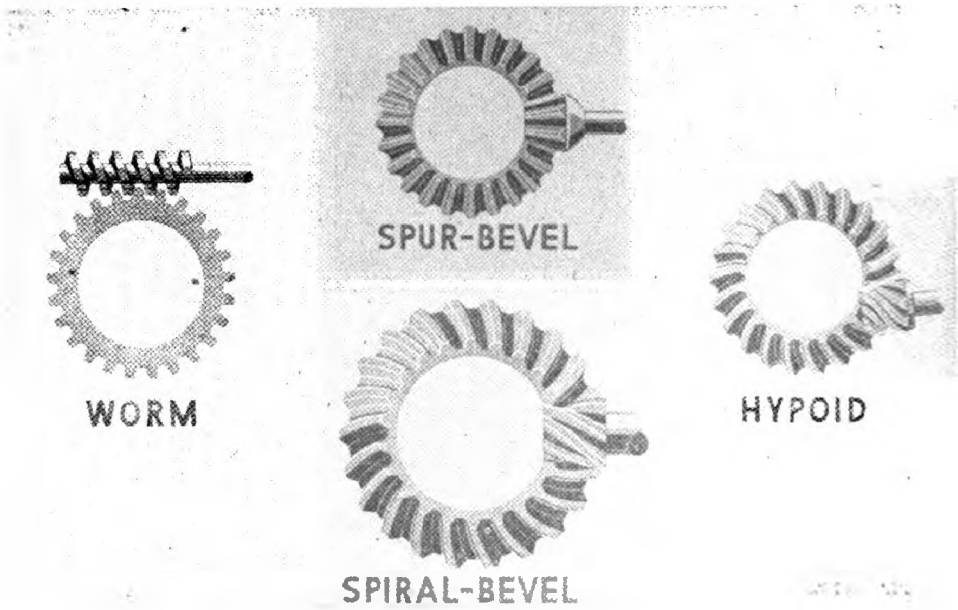
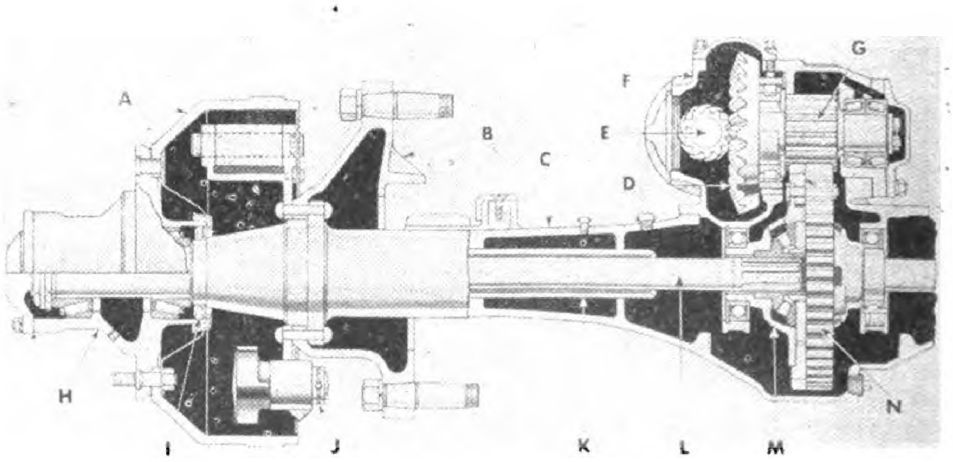


Figure 83. Gears Used in Final Drives.



A	BRAKE DRUM	H	HUB
B	TORQUE ROD BRACKET	I	OIL SEAL
C	AXLE HOUSING	J	BRAKE CAMSHAFT
D	BEVEL GEAR	K	AXLE TUBE
E	BEVEL PINION	L	AXLE SHAFT
F	DIFFERENTIAL CARRIER HOUSING	M	DIFFERENTIAL CASE
G	SPUR PINION	N	SPUR GEAR

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Figure 84. Cross Section of the Rear Axle.

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spline, a grease seal and a lubrication fitting. The male spline is welded to the propeller shaft and the female portion fixed to the universal joint directly behind the transmission or transfer case. As the axle housing moves forward and backward, the slip joint gives freedom of movement in a horizontal direction and yet is capable of transmitting rotary motion.

FINAL DRIVES

As the power leaves the conventional universal joint mounted on the rear end of the propeller shaft, it flows into a unit known as the final drive—the last gear reduction of the power prior to delivery to the wheels. The final drive also changes the direction of power flow 90° so that it can be transmitted to the wheels.

There are several types of conventional final drives; the spur bevel, the spiral bevel, the hypoid, and the worm and worm gear. The most common types are the spiral bevel and the hypoid usually found on vehicles of under four ton payload capacity and the double reduction type used on vehicles of greater than four ton payload capacity. The hypoid final drive is one in which the pinion is below the center line of the ring gear. This feature permits a lower center of gravity and the pulling of heavier loads. Due to the increased pressure between the pinion and the ring gear, an extreme pressure lubricant is required.

DIFFERENTIALS

Conventional. When a column of soldiers performs a column movement, it is necessary for the outside file to cover a greater distance than the pivot file, and therefore the pivot file takes only fifteen inch steps (as compared to the normal thirty inch steps on the outside file), until such time as the first rank comes abreast. Similarly, when a vehicle turns a corner, the outside wheel must make a larger arc than the inside wheel. No difficulty is found with wheels that are not driving wheels, *i.e.*, front wheels on conventional passenger cars, but rear

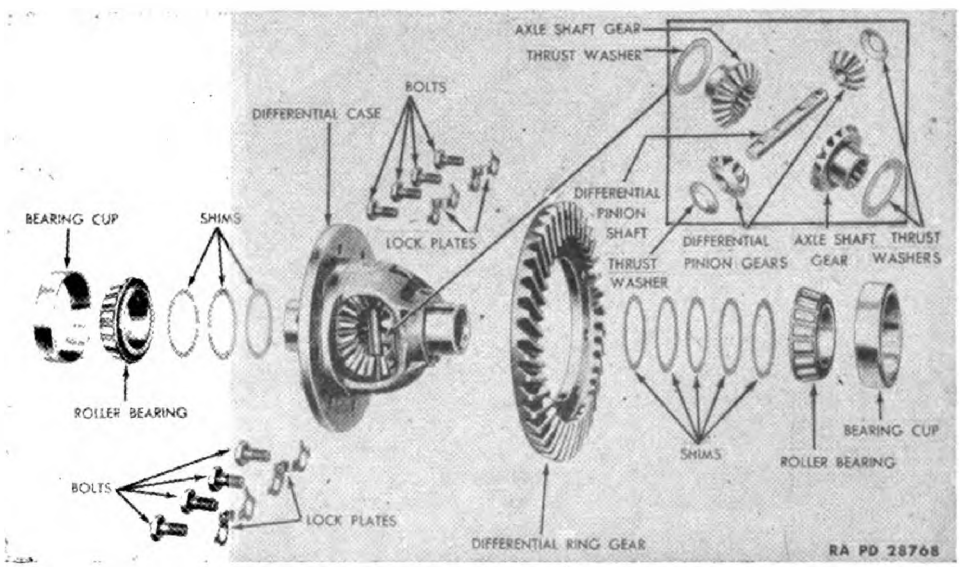

Figure 85. Differential Assembly, Exploded View.

wheels require a unit that permits the two wheels to rotate independently. This unit must allow the vehicle to turn corners without strain or slippage and also permit power to be transmitted to both wheels equally when the vehicle is traveling straight ahead.

Each rear axle has at its outer end a wheel splined or keyed to it. At its inner end is splined a differential side gear. Therefore, any movement of the wheel is reflected in a movement of the gear on that axle. Between the two

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side gears is a pinion gear mounted on a pinion. The pinion is fixed in a differential case which in turn is bolted to the ring gear of the final drive. As the ring gear rotates it causes the case and pinion to rotate in the same direction and at the same speed. If the resistance on both rear wheels is the same, the differential does not function as such, but instead causes both wheels to rotate at the same speed and torque. The vehicle will be moving straight, either ahead or to the rear. However, if the resistance on one wheel is greater than the other the differential comes into operation. The pinion gear walks around the side gear with the greater resistance and imparts engine torque, which is constant, to the side gear with the least resistance. As a result the side gear with the least resistance gains in R.P.M. the amount lost to the side gear with the greater resistance, because the speed of the pinion gear is added to the speed of the differential case. Ring gear speed is just half of the sum of the speeds of the two side gears. For example: If ring gear speed is unknown but the side gears rotate at 200 and 400 R.P.M., then R.G.S. $= \frac{200 + 400}{2} = 300$ R.P.M. If any two of the factors are known the third can be found.

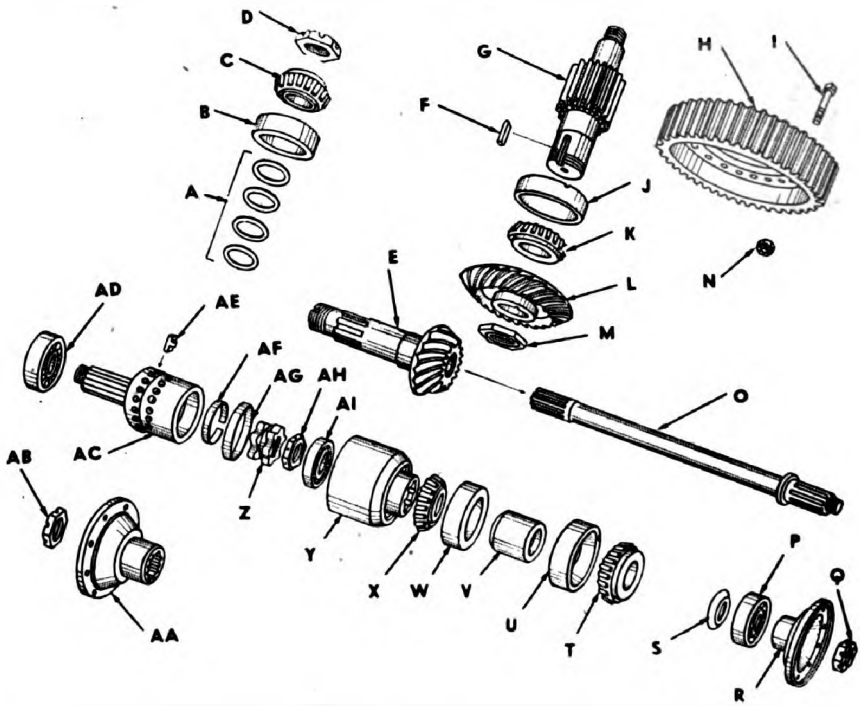

Figure 86. Power Divider and Double Reduction Gear Parts.

A—Bearing Adjusting Shims
B—Outer Bearing Cup
C—Outer Bearing Cone
D—Bearing Nut
E—Bevel Pinion Shaft
F—Pinion Shaft Key
G—Spur Pinion Shaft
H—Bull Gear
I—Bull Gear Bolt
J—Inner Bearing Cup
K—Inner Bearing Cone
L—Bevel Gear
M—Gear Retaining Nut
N—Bull Gear Bolt Nut
O—Inter-Axle Drive Shaft
P—Drive Shaft Bearing
Q—Drive Flange Nut
R—Drive Flange
S—Oil Slinger
T—Rear Bearing Cone
U—Rear Bearing Cup
V—Bearing Spacer
W—Front Bearing Cup
X—Front Bearing Cone
Y—Powder Divider Cam (Female)
Z—Powder Divider Cam (Male)
AA—Driveshaft Flange
AB—Flange Nut
AC—Power Divider Driving Cage
AD—Power Divider Ball Bearing
AE—Power Divider Wedge
AF—Inner Retainer Ring
AG—Outer Retainer Ring
AH—Bevel Pinion Nut
AI—Power Divider Roller Bearing

Power Divider. The 'power divider' is a device for dividing or proportioning the power available according to the requirements. It may be used to replace the differential gears between two axles.

As used in either application, the power divider provides substantially the same action as a differential under normal conditions in that it permits the wheels or axles to drive with an equal division of power. It differs, however, from a gear differential under conditions of *unequal* wheel or axle traction. The

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divider has the ability of dividing the power unequally between the wheels or axles and supplying the greatest power to the wheel or axle with the better traction.

The rate of the power split is determined by the design; it may be designed for an equivalent power split in either direction or it may be designed for a power split with directional characteristics. As used to divide the power between the wheels of a single axle or between the two rear axles of a six wheel bogie, it divides the power on a seventy-five to twenty-five basis in either direction. If used between the front and rear axles of an all-wheel drive vehicle, it may be designed to provide a full one hundred percent to the rear axles if necessary, while under other conditions, it can limit the maximum power available to the front wheels to a predetermined percentage which might be as low as thirty.

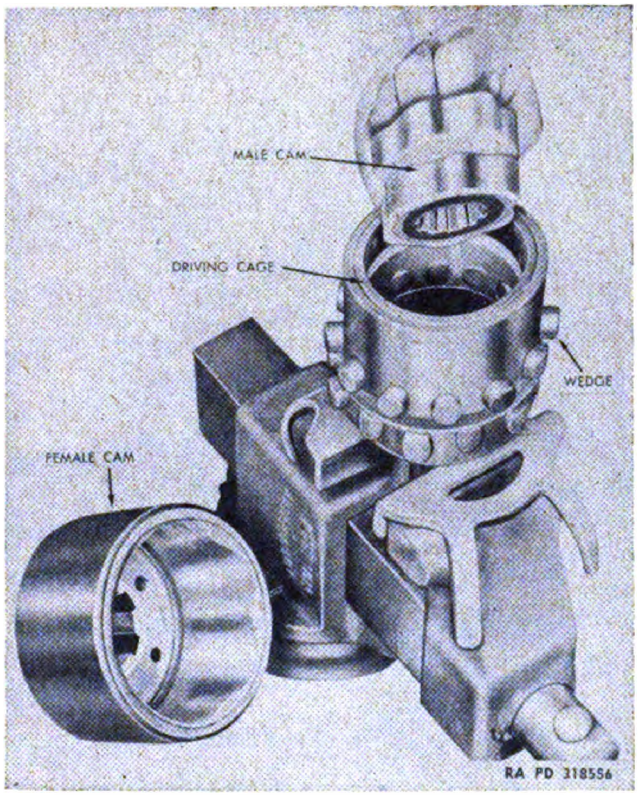

Figure 87. Inserting Male Cam in Driving Cage.

Since the operation of the power divider is based on a percentage division, a slight amount of traction is necessary on one side if maximum traction is to be realized on the other side. When there is no traction on one side, a slight application of the brakes will develop sufficient resistance on that side to insure the desired operation of the power divider.

The power divider comprises three main elements: The driving cage, which is driven by the engine and carries two rows of plungers free to slide endwise in holes in the cage; an outer member which surrounds the cage and has a wide six-lobed cam track formed on its inside circumference; a member inside the cage which has a pair of six-lobed external cam tracks in staggered relation to each other. Each of the cam members is splined internally to receive one end of the out-put or axle shafts.

In figure 88, the whole assembly rotates on bearing "E" and power is applied to the driving cage "A" from the immediate source of power which in this case is the gear "F." Under normal operating conditions the cage "A" will carry the plungers "B" against the cams, driving both cams at the same speed as the cage

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"A." If, however, one cam member is held and the cage is rotated, the plungers "B" will move in and out over the cam lobes forcing the other cam members to turn at twice the speed of the cage. Due to friction, however, and according to the particular design characteristics, the greater percentage of the driving effort will be applied to the satisfactory cam while the balance will be applied to the moving cam.

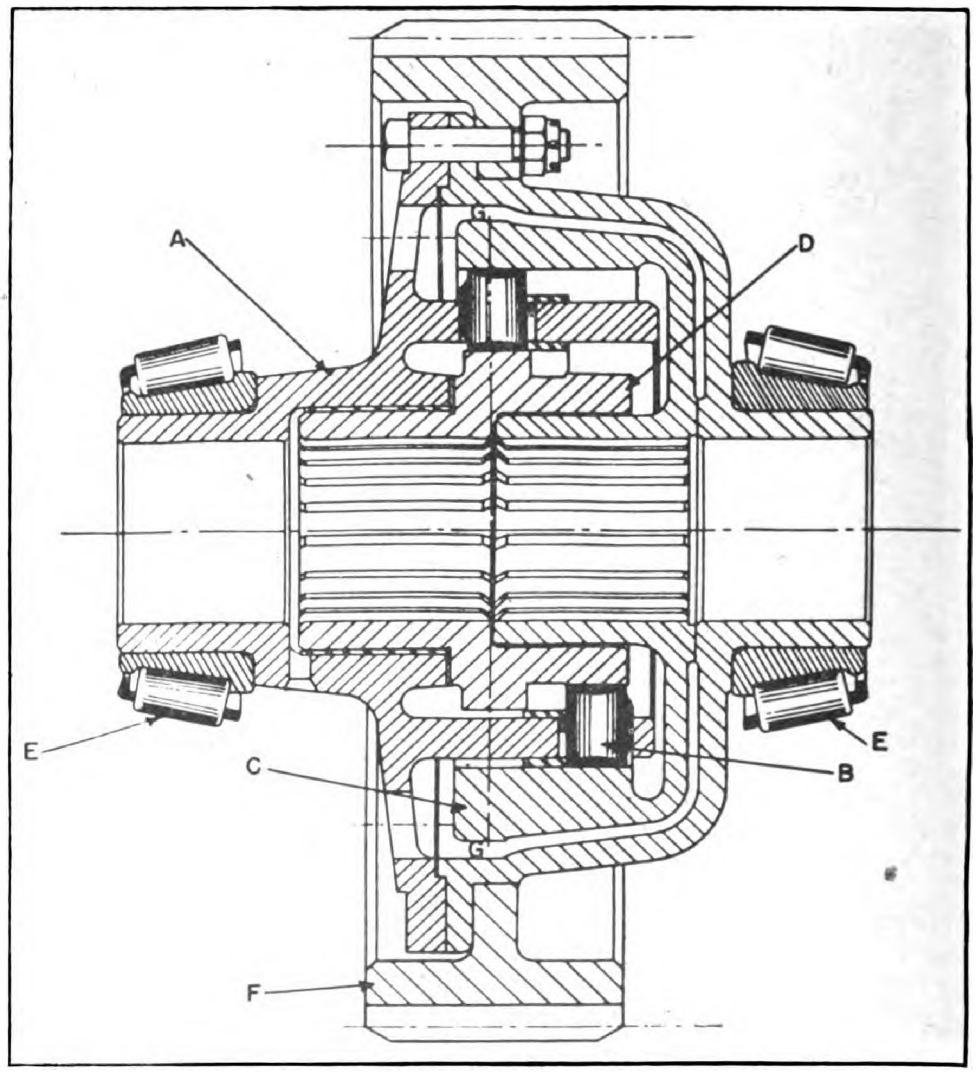

Figure 88. Power Divider.

With a gear type differential, the total tractive force at the wheels is equal to twice the tractive force of the wheel with the less traction. With the Mack power divider, the design makes it possible to obtain a tractive force which may be three times greater in one wheel than in the other. The power divider, therefore makes it possible to obtain one hundred percent more draw bar pull than the conventional gear differential under adverse conditions.

CONTROLLED DIFFERENTIAL

A controlled differential in a tank can be likened to the function of a team of horses pulling a plow. The team of horses determines whether the plow will move right, left, or straight ahead; moreover, the horses act as braking system. In a somewhat similar way the controlled differential determines the direction in which the tank moves as well as functioning as a brake to stop it. Essentially

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this type differential is found in use only in full track vehicles such as tractors and tanks. Although wheeled vehicles have been known to use a type of controlled differential, such use is not conventional.

The reins with which we control the direction of the horses are replaced by two steering levers in the tank; one controlled by the right hand, the other by the left hand. Each of these levers controls through linkage a contractable brake band which when contracted places a frictional resistance on one or both brake drums that, in turn, are a part of the controlled differential. We cause the team of horses to turn to the right by pulling back on the right rein and allowing the left rein to remain slack. Likewise, when we wish the tank to turn to the right we pull back on the right steering lever and allow the left steering lever to remain in its released position.

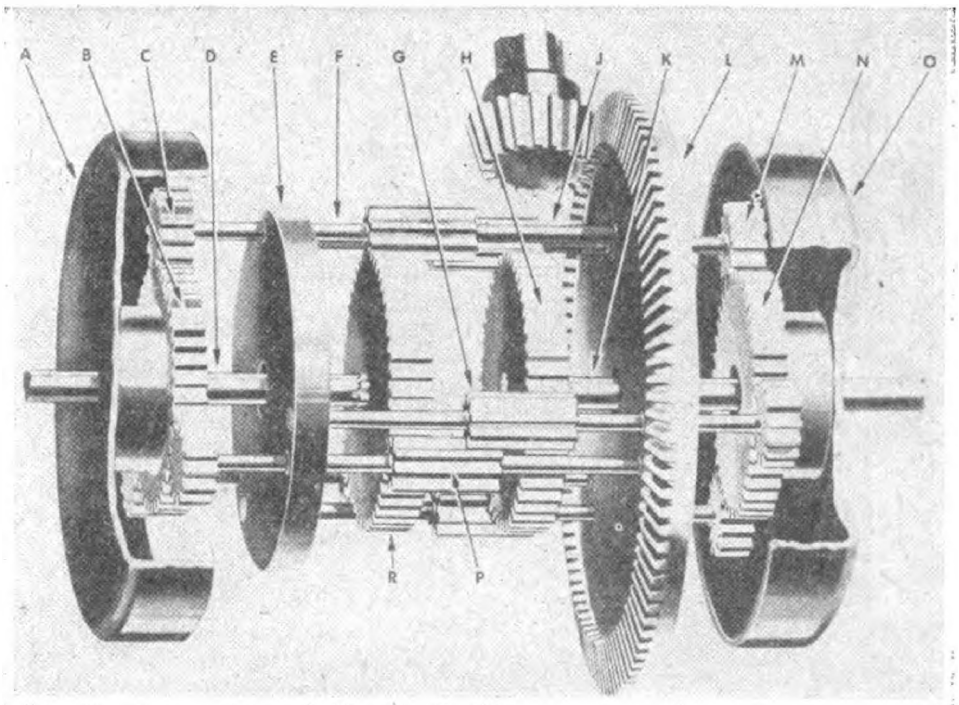

Figure 89. Spur Gear Controlled Differential (Schematic).

A—Rim, Steering Brake
B—Gear, Steering Brake Rim Flange
C—Pinion, Differential External, R. H.
D—Shaft, Final Drive
E—Cover, Compensating Gear Case
F—Shaft, Pinion
G—Pinion, Internal, L. H.
H—Gear, Compensating, L. H.
J—Shaft, Pinion
K—Shaft, Final Drive
L—Gear, Spiral Drive
M—Pinion, Differential External, L. H.
N—Gear, Steering Brake Rim Flange
O—Rim, Steering Brake
P—Pinion, Internal, R. H.
R—Gear, Compensating, R. H.

The right brake drum that now has a frictional resistance on it and is connected to the right track through differential gears, slows down. The left track increases its speed the same amount as lost by the right track and that speed is added to the normal speed of the left track because the differential gives a compounded speed similar to a person who, while riding an escalator, walks in the same direction as it is moving.

The result is that the tank turns to the right. Should we wish to turn the horses to the left, we leave the right rein slack and pull back on the left rein. Similarly, in the tank, by not moving the right steering lever and pulling back on the left steering lever, the brake band contracts on the left drum giving a frictional resistance through the differential gears to the left track thereby slowing its speed. The speed that is deducted from the left track causes (through differential gears) the speed of the right track to increase that same amount above its normal speed. The result is that the left track slows down, the right increases its speed and the tank turns to the left. What causes the horses and plow to go in a

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straight ahead direction? Freedom or slackness of both reins. What causes the tank to move straight ahead? Freedom on both steering levers. There is no frictional resistance through contracted brakes on the drum and the drums are connected indirectly to the tracks. Both tracks then pull with equal force. What causes the horses to stop? Pulling back with equal force on both reins. What causes the tank to stop? The same function. As a result, equal resistance on both tracks causes the differential gears to lock; and by similtaneously disengaging the clutch by foot the tank will come to a halt.

AXLES

We will limit the discussion of axles to live front and rear axles only. There are three forces acting on a live axle; weight, twisting, and end thrust. Weight on the axle causes bending and shearing. Twisting is caused by skidding, turning, hitting curbs, and driving on a side slope.

We in Ordnance are concerned principally with 'floating' axles of the live type. These are: the 'semi-floating', 'three-quarter floating', and 'full floating'.

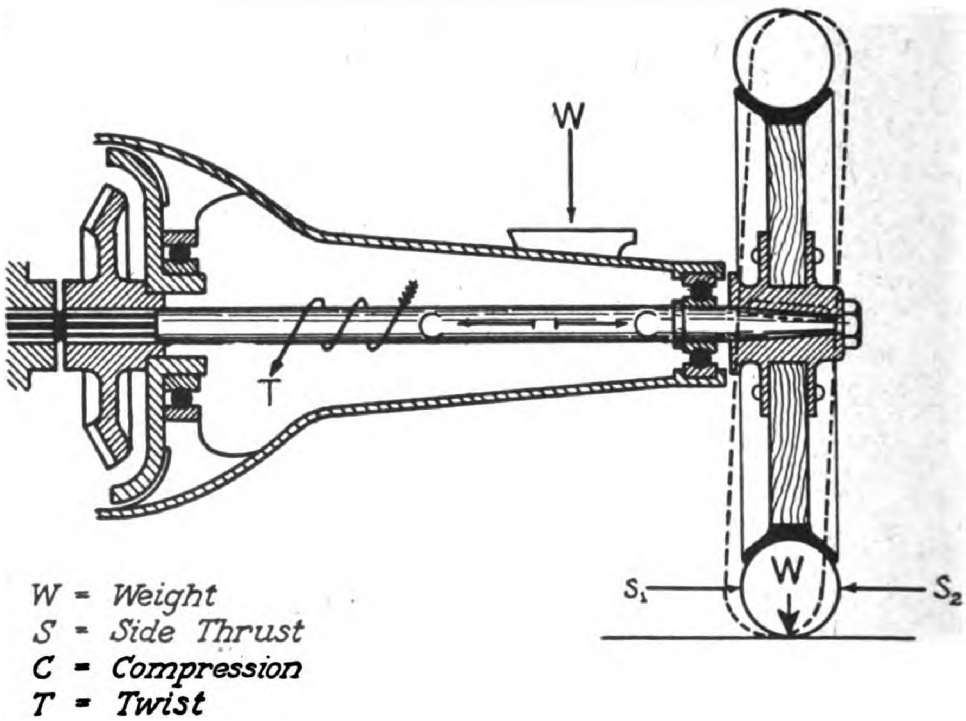

Figure 90. Forces Acting on a Drive Axle.

Actually we are speaking in terms of how the axle is physically mounted within the axle housing, whether banjo or split, and principally, whether the bearings are mounted internally or externally on the axle housing, and how the wheel hub is fixed to the axle shaft. As a result we can determine how the forces of weight, twisting, and end thrust are handled.

A semi-floating axle has the outer end mounted in a bearing within the axle housing. The hub of the wheel is keyed on the shaft. As a result this type is subjected to axle load, bending, and torque of the engine.

When the wheel bearing is mounted externally on the axle housing and the hub is keyed to the axle shaft, it is a three-quarter floating axle. It delivers the torque of the engine as well as absorbing the stresses caused by turning, skidding, and wobbling of the wheel.

When the axle is full floating it delivers only the torque of the engine, because the tapered wheel bearings are mounted externally on the axle housing and the axle is splined to a female splined flange which in turn is bolted to the hub. The weight and bending forces are therefore absorbed by the axle housing.

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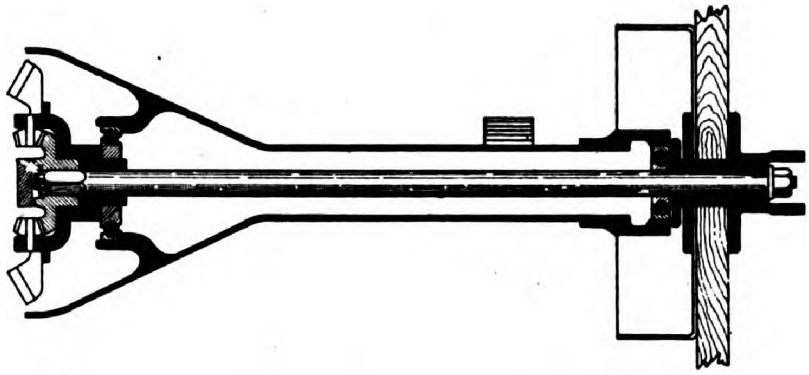

Figure 91. Semi-Floating Axle.

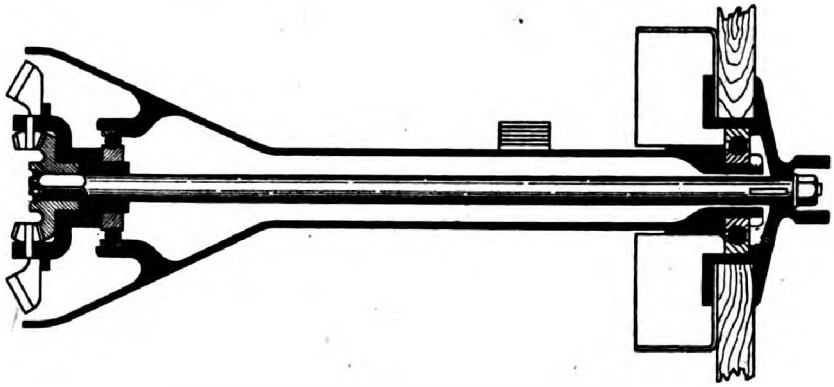

Figure 92. Three-Quarter Floating Axle.

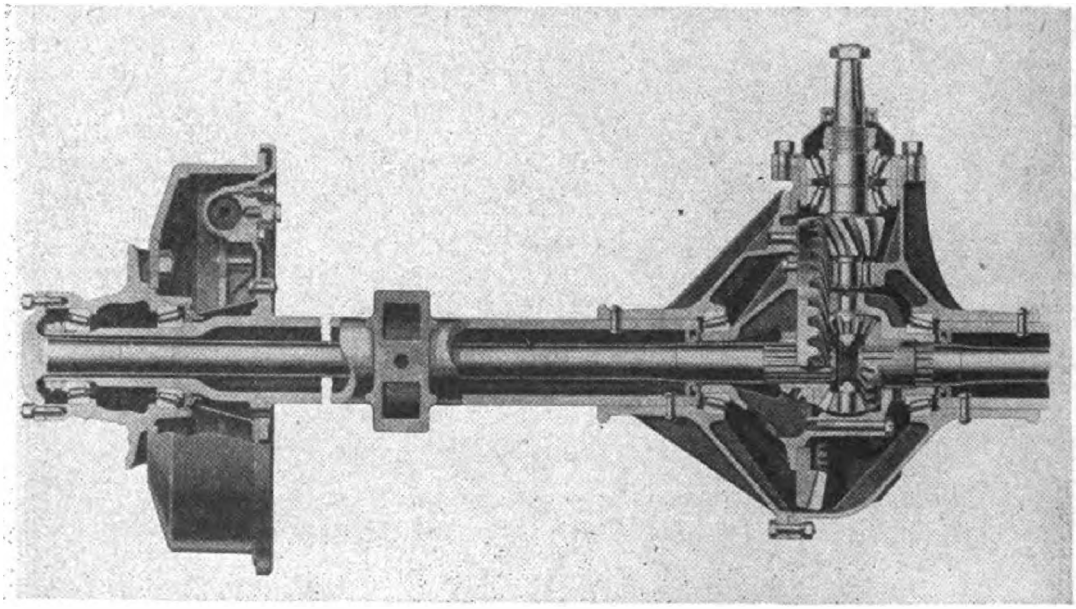

Figure 93. Full-Floating Rear Axle.

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BRAKES

Brakes are necessary to control the speed of the vehicle, stop the vehicle when necessary, and hold the vehicle in place without the presence of the driver.

The braking power of any vehicle should be proportionate to its weight and speed in order to assure complete mastery by the vehicle's operator. The general construction and the materials used are the deciding factors which determine the efficiency and success of any braking system.

Automotives brakes can be divided into two classifications; service brakes and parking brakes. Virtually all wheeled vehicles have both. This has been brought about by state laws as well as the competitive nature of industry.

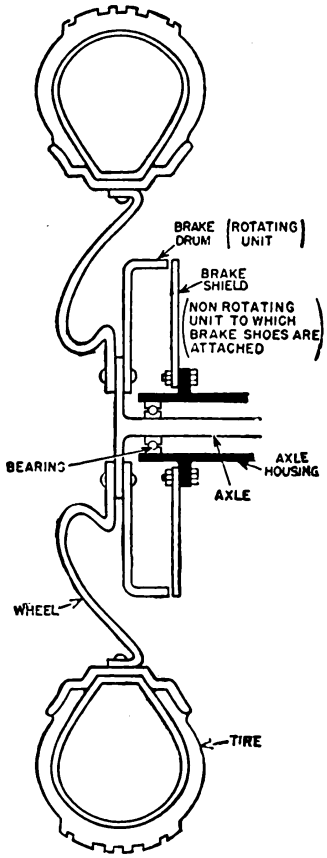

Figure 94. Wheel Brake Mounting.

The service brakes are confined almost exclusively to the internal expanding type of construction. In this type of construction a rotating member (drum) is fastened by some mechanical means to the wheels and the non-ratating members are securely fastened to a backing plate which in turn is secured to the axle housing or steering knuckle. The shoes attached to these backing plates are so constructed that when expanded they will contact the metal surfaces of the drums and thereby set up the friction necessary to retard or stop the motion of the vehicle.

The brake drums are cylindrical members, either of cast iron or steel, depending upon the requirements. A third type of drum is known as centrifuge, and combines the desirable features of the above mentioned two metals into a light but strong unit.

This type of drum will be found on the majority of the Army vehicles. The steel is used to strengthen the drum against deformation and vibrations, and the cast iron is used as a liner because of its frictional qualities.

There are varying interpretations of the engineering features depicted in the

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mounting of these shoes on the backing plate. Generally, they contain two shoes to each wheel. These shoes are semi-circular segments with a friction material of specially treated asbestos riveted to the outside. They can be of the single or double anchor type, depending upon the manufacturer and the means by which they are expanded. One feature which bears heavily upon the selection of the type of mount is the self-energizing factor obtained when the non-roatating member makes contact with the drum. See figure 95.

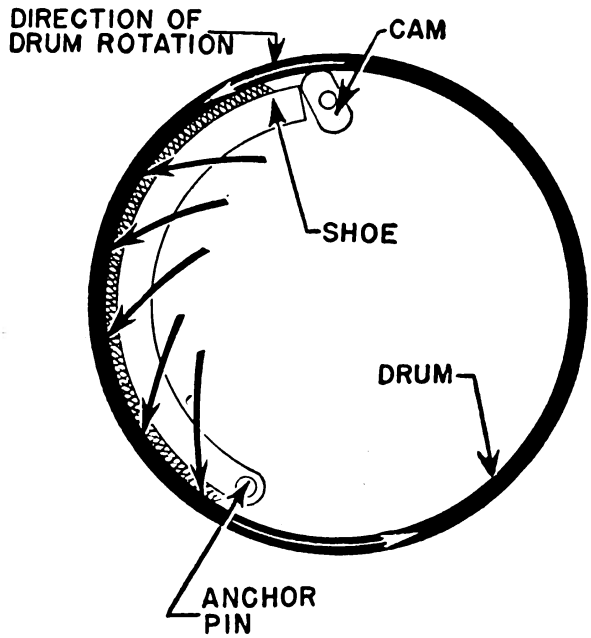

Figure 95. Self-Energizing Action.

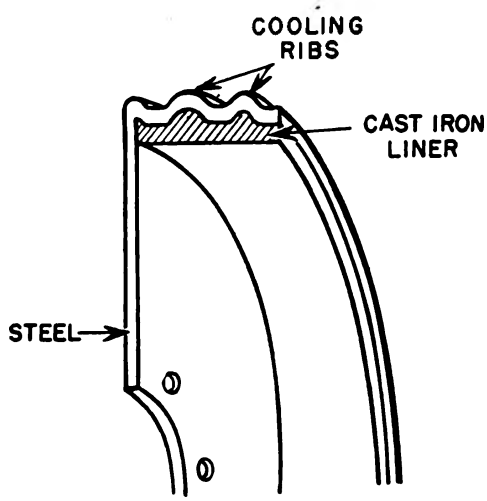

Figure 96. Centrifuge Brake Drum.

The tendency for the shoe to rotate with the drum tends to apply itself in proportion to the initial application. The direction of rotation determines which of the two shoes is self-energizing. Some manufacturers, in order to take full advantage of the existence of this factor, construct their brakes so that there is but one anchor pin for the two shoes. In this manner, they can achieve the self-energerizing action in either direction. The shoe towards the front of the vehicle is considered the primary shoe and the shoe to the rear of the vehicle is

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considered the secondary. All brakes of this nature use a retracting spring to draw the shoes back to their normal position and out of contact with the drum on release. The springs are of sufficient strength to overcome the self-energizing action present.

The method of adjusting brakes is dependent upon the manner in which the shoes are mounted to the backing plate. All, however, in a general sense, accomplish the same results. The adjustment is divided into two phases; minor and major. When the friction material wears or disseminates due to the extreme temperatures, the clearance between it and the drum increases, thereby requireing too much travel of the foot pedal to cause the shoes to expand sufficiently to contact the drum. Some means is provided in all systems to limit this clearance. The means of applying brakes will govern the location of this adjustment. This adjustment is considered minor.

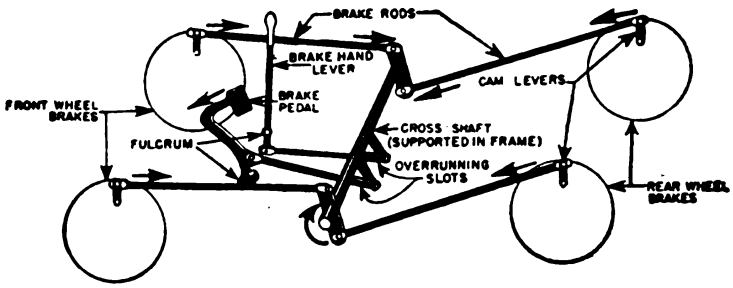

Figure 97. Mechanical Brake System With Single Cross Shaft.

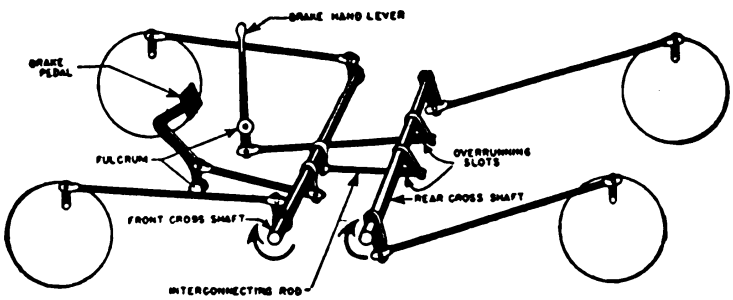

Figure 98. Mechanical Brake System With Two Cross Shafts.

The shoe, itself constituting a second class lever,* will have a varying amount of movement throughout its length. This is particularly true in the two-shoe, two-anchor pin type. For this reason there has to be some means of moving the anchor in its relation to the drum, either toward or away, in order to have the shoe contact the drum over its entire length. A rule of thumb in making this adjustment would be to have one half as much clearance at the anchor end of the shoe as you would have at the opposite end. In order to be absolutely correct. the maintenance manual of the particular vehicle would have to be consulted. The anchor adjustment is considered major.

The desired effect from a braking system is to have sixty percent of the effort on the rear wheels, in as much as most vehicles are designed to take about that precentage of the weight on those wheels. This can be done by exerting more force on the same size shoes. This is the case in some hydraulically operated brakes.

A further breakdown of the types of service brakes can be made in respect to the nature of the power used to expand the shoes. The Army vehicle uses one of four means:

* A second class lever is one in which the fulcrum is at one end and the force is at the opposite end; the resistance being between them. An example would be a wheelbarrow.

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MECHANICAL BRAKES

Mechanical brakes were the original means of expanding the shoes to contact the drums and were used by some manufacturers until recent years. However, with the development of the other systems, mechanical brakes have been gradually outmoded. The foot pedal was connected by steel rods and pivots to a centrally located cross-shaft. From this cross-shaft, by suitable arms and rods, the connection was formed with each of the wheels. Thus, by mechanical linkage only, the brakes were energized.

Many variations of this system have been created, such as substituting steel cables instead of the conventional rod and various mechanical means of equalizing the pressures to all of the wheels. To adjust this type of brake, turnbuckles are usually provided on one end of each rod.

Periodic inspection of all the linkage should be made to prevent binding and 'freezing' of the parts and connections. It is also essential to keep the parts free from dirt and other foreign matter.

HYDRAULIC BRAKES

In understanding hydraulic brakes, it is necessary to keep two laws of physics in mind; the first being Pascal's law stating that "an external force exerted on a confined liquid is distributed equally throughout the liquid in all directions upon equal areas," and the second that "for all practical purposes, a liquid cannot be compressed." A hydraulically-operated system consists, basically, of a pump and a sufficient number of cylinders for each wheel of the vehicle.

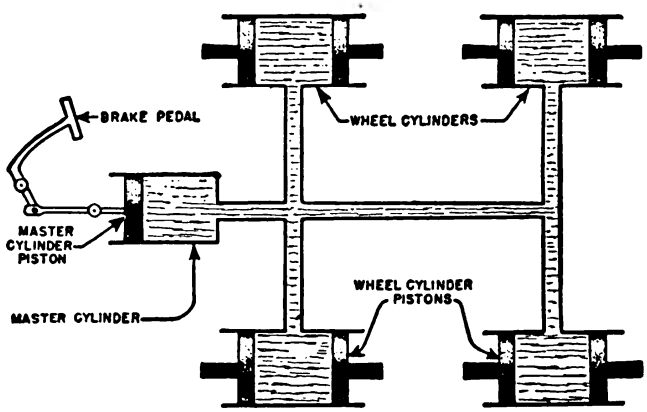

Figure 99. Diagram of Hydraulic Brake System.

A master cylinder or pump is located at the brake pedal, accessible to the driver. Within the pump, through leverage, we exert the force that is transmitted through the liquid within the lines to the cylinders at each wheel; there to be converted into mechanical force to expand the shoes.

Master Cylinder. Mounted directly over the power chamber of the master cylinder is a reservoir which carries sufficient fluid to assure proper operation of the braking system. It is filled through a hole at the top and is sealed with a removable filler cap containing a vent. The vent allows for expansion and contraction of the fluid.

The power chamber is connected to the reservoir by two ports, the larger referred to as a breather port through which the system is fed. The smaller is referred to as a compensating port, through which excess fluid within the system returns to the reservoir. Within the power cylinder there is a piston similar to a spool that has, resting against its forward end, a rubber seal known as a primary cup. The primary cup is so constructed that any movement forward of the piston utilizes the pressures created to form a perfect seal. The breather port enters the chamber to the rear of the piston head and the compensating port just to the front of the piston head so that the first movement of the piston will close it off from the chamber.

Covering the outlet of the chamber is a check valve which is held on its seat

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by a piston return spring. Upon application, the pressure developed forces the liquid through the one-way valve and out to the brake lines leading to the wheel cylinders. In order to seal the space occupied by the piston from the atmosphere, a second rubber cup or seal is installed on the rear end of the piston itself; thus, the fluid present around the spool-like portion of the piston cannot escape to the atmosphere.

Upon release of the brakes, a pedal pull-back spring returns the pedal and operating rod to its normal position. The force of the retracting springs on the brake shoes forces the liquid through the lines to the master cylinder, and with the aid of the piston return spring, forces the piston back to its 'at-rest' position. Due to the one-way arrangement of the valve, in order for the liquid to enter the power-cylinder on its return, it has to compress the piston return spring and enter the cylinder between the valve cage and its seat. Therefore, the strength of this master cylinder spring is at all times resisting the motion of the fluid on its return and will retain a corresponding amount of pressure within the lines.

The strength of this spring tends to return the piston faster than the fluid is returning to take its place, thereby creating a momentary vacuum at the forward end of the piston. In order to allow this piston to travel at a faster rate, drilled passages are made through the head allowing the fluid which surrounds the piston to be forced through the passages and around the primary cup, thus relieving the vacuum. In doing this, more fluid is taken in the system than is necessary for an application. This excess fluid, as before stated, passes through the compensating port to the reservoir as soon as the primary cup passes to the rear of this port.

Wheel Cylinders. The wheel cylinders are sealed by the use of two opposing pistons which use rubber seals or cups similar to the primary cup of the master cylinder. The lines leading from the master cylinder enter the wheel cylinder between these two cups, so that any fluid entering will tend to force the two pistons in opposite directions. Usually, the cups are held against the head of the pistons by a coil spring. This type of cylinder is adaptable to the 2-shoe 2-anchor type of brake, though they are sometimes used on the single anchor type.

In order to compensate for the difference in braking effort of the two shoes, a larger piston is sometimes used for the secondary shoe.

Adjustments. There are two ways in which the minor adjustment is accomplished in the hydraulic system. One is by way of a cam that backs up the shoes in their released position. The cam, being fastened to the backing plate, can vary the distance that the shoe can travel on its release by varying the position of the lobe that makes the contact. By using this method, the system takes on additional fluid to compensate for the distance that the shoes move outward. The second method is by threading an adjusting screw into the metal end cover of the wheel cylinder. Threading the screw in or out will vary the clearance between the shoe and drum. The pistons of the wheel cylinder rest against the end covers at all times, therefore, there is no need of additional fluid to enter the system.

The major adjustment is accomplished by making the anchor eccentric. Because the anchor is mounted on the backing plate, any rotation will either lower or raise the shoe.

AIR BRAKES

Air operated brakes differ from the hydraulically operated in that the force necessary to actuate the brakes is stored and the degree of application has to be controlled by metering the amount of air that is to apply the brakes. This type of system is only used in the heavier vehicles.

A compressor is mechanically connected to some rotating member of the engine and forces the air into one or more reservoirs where it is stored until such time as a brake application is necessary. From the reservoir the air is piped to a unit called a brake valve that controls the brake operation by directing the flow of air to the brake chambers during brake application and from the brake chambers to the atmosphere during release.

The amount of air allowed to go to the brake chambers corresponds to the distance that the brake pedal is depressed. The amount of air that is directed

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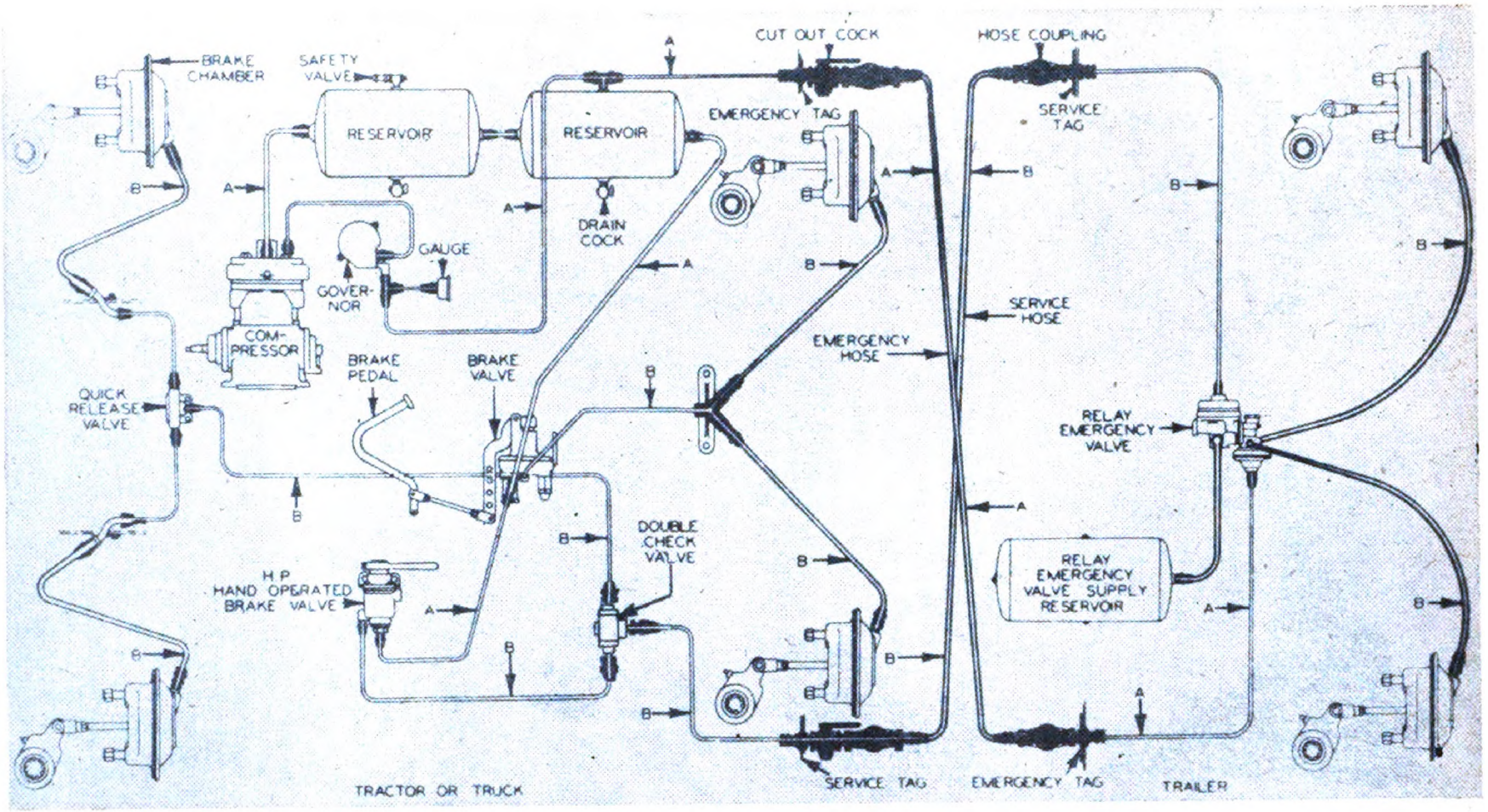

Figure 100. Air Brake System (Westinghouse).

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to the brake chamber is governed by the use of spring pressure balanced with air pressure on opposite sides of a metal diaphragm.

Because the compressor is mechanically connected to the engine, a means of starting and stopping it has to be provided. This is done by the use of unloader valves that are actuated by the pressures released by the governer.

The governor operates on the principles of the Bourdon tube. Reservoir pressures exist within the tube at all times. By adjusting the tension in the tube we can determine the amount of pressure required to straighten the tube sufficiently to open a passageway that leads to the unloader valves. As soon as the pressures are released to the unloader valves, and they are actuated, a passage is opened between the two cylinders of the compressor. The air within the compressor then oscillates from one cylinder to the other; none is allowed to enter the reservoirs.

When the pressure drops below a predetermined figure the tension within the Bourdon tube again closes the valves and vents the air actuating the unloader valves into the atmosphere. At this time the compressor again starts to compress the air, forcing it into the reservoirs.

We know that air pressure is controlled by volume to a great extent. In order to speed up the release of the brakes, a quick release valve is installed between the brake valve and the front brake chambers, so that only the air in the line between the quick release valve and brake valve is exhausted to the atmosphere through the exhaust valve of that unit. Upon application, the pressure released through the brake valve closes a spring loaded valve in the quick release valve and holds it closed as long as the pressure on that side exists. Upon release of that pressure, the air within the brake chambers forces the valve in the opposite direction, venting itself into the atmosphere.

The brake chamber is a unit devised to change air pressure into mechanical force. It is constructed of two dished metal halves that are separated by a flexible diaphragm. One side of the diaphragm is a confined chamber into which the air enters, the opposite side has a coil spring that keeps the diaphragm forced toward the air chamber side at all times. A metal push rod is attached to the spring side of the diaphragm and in turn connected to a slack adjuster. Because the slack adjuster is splined to a cam shaft (which is inserted between the two shoes within the brake drum), it will change the lateral movement introduced by the brake chamber and the push rod into the rotary motion necessary to apply the brakes.

Due to the distance between the brake valve and the rear wheels, a relay valve has to be installed in order to have all the wheels apply the brakes at the same time. The operation of a relay valve is similar to that of the brake valve's substituting in place of the spring pressure on top of the diaphragm the pressures that are regulated by the brake valve. Reservoir pressure is present in the lower chamber of the relay valve at all times and needs only the presence of the regulated pressures of the brake valve at the upper chamber to release it to the rear wheel brake chambers. Therefore, the pressures directed to the rear wheel brake chambers through the relay valve will be corresponding to the pressures directed to the front wheel brake chambers through the brake valve. A means of quick release is incorporated within this unit.

These basic units plus the necessary tubing are all that are required to make a satisfactory braking system. However, for trailed loads, additional units must be placed on the trailer. They usually consist of the conventional brake chambers for each wheel, a reservoir, and an emergency relay valve. The emergency relay valve operates on the same principles as the relay valve of the tractor or prime mover and incorporates two additional functions; charging the tractor reservoir and making an emergency application in case of a break away from the prime mover.

Various other units are found in a typical air brake system to insure safety and ease of operation. Some of these units are listed below:

1. A hand-operated brake valve that is used to actuate the trailer brakes only.
2. A pressure gauge mounted on the dash that registers reservoir pressure.
3. A stop light switch that is connected to a line that has pressure in it only when the brakes are applied. That pressure acting on a diaphragm closes a circuit.
4. A safety valve that is a spring loaded valve within the safety limits of the

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tank or reservoir, and mounted on the reservoir, so that in case the compressor continues to force air into the reservoir after the maximum operating pressure is obtained, this valve will be opened before the limit of the reservoir is reached.

5. A low pressure indicator that is a warning signal or buzzer and comes into operation when the pressure is lower than the safe limit. A certain pressure is required to apply the brakes with sufficient force to stop the vehicle without load. When this pressure is reached, it will open the electrical circuit that connects the buzzer.

The adjustments necessary on an air operated system are primarily the same as on any other system. The slack adjuster is so constructed that the position that the arm comes off the shaft can be changed to suit the required positioning of the cam. The position of the cam determines the amount of clearance of the shoes. The adjustments of the governer limiting the pressures of the reservoirs, and the range within which the compressor will not be doing work, pertain only to the air brake system.

Specifications can be found in the maintenance manuals or in the Westinghouse manual on air brake systems.

VACUUM BRAKES

In order to understand the principles upon which vacuum brake systems operate, it is necessary to know what a vacuum is and the extent that it can be used.

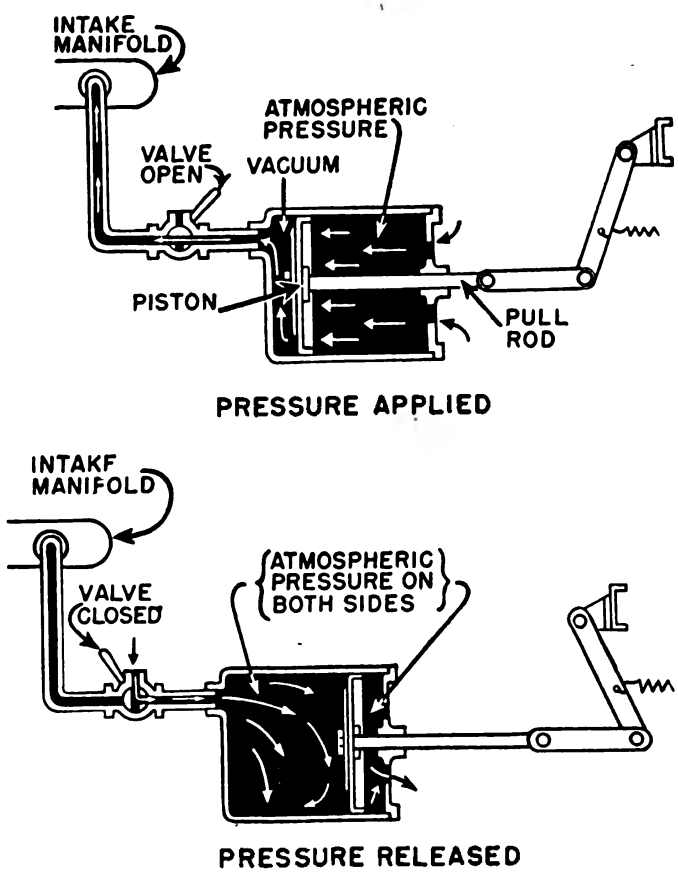

Figure 101. Action of Vacuum Power Cylinder.

Vacuum can be defined as a space from which air or gas has been partly exhausted. Air, like matter, has weight. Since air extends upward from sea level for several miles, the weight of this air exerts a pressure termed 'atmospheric pressure' at sea level of about 15 lb./sq. in. This pressure is equally distributed in all directions upon all objects on the earth's surface.

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This atmospheric pressure can be used to operate brakes by creating a vacuum on the opposite side of a piston within a confined cylinder. Within the internal combustion engine, a vacuum is created in the intake manifold by the pumping action of the pistons. This vacuum is greater when the vehicle is not being accelerated. In the average engine the pressure within the intake manifold is reduced to approximately 5 lb./sq.in. at this time. The brakes are rarely applied at any time other than when the engine is not being accelerated, therefore, the difference between atmospheric and manifold pressure is about 10 lb./sq. in. This 10 lb./sq. in. is the pressure used to apply a vacuum brake.

In the figure referred to, a simple diagram showing the effects of this pressure in both the applied and released position is shown. This pressure can be used as the sole force applying the brakes or it can be used as a booster to the mechanical linkage of a braking system.

There are two ways that the control of the system is accomplished. In one, known as the vacuum suspended system, a vacuum is created on both sides of the piston and the amount of air the atmospheric pressure forces into one side is controlled. The other means is atmospheric suspended in which the degree of vacuum the engine is allowed to establish is controlled.

The vacuum suspended system is becoming the more popular because atmospheric pressure exists at all times on the outside and can be easily metered. In the atmospheric suspended system, it is necessary for the engine to create the vacuum after the brakes have been applied. Along these same lines, the vacuum suspended system allows one brake application after the engine has stalled.

One popular means of utilizing vacuum pressures to augment or boost brake application, is the vacuum suspended 'Hydrovac' (trade name).

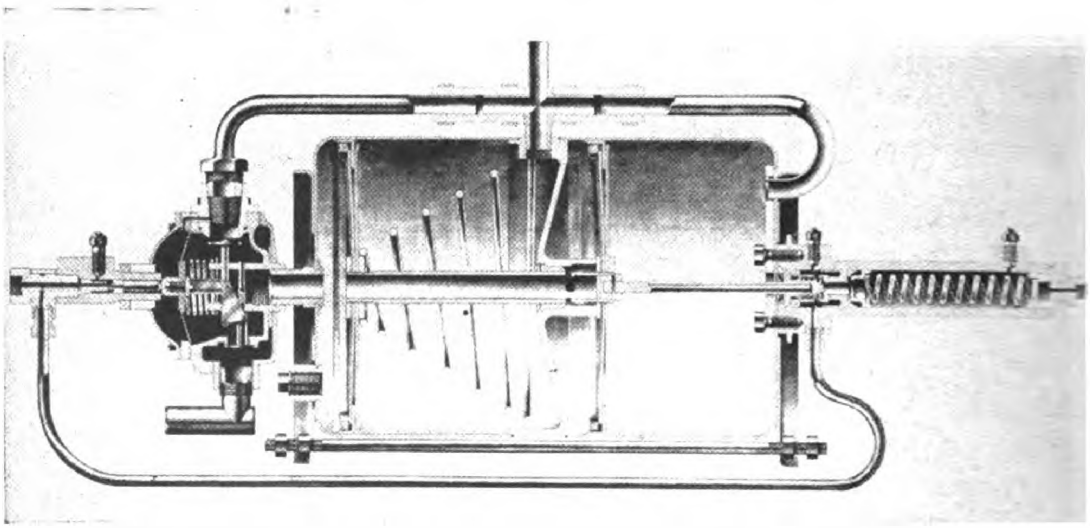

Figure 102. This View Shows the Inside Working Parts of Hydrovac (1st Series Unit.) From this Picture it is Easy to Distinguish Three Basic Units; Namely the Power Cylinder (Center) the Control Valve (Left) and the Hydraulic Slave Cylinder (Right).

It is a one unit power braking device used in heavier vehicles with hydraulically actuated brakes. Unlike some vacuum boosters, there is no linkage attaching it to the brake pedal. Connections to the vehicle braking system are entirely hydraulic.

The hydrovac is divided into four parts:

(a) A hydraulic adapter that converts hydraulic pressure to mechanical force.

(b) A relay valve that is actuated by the mechanical force resulting from the hydraulic adapter and which controls the operation of the atmospheric valve and the vacuum valve.

(c) A power cylinder that contains two pistons hooked in tandem so as to increase the area upon which the pressure can be exerted. A piston push rod

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is attached to the pistons and extends into the slave cylinder. A coil spring forces the pistons toward the released position at all times.

(d) A slave cylinder similar to the master cylinder of the hydraulic system, except that the push rod coming from the power cylinders actuates the piston.

The entire system is vacuum suspended. By that it is meant that all of the chambers in the power cylinder and relay valve have vacuum pressures present when the unit is not in use.

When motion is put into the pistons of the hydraulic adapter, they impart motion to the linkage that operates the valves. The valves in turn allow atmospheric pressures to enter on one side of the two power pistons, moving them toward the slave cylinder. The push rod in turn transmits this force to the piston and fluid within the slave cylinder and on out to the wheels.

The amount of air allowed to enter these cylinders regulates the amount of force the unit will produce. Therefore, the pressures built up by the hydrovac will be proportionate to the pressures developed in the master cylinder.

The unit does not constitute a hazard even though it fails to operate. Provisions are made within the slave cylinder to allow fluid to pass through it in case the power cylinder fails.

A simple check to determine whether the unit is being actuated is to apply the brakes with the engine not running and then start the engine. If the vacuum set up by the engine is allowed to activate the piston, a fading-away of the foot pedal will be easily noticed.

ELECTRIC BRAKES

Though this type of brake is not used on any of the Army self-propelled vehicles, it is used on some trailed loads, particularly the artillery pieces.

A description of a typical unit is as follows: A controller is mounted somewhere accessible to the driver of the vehicle; this unit will vary the amount of current allowed to go to the magnet from the battery. The brake itself is essentially a simple mechanical brake, actuated by an electro-magnet. A magnet is

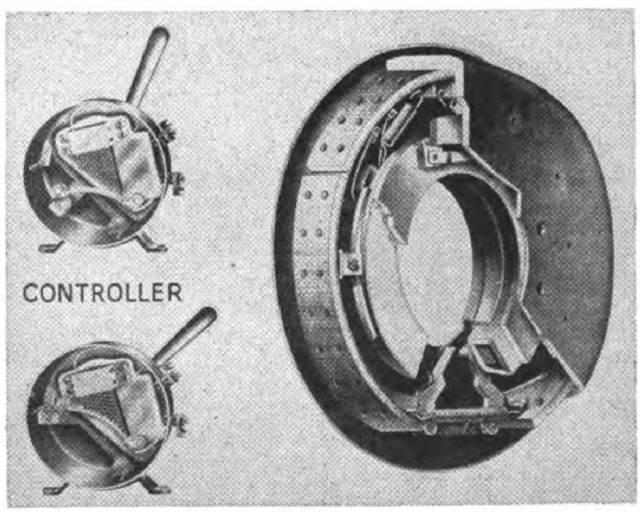

Figure 103. Sectional View of Electric Brake.

mechanically fastened to the axle housing and has limited movement. An armature is bolted to the brake drum and revolves with the wheel.

As the regulated flow of current from the controller flows through the magnet, the magnet is energized and clings to the revolving armature. This causes the magnet to move in the direction of rotation. A lug attached to the magnet contacts one end of the brake band, forcing it against the drum.

This type uses a continuous flexible band; therefore, a greater surface upon which to generate heat is present.

Another advantage of this brake is that the faster the wheel is rotating, the greater the application. Also, the self-energizing action is throughout the entire length of the shoe.

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Adjustment is not necessary; however, limiting the amount of travel of the magnet will limit the amount of lining that can be used.

PARKING BRAKES

Parking brakes normally are located in the rear of the transmission and may be of the drum or the disc type. The drum type is external contracting and the operation of a hand lever forces the non-rotating unit to contract around the drum with sufficient force to make it immovable.

The leverage actuating this type of brake can be either single acting or double acting. The single acting only employs the self-energizing action with the drum rotation in the same direction of pull. The double acting will give self-energizing action in either direction.

The disc type employs the same principles involved in the construction of a clutch in that we have a rotating member being clamped securely between two non-rotating members.

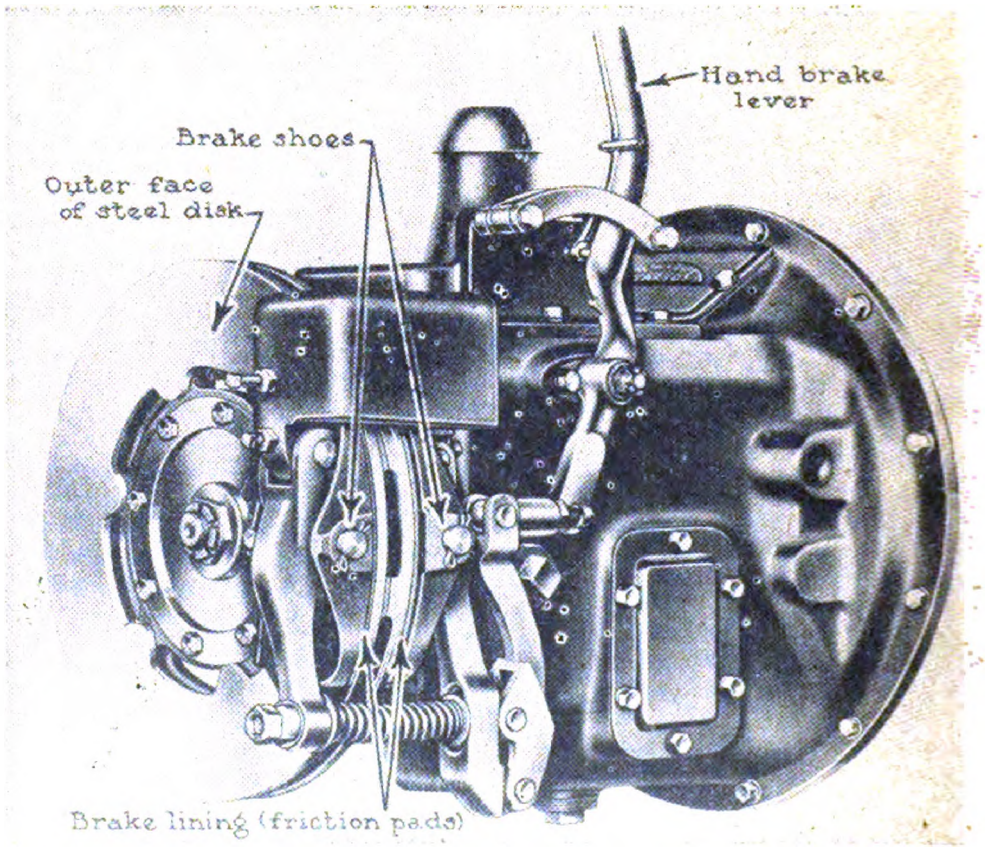

Figure 104. Transmission Brake, Disc Type.

Both of these brakes are of no value as service brakes because of their vulnerability to sand, oil, water, and other damaging elements.

A portion of the existing service brake can also be used as a parking brake by the use of a mechanical means of expanding the brake shoes, usually of the rear wheels only.

STEERING GEARS

The steering gear is the mechanism through which we position the wheels. There are four types used in the automotive industry at the present time.

WORM AND SECTOR TYPE

The worm and sector steering gear consists of a worm, or exaggerated screw, that has meshed with it a segment of a gear which is an integral part of a shaft. This shaft is commonly known as a cross shaft. By establishing the worm so

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that its lateral motion is limited or confined, any rotary motion of the worm will impart rotary motion to the sector and sector shaft. An arm (steering gear arm)

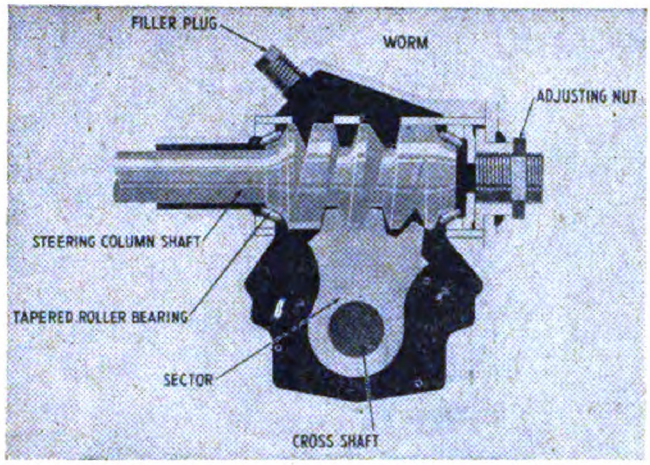

Figure 105. Worm and Sector Steering Gear.

splined to the opposite end of the sector shaft, and at right angles, will convert this rotary motion into a backward and forward motion. This series of mechanical connections is the basis upon which all four of the steering gear types operate. The mechanical advantage is limited by the pitch of the teeth of the worm.

WORM AND ROLLER TYPE

The worm and roller deviates from the pattern set by the former type only in that it mounts a grooved roller on bearings to take the place of the sector, so as to eliminate as much as possible the sliding friction between the teeth. In this

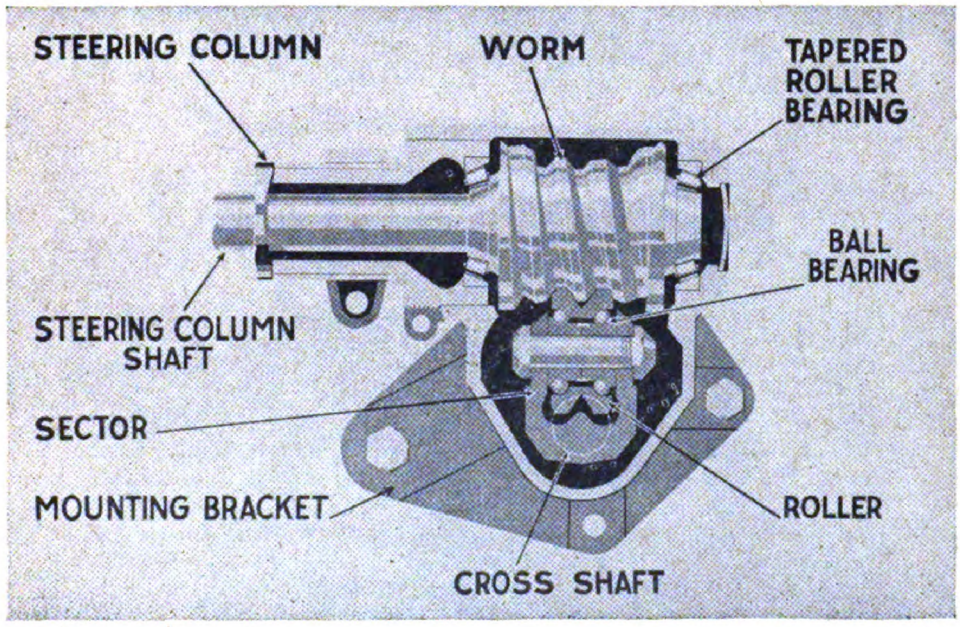

Figure 106. Worm and Roller Steering Gear.

design, the designers were confronted with the problem of the roller leaving the worm as the sector shaft rotated, because there was only one point of contact with the worm. This problem was met by shaping the worm like an hourglass.

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CAM AND LEVER TYPE

The cam and lever and cam and twin-lever use the same principles in different designs. Instead of having the worm or cam mesh at the bottom, as in the case of the aforementioned types, a stud attached to a lever engages it on the side. The same relative motions are present.

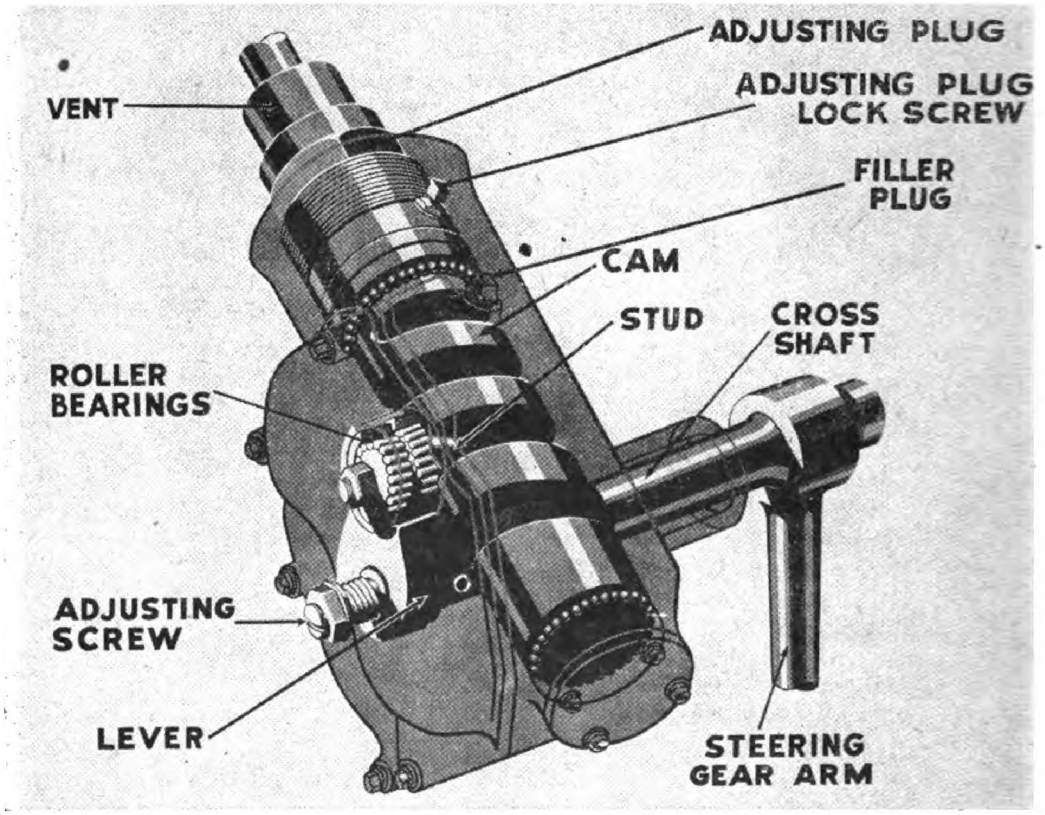

Figure 107. Cam and Lever Steering Gear.

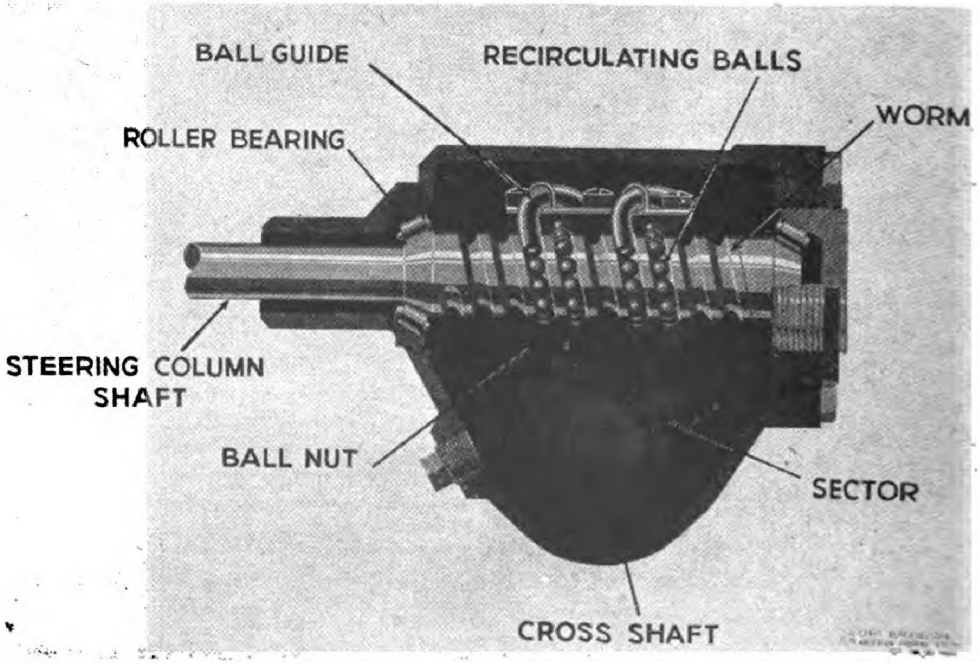

Figure 108. Worm and Nut Steering Gear (Recirculating Ball Type).

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RECIRCULATING BALL TYPE

The recirculating ball type, a development of the older worm and nut type, goes a step further in reducing friction. All of the force created by the rotary motion of the worm is transmitted through ball bearings within a nut. The nut then imparts power to the sector shaft. The worm and nut have corresponding races machined in them to house the ball bearings. The ball bearings in this manner are used as the threads by which the nut is moved in either direction.

In realizing that all of the control of the vehicle goes through the steering gear, you will note that proper relationship must be maintained between all of the parts. Along this line, there are three adjustments in all steering gears. They are; end play of worm, end play of cross-shaft or sector shaft, and mesh (backlash). They should be corrected in the sequence given. There are assemblies which incorporate a fourth adjustment. It is entirely a result of design and statistics can be found in any maintenance manual of the vehicle using this type of gear.

Due to the extreme pressures developed within the gear box, lubrication is of prime importance and therefore must have diligent care. The Ordnance Department has simplified this to some extent by standardizing the type of lubricant used in all gear boxes.

FRONT WHEEL ALIGNMENT

All army wheel vehicles are controlled from the left side of the front seat; consequently, the steering gear is mounted on the left side of the frame. The back and forth motion set up by the steering gear arm is transmitted to the left steering knuckle by the use of a drag link (steering gear connecting rod). A steering arm connected to the knuckle will cause it to pivot around its king pin (pivot pin), thereby changing the plane in which the wheels rotate in respect to the frame. The right knuckle is connected to the left knuckle by a tie-rod and will have corresponding motion imparted to it.

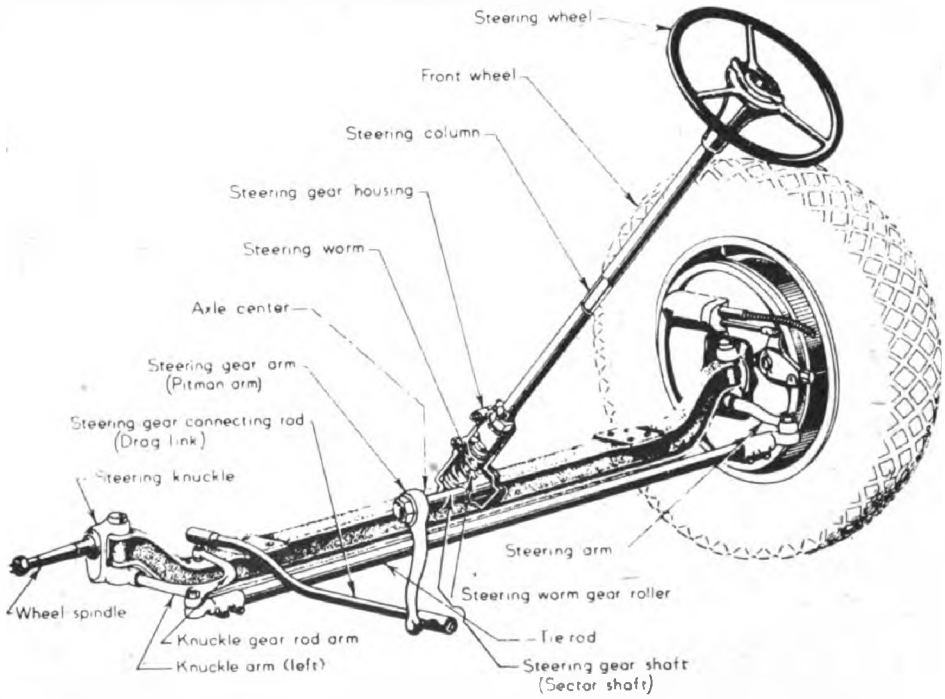

Figure 109. Diagram and Nomenclature of Complete Steering Mechanism.

This system of steering is known as the Ackerman system, and is the principle used for steering Army wheel vehicles. There are a few exceptions to the construction in some special types.

An improved Ackerman system has been developed to eliminate the scuffing of tires on a turn caused by the difference in length of the radius of the circle the two front wheels inscribe.

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Front wheel alignment in any vehicle using the improved Ackerman system of steering is one of the most neglected factors of maintenance. This is partly due to ignorance and partly because the adjustments are so minute that they are hard to accomplish in the field. The condition of the front tires and the manner in which they are wearing is undoubtedly the best way to tell the condition of the front end.

Under operating conditions the ideal is to have the wheels pointing straight ahead and vertical with the ground. In order to have this effective at normal operating speeds and loads, certain deviations have to be set into the mechanisms to compensate for load deflections and to absorb the tolerances of the various connections.

Front wheel alignment can be defined as "the mechanics involved in keeping the front wheels in proper relationship with each other and the rest of the vehicle." It embodies five separate and distinct factors; caster, camber, toe-in, pivot pin inclination, and toe-out or steering geometry.

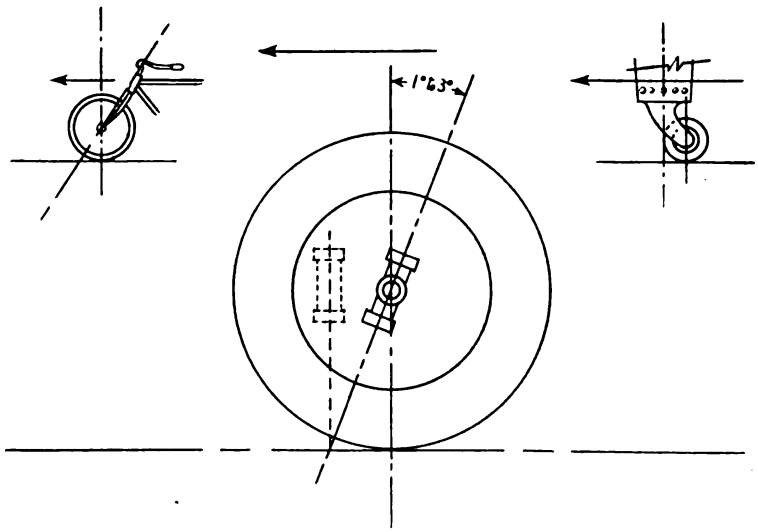

Figure 110. Castering or Trailing Resulting from Inclined Knuckle Pivots.

Caster. Caster is the number of degrees the axle is tilted from the vertical toward the front or rear of the vehicle. Positive caster is present in most vehicles, *i.e.*, the top of the axle is tilted toward the rear of the vehicle. With positive caster present, a line drawn through the center line of the axle will strike the ground ahead of the point of contact of the tire. This line is considered the load line and will give a trailing action to the wheels. Its prime purpose is to stabilize the steering in a straight ahead position. It also aids in returning the wheels after making a turn.

Camber. Camber is the number of degrees the wheels are tilted from the vertical, away from the center line of the vehicle. In other words, positive camber will cause the top of the wheels to be further apart than the bottom. Its purpose is to compensate for the load deflection of the metal parts and the tolerances set up within the bearing adjustment. Originally, road crown was a determining factor; however, it has now been so nearly eliminated that it no longer plays an important part.

Toe-In. Toe-in is the amount measured in inches that the front of the wheels are closer together than the rear of the wheels. Because of camber, the axes of the two wheels are not parallel and this introduces the tendency of the wheels to roll away from each other. Toe-in is introduced to off-set that tendency and also the load deflection in the horizontal plane.

King Pin inclination, as shown in Figure 111, is the number of degrees that the top of the pivot pin is inclined toward the center line of the vehicle from the vertical. Its purpose is to point the thrust of the load toward the point of contact of the tire. This will relieve the tendency to shear the pivot pin and distribute the weight evenly on the wheel bearings.

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Toe-Out, or steering geometry on turns, is the number of degrees more that the inside wheel turns in its relation to the axle than the outside wheel. This is necessary because the outside wheel inscribes a larger arc around a given center of rotation. The axle, being attached to the frame of the vehicle, cannot change its relation to that member, and therefore, the inside wheel of the ve-

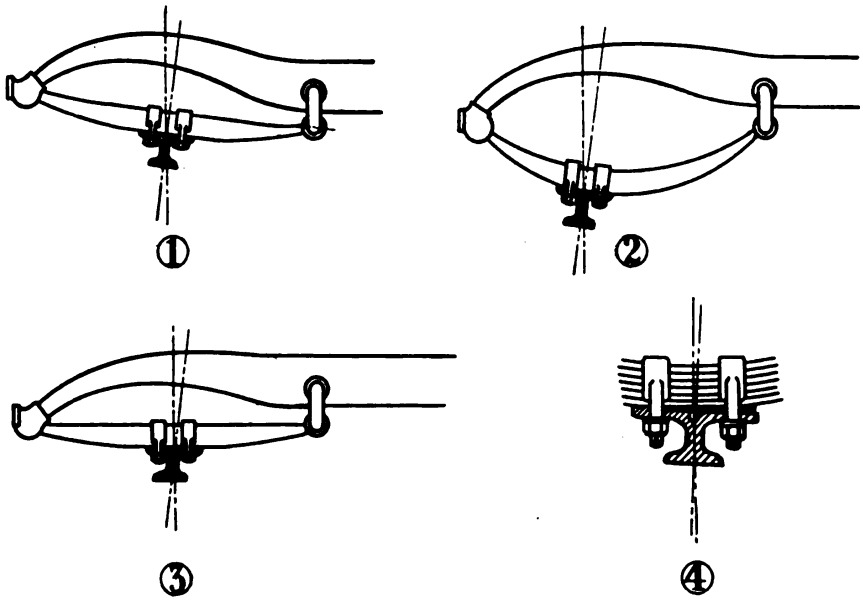

Figure 111. Method of Obtaining and Adjusting Caster.

hicle on a turn will be slightly ahead of the outside. This makes it necessary for the inside wheel to form a larger angle in relation to the axle in order for the spindle to point toward that common center. This is accomplished by form-

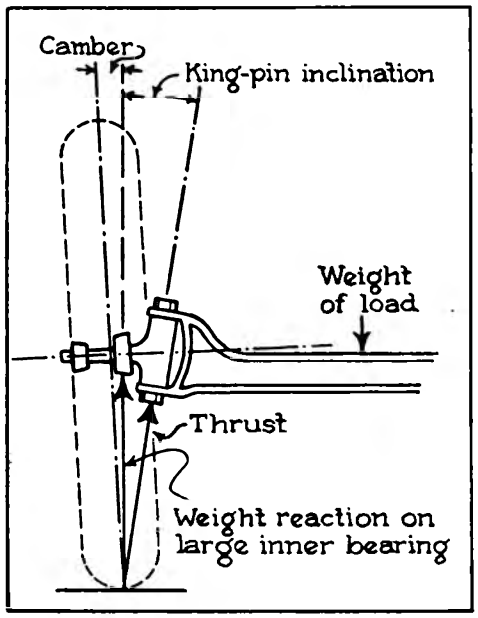

Figure 112. Camber and King Pin Inclination.

ing a trapezoid with the steering arms making up the short sides and the axle and tie rod making the other two. A rule of thumb to determine the amount that the steering arms are away from the parallel is to have them point toward the center of the rear axle housing.

The relationship of these factors, if properly understood, can be of unlimited

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value when steering defects are diagnosed. Each of the factors has a separate effect on the relationship of the spindle to the axle. When a corner is being turned, caster will tend to raise the spindle when it goes toward the front of the vehicle and lower it when it goes toward the rear of the vehicle, while pivot pin inclination will tend to lower the spindle in either direction. The result of combining these two features will be that the spindle that is moved toward the front of the vehicle will have opposing actions present and therefore will remain about level, while the spindle that moves toward the rear of the vehicle will have the combined actions put into it and tend to drop much lower than when just one factor is present. With this statement we refer to a vehicle with positive caster.

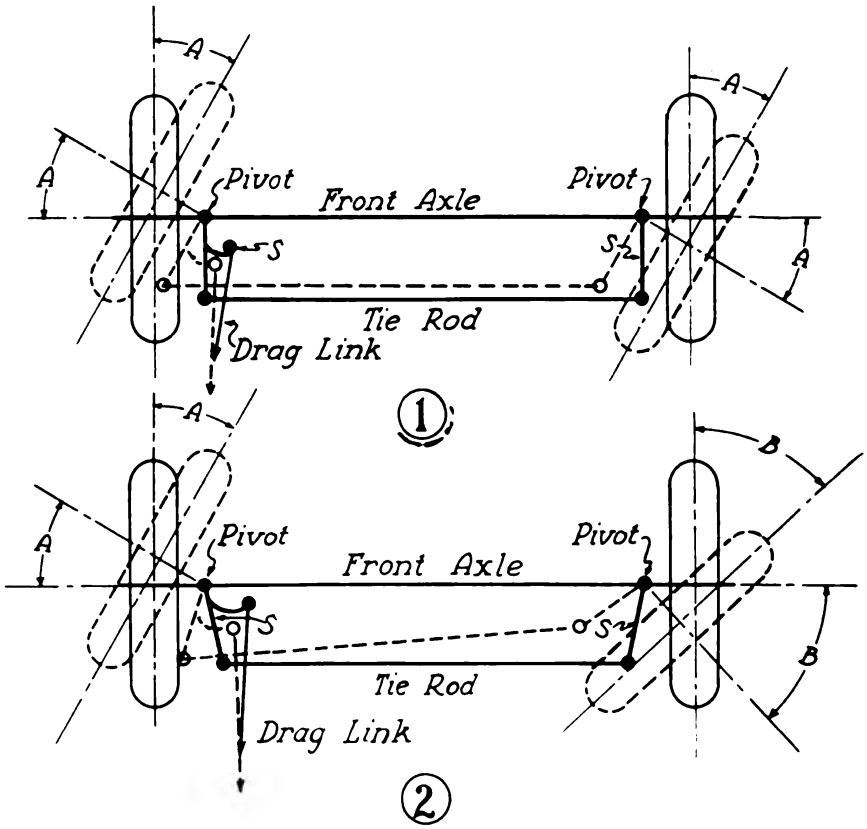

Figure 113. Angularity of Steering Knuckle Arms.

In relating the effects of caster and camber we have referred to the spindle either raising or lowering for simplicity of explanation. However, knowing that the distance between the spindle and the ground cannot change because of the wheel being mounted on it, reverse action will be put into the axle. That is, the spindle that tends to lower will in effect raise the axle and consequently raise the vehicle. This result is utilized in straightening the wheels after a turn in that the weight of the vehicle will try to find its lowest level and therefore force the spindle up the inclined plane to its highest level.

Due to these same reactions there will be an increase of camber on the inside wheel which will tend to brace the vehicle to offset the inertia that is trying to keep the body going in its original direction. Therefore, an increase in camber aids the vehicle in much the same manner as a person standing on a vehicle making a corner would aid himself by leaning in the direction of the turn in order to keep his balance.

Toe-in and steering geometry have their effects too, but they are in the horizontal plane only and have been discussed previously.

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TIRES AND TUBES

Tires may be one of three types; solid, cushion or pneumatic. Solid and cushion tires are still used to some extent on motor vehicles. Their principal use is on interior plant vehicles. Pneumatic tires are used extensively on military vehicles. They vary from the wide, thin wall, low pressure balloon type to heavy thick walled, high pressure, special purpose tires. In most instances air is confined to the inside of the tire by an inner tube, which, when inflated, conforms to the inside of the tire and rim. (This chapter will discuss only the types of tires used by the Army).

Military mobility depends upon tires. They must stand the most severe service; road shocks, cuts, moisture, and abuse. When a tire fails it may cause the failure of the vehicle, thereby putting out of action its load of troops or supplies.

A tire will wear through natural causes, but abuse and neglect will greatly hasten the ultimate failure of a tire. Proper maintenance, attained by a comprehensive understanding of tires and their care, will go a long way toward reducing tire wear, and thereby help to conserve rubber, one of the most vital of war materials. Proper maintenance can only be attained when all personnel using vehicles have a thorough knowledge of preventive maintenance procedures.

The term 'tire assembly' refers to the tire, inner tube, flap, and rim.

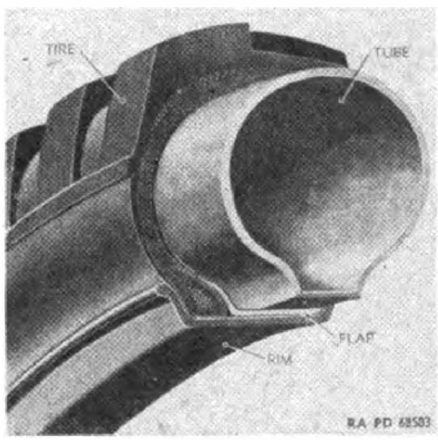

Figure 114. Tire Assembly on Flat Base Rim.

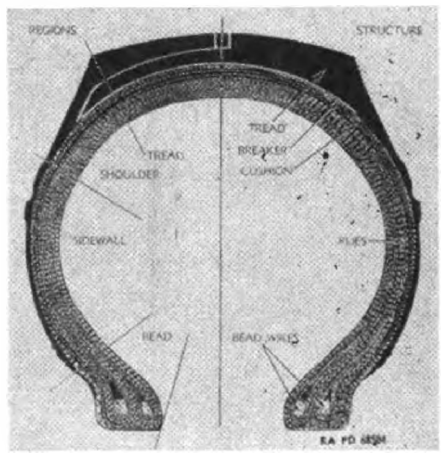

Figure 115. Cross Section of Tire.

Tire. Structural parts of a tire are the tread, breaker, cushion, plies, and bead. Each part of the tire serves a purpose:

(1) The *tread* is a layer of rubber on the outside circumference of the tire, and is the wearing surface. There are several types of tread designs used on military tires. A non-directional tread gives good traction in either direction in mud or snow, on dirt or temporary roads, and cross country. It is also practical for hard surfaced roads. A directional tread, when properly mounted, gives maximum traction in mud, snow, dirt roads, and cross country driving. A standard highway tread gives satisfactory traction on highways and delivers longer mileage than either directional or non-directional.

(2) *Breakers* are layers of rubber covered cords, similar to plies, except that the cords are spaced further apart. They are designed to distribute road shocks and to prevent separation of the tread from the carcass.

(3) The *cushion* is of soft, heat resisting rubber. It absorbs road shocks and bonds plies and breakers together.

(4) *Cord plies* give strength to resist internal pressure, to support loads, and to absorb shock.

(5) The *bead* is that portion of the tire which contains the steel wires and which comes in contact with the rims. Its function is to hold the tire on the rim.

Inner Tube. Another part of the tire assembly is the inner tube. It is a continuous, circular, rubber container that fits inside the tire and holds the air which supports the vehicle. Tubes will stand only a few pounds of air pressure

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when not confined in a tire. This same tube will bear extremely high pressure when enclosed in the tire. The tube may be easily chafed, pinched, or punctured because it is constructed of comparatively soft rubber.

Three types of tubes are used by the Army. They are:

A. The standard tube which is constructed of one layer of molded rubber. This type is used in the standard type of tire.

B. Combat tire standard tubes differ from the standard tube in that they are smaller but with the same size markings. This is necessitated by the fact that the inside air space of combat tires is smaller. The tubes are marked 'combat' and should be used with combat tires *only*.

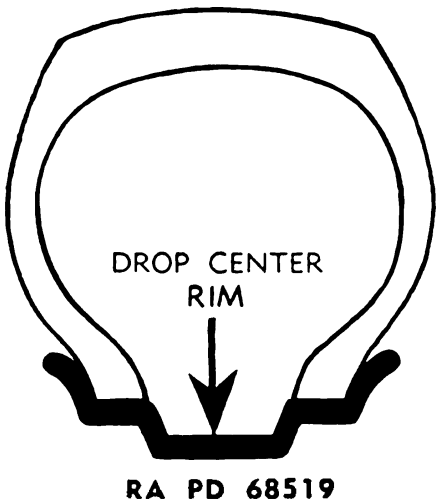

Figure 116. Drop Center Rim.

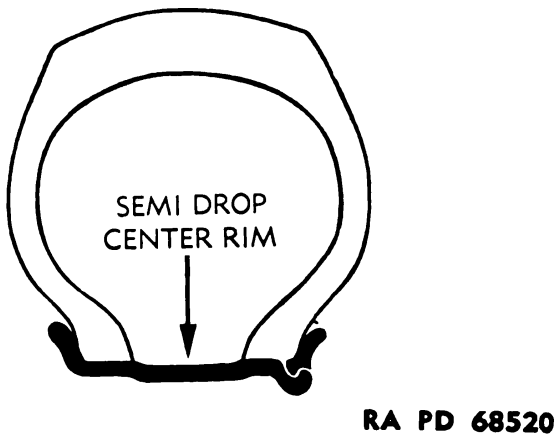

Figure 117. Semi-Drop-Center Rim.

C. Bullet-resisting tubes are easily identified by their excess weight and thickness. Generally the valve stems are painted green. The tubes are so constructed as to automatically seal bullet punctures.

The *flap* as shown in figure No. 115, is placed so as to protect the tube in the rim and bead area.

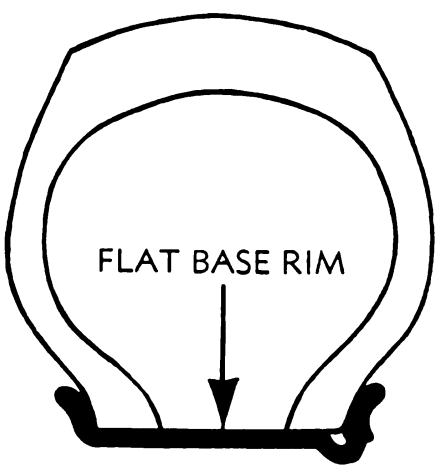

Figure 118. Flat Base Rim.

The *rim* completes the enclosure for the tube, holds the tire beads rigidly in place, and connects the tire to the wheel. In most instances rim and wheel are permanently fastened together as one unit and are bolted to the hub.

There are several types of rims employed on military vehicles. The drop center rim is made in one piece and is permanently fastened to the wheel. Its im-

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portant feature is a well which permits mounting and demounting of the tire. Drop center rims are generally used on smaller vehicles, such as passenger sedans and ¼ ton 4x4 trucks. Some passenger cars and light trucks are equipped with safety type drop center rims. Safety rims have a slight hump at the edge of the bead ledges which hold the beads in place when the tires go flat.

The semi-drop center rim and flat base rim are two other common types. The latter is generally fastened to the wheels while the former is always fastened. The flat base rim has a demountable side flange to permit mounting and demounting the tire. Flaps are required on the flat base rim to protect that part of the tube not covered by the tire.

A divided wheel and rim is used only on small vehicles. The sections are of equal width, fastened together with studs. The wheel is designed to accommodate continuous channel type bead locks. This type is designed for use with combat tires; however, conventional tires can be used when they have 'BL' molded on the side walls.

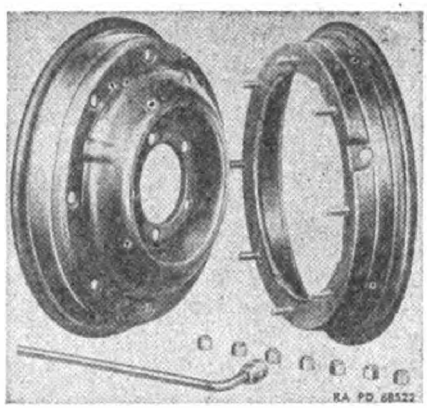

Figure 119. Divided Wheel for Small Vehicles.

Divided rims are used extensively on many types of vehicles. The two sections of this type rim are not of equal width. They are fastened together with studs or bolts. With this type rim, the tire is held in position by a hinged or segmental type beadlock. Divided rims are designed for use with combat tires, but standard tires can also be used.

In describing the build-up of a tire, the function of a bead was discussed. Utilizing the bead, another device is encountered which is called the 'beadlock.' It is a metal unit which fits between the beads of the tire, so that pressure can be applied by tightening the rim flanges against the outside of the bead. The beadlock is so constructed as to be slightly wider than the space between the tire beads when mounted on the rim. Therefore, a compression fit is obtained which locks the beads into place, so that slippage is prevented and the tire will remain in position. As can readily be seen, this is a necessity in combat in order to support the load when operating without air pressure.

There are several types of beadlocks which are identified as follows:

(A) Channel and hinged types; size and code number are branded near the valve hole.

(B) Segmental type; size and code number are stamped on rim side of each segment. The continuous or channel type is a solid band of steel which is easily inserted into position. Flaps are not required. The hinged type is adapted from the continuous type. It is fitted with a hinge which permits collapsing of the beadlock, thus permitting insertion. The segmental or spacer type has blocks of hard steel fitted on a flexible steel band. It can be collapsed for removal or insertion into the tire. It requires the use of the correct size and type of flap.

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THE COMBAT TIRE

Often during movement a tire will go flat for any of several reasons. Under ordinary conditions it is possible to stop and replace the deflated tire. However, under combat conditions it is often impossible to stop. Therefore, a tire has been designed and constructed to keep running for limited distances when completely deflated of air. Only one type of tire has this advantage; the combat tire. These tires are of much heavier construction and are more rigid than

Figure 120. Combat Tire.

standard tires. The body has more plies of fabric with a heavier, thicker cushion of rubber between plies. The inside of the tire has a heavy rubber lining which is an integral part of the tire. Combat tires are used generally on half track units, armored cars, artillery carriages, and other vehicles used in combat zones where a flat tire might result in loss of lives and equipment. Each combat tire is marked 'combat' on the side of the tire that shows the serial number.

SYNTHETIC RUBBER

Since the start of the war, the enemy has been in possession of a large percentage of the world's supply of crude rubber. Until the supply is retaken we must depend upon our stocks of crude rubber, which are rapidly being depleted, and on synthetic rubber. For some purposes synthetic rubber is superior to crude but for other purposes it is far inferior. To overcome some of the shortcomings of synthetic rubber the Army has promulgated all the available information pertinent to prolonging the life of the rubber. As an example we have learned that tires made of synthetic rubber will chip, cut, crack, and snag more easily than natural rubber. Daily inspections will enable the driver of the ve-

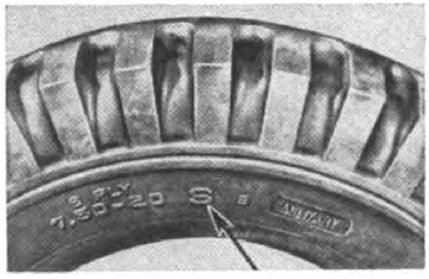

Figure 121. Identification of Synthetic Tires.

hicle to locate any break point of the tire. After locating the damage the tire should be removed and forwarded to a repair unit unless local repairs will suffice.

It is known that synthetic tires will generate heat more rapidly and as they do not have the ability to resist high temperatures as do natural rubber tires, failure results. To overcome this characteristic, lower speeds are mandatory.

In tubes, synthetic rubber has certain weaknesses. They tear easily when hot and are less resistant to chafing. A new hot patch has been developed for syn-

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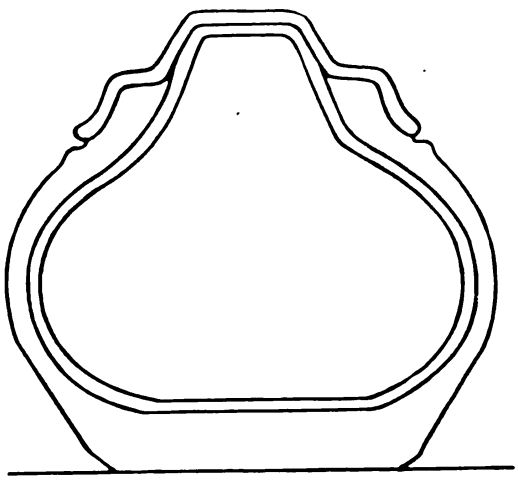
thetic tubes as the cold type patch used on crude rubber inner tubes will not hold in many instances. This patch has been given a Federal stock number. Each organization should maintain a stock. Thorough cleaning of the inside of tires and the outside of tubes plus an application of tire talc to allow free movement will prolong the life of the synthetic tube.

Natural rubber tubes will give very efficient service if properly cared for. Unless improperly inserted, punctured, or misused they seldom fail. Patches of all descriptions, hot or cold, are available for mending. Faulty valves and stems can be completely and easily replaced.

MAINTENANCE OF TIRES

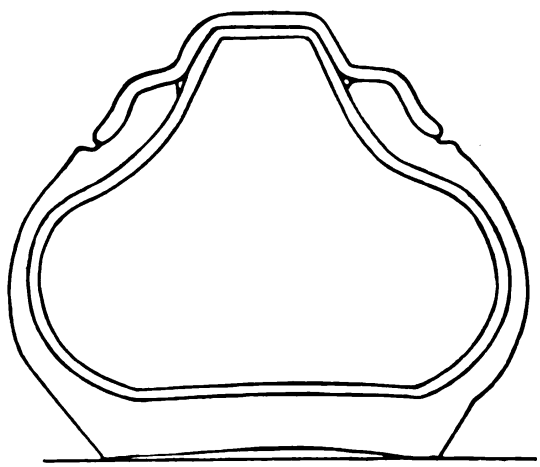
No two tires, though manufactured from the same material and specifications, will wear alike. The only conclusion that can be justified for the above statement is that road conditions are never identical even for tires on the same vehicle. Some conditions can and *must* be controlled to prolong the life of tires. Among them are such general operating conditions as proper air pressure, good wheel alignment, correct brake adjustment, careful driving to avoid sudden stops or rapid acceleration, avoiding of overload, and maintaining reasonable driving speed. Some conditions such as road obstacles and sharp objects which are hit before they are seen, are impossible to control.

In the following paragraphs elements that control tire life and which can be controlled will be discussed. The first, and perhaps the most essential element in reliable tire performance, is correct air pressure. When a tire is designed, the amount of air pressure that it is to carry has been taken into consideration. Therefore, if the tire is operated under other than specified conditions, it will not wear as long. Air pressure should be checked daily and corrected, if required, to the prescribed pressure. An accurate gage should be used at all times. All



RA PD 68547

Figure 122. Correct Air Pressure.



RA PD 68548

Figure 123. Underinflated Tire.

gages should be checked periodically with a precision type gage to assure correct readings. Never 'bleed' (let air out) of a tire during or immediately after operation. Tires heat as they roll; this heat causes expansion of the air and a subsequent increase in pressure. After a tire is bled and then cooled it will be underinflated. Remember that an underinflated tire does not carry enough air for its size and the load it must carry. As a result it will flex excessively and will generate heat. The heat will weaken the cords, eventually causing a blowout. The underinflated tire can be injured much easier and will wear unevenly. Conversely, an overinflated tire will not flex enough and will therefore be subject to hard jolts. When an overinflated tire hits a stone, curb, or other obstacle, a break in the cord body will probably result. It will also be noted that the center of the tire will wear excessively.

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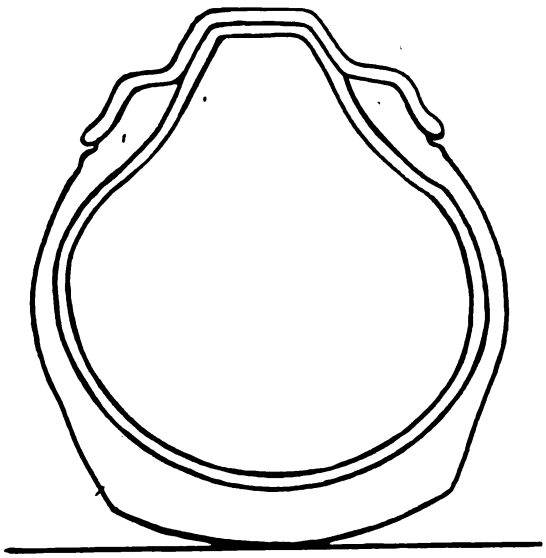
Equip all tires with valve caps. This will prevent dirt from entering the valve core and causing leakage. The cap also provides a final air seal.

Tires must be properly matched for longer tire life and more efficient performance. Dual tires and tires on all-wheel drive vehicles must be of the same size, tread design, and tread wear. Improperly matched tires cause rapid and uneven wear, and transfer case and differential failures. It must be remembered that tires on all-axle drive vehicles rotate at the same speed when all axles are engaged. Dual wheels are locked together and consequently turn at the same speed. It can be readily seen that any difference in tire diameter will result in uneven or rapid tire wear. Keep rotating the tires so that a different tire will be used as a spare tire at least once every ninety days. This is conducive to even tire wear on all wheels.

Wheel alignment is important in prolonging tire life. If a tire shows any sign of uneven wear, change it to a different wheel and investigate the cause. It may be improper toe-in, caster, or camber, wobbly wheels, sprung axles, faulty bearings, brake drums, brakes, or springs. To illustrate the importance of correct wheel alignment; a tire on a wheel ½ inch out of alignment is dragged sidewise 87 feet in every mile.

Speed is another factor causing excessive tire wear. In going around curves at high speeds there is a tendency for the car to skid. Only the tires can prevent skidding and this extra friction will obviously increase wear. Refer to the graph for the effect of speed on tire wear.



RA PD 68549

Figure 124. Overinflated.

Common sense should be a guide in your maintenance program. Instruct drivers to avoid sudden starts, jamming on of brakes, sudden acceleration, and driving which will in any way misuse the vehicle or any component part of the vehicle.

Don't overload the tires. Experience and tests indicate that with a 50 percent overload, tire wear decreases to only 40 percent of normal.

Remember, adequate inflation is essential at all times if satisfactory mileage is to be expected. Overload causes fast tread wear. Tread mileage is inversely proportional to temperatures, and high speed increases temperatures. Rotation of tires prevents uneven wear. 'Bleeding' tires increases flexing. These are but a few of the conditions and practices which vary tire wear.

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Figure 125. Duals are Same Size, Make, Tread Type and Have Same Amount of Wear.

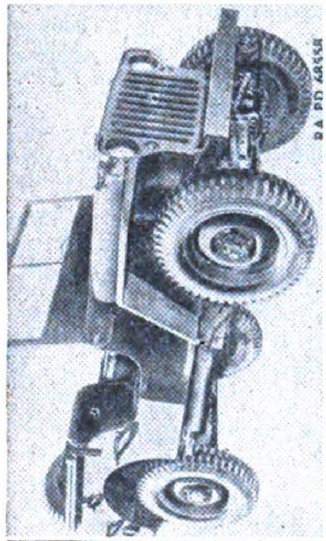

Figure 126. Tires are the Same Front and Rear.

Figure 127. All Tires Have Same Circumference.

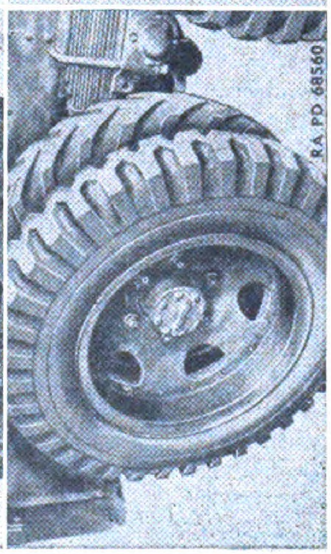

Figure 128. Different Type Tread Designs Should Not be Matched in Circumferences on a 4x4.

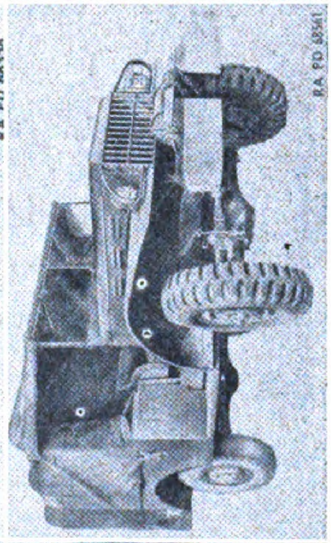

Figure 129. Different Amount of Wear on Tires With Too Great a Difference.

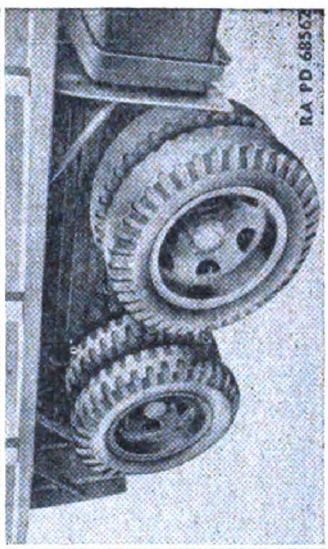

Figure 130. Different Amount of Wear on Tires on Rear Axle of 6x6.

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ENDLESS BAND TRACKS FOR HALF-TRACKS

The half-track vehicle was designed primarily for use where all-wheel vehicles cannot operate successfully and to carry heavy loads over rough or soft ground. Since more supporting surface touches the ground in a half-track vehicle, it has greater traction and floatation than a wheeled vehicle. Floatation is comparable to the use of snow shoes which prevent the wearer from sinking in soft, deep snow. Obstacles which an all-wheel vehicle cannot climb are easy for the half-track as the slant of the track between the sprocket wheel and front bogie wheels forms a moving incline plane which climbs up and over the obstacle. Wide

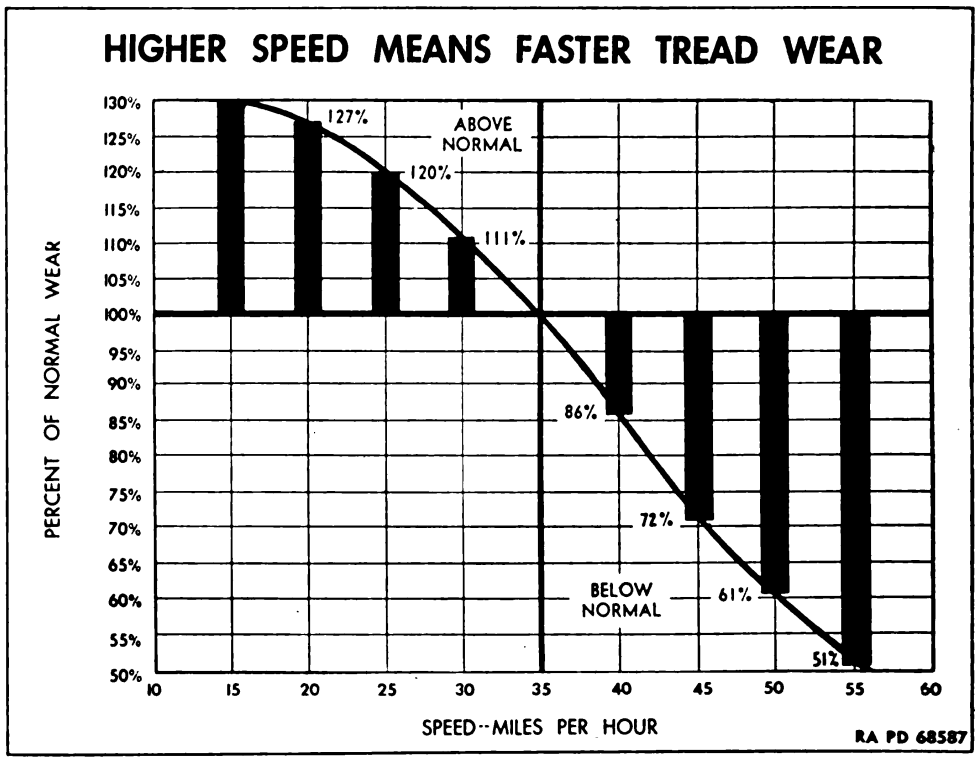

Figure 131. Graph Showing Effect of Speed on Tire Wear.

ditches can be crossed with the half-track because the track conforms itself to the uneven ground thus having the traction to roll the front wheels out of and over ground irregularities which would stall all-wheel vehicles.

The track assembly consists of the following:

1. The *track*, which provides road contact. It is an endless band constructed of lengths of steel wire cable insulated with rubber. Interlocking guides fastened to the center of the track hold it in position. Driving lugs engage the sprocket wheel.

2. The *sprocket wheel* drives the track. It receives its power from the engine via the rear axle.

3. The *idler wheel* supports and guides the track at the rear. It also provides a means of adjusting the track.

4. *Rollers* act as a support. Guide units have been discussed in more detail in other chapters.

Maintenance of Tracks. The most certain way to keep half-track vehicles running at their best and get the longest possible service out of them, is to take care of the preventive measures set up by the army.

Unequal wear sets up in the tracks with the right hand track tending to wear faster than the left. The most suitable method of correction is to use two left handed tracks or two right handed tracks from two different vehicles and mount them on one vehicle. If this is not possible, interchange the tracks.

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Tracks should be removed when the rubber on the 'ground' side has worn to the point where the cable or steel plates can be seen, or they are close to the track surface.

Always remove all oil or grease from the tracks as petroleum products tend to destroy rubber. When removing oil or grease inspect for stones, sticks and other foreign objects which may damage the track. During freezing weather never park a half track in water. It is difficult to loosen tracks once they are frozen in and it might damage the driving mechanism.

Do not forget the guides. Replace broken or badly bent guides immediately. More than three missing in a row may cause the track to jump off. Another malfunction which may cause track jumping is an idler wheel which is out of alignment. Alignment can be checked by measuring between the frame and the idler flange on the front and back sides of the idler. The idler should toe-out a maximum of 1/16 of an inch.

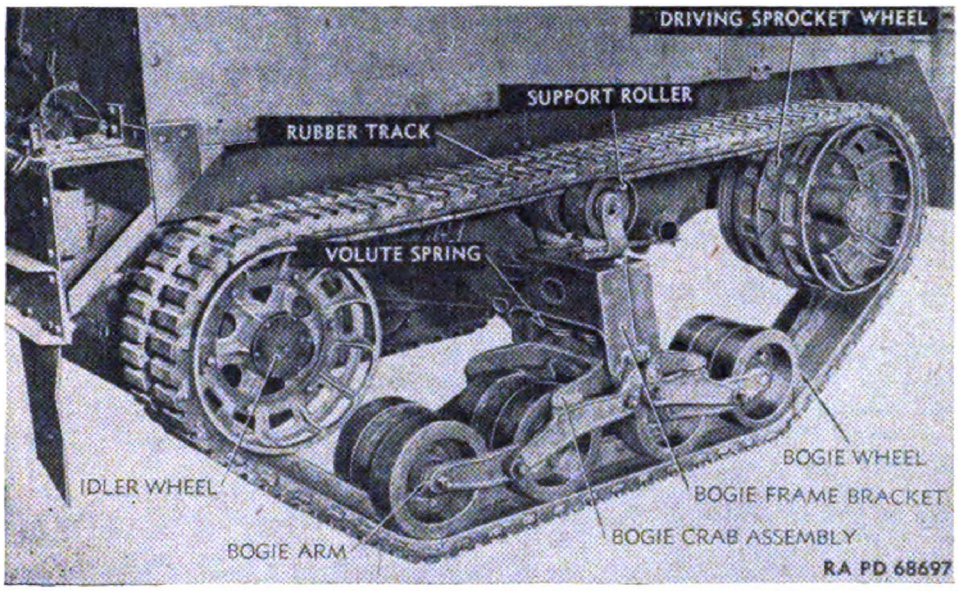

Figure 132. Track Assembly.

Another important adjustment is track-tension. A maximum of 1-inch and a minimum of ¾-inch sag are the limitations. Tracks set too tight act as a brake, cutting down on power and speed. A tight track will set up a strain on the rear idler and pull it out of alignment which in turn causes a thrown track. Another thing which may result from a too-tight track are excessive wear of sprocket teeth, driving lugs, guides, and guide nuts; the track will be strained and cracked and the rubber pulled away from the metal. Other units may fail as a result. Consult your T.M. for additional information concerning track adjustment.

To provide extra traction chains or grousers can be used. Never use either on a highway or solid ground. They are designed for use in snow or mud only. Chains should only be put on tracks having cross bars without hooked ends. Tracks having cross bars with hooked ends require grousers.

With the proper care and maintenance the track will give little difficulty and provide the vehicle with a most satisfactory traction device.

FULL TRACKS

The track-laying assembly on full-track vehicles such as the light or medium tank, consists of:

1. *Rubber track blocks* which provide wearing surface and traction.
2. *Bogie wheels,* which run on the track and support the vehicle.
3. A *driving sprocket wheel,* which revolves the track.

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4. *Support rollers.*
5. An *idler wheel* for adjusting tension.

The rubber block or shoe is vulcanized around a metal link or frame. Rubber bonded bushings, called 'doughnuts', pass through the block and are connected into an endless chain by steel end connectors, thus forming the track. The purpose of the bushings is to absorb twisting as the track flexes.

There are two general types of blocks used. One type has a smooth surface with the same construction on both sides. Another, the non-reversible type, is thicker on one side than the other, and may have a 'V' or 'I' shaped design for additional traction.

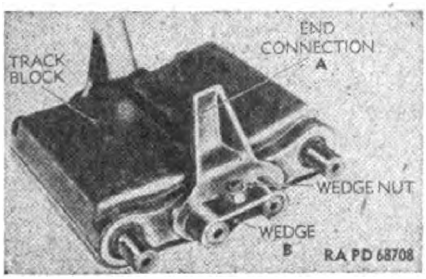

Figure 133. Track Block Assembly.

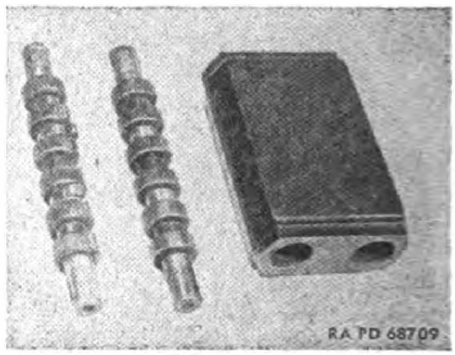

Figure 134. Rubber Bushing Assembly.

Maintenance. It will be noted that some tracks tend to wear faster on one end of the block than the other. If this occurs, reverse the direction of the track by turning it around or by mounting it on the other side of the vehicle.

Blocks of the track will gradually wear. On reversible tracks they should be turned over when the rubber on the wearing side is worn down to the extent that wear on the end links of the metal frames is imminent. If the rubber has cracked over the frame tubes so that separation from the frame tubes is about to take place (or has taken place) they again should be turned. The tracks should be replaced when the above condition has occurred on both sides of the track.

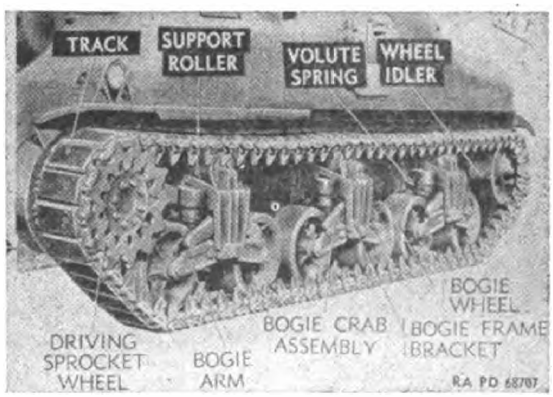

Figure 135. Track and Driving Mechanism.

Occasionally a block can be seen on a track which will rise up above the level of the same side of the other blocks when on the upper side of the track. This is termed a 'dead block' and should be replaced. This condition is caused by the doughnuts or bushings becoming separated from the pin.

There are a few precautions to take which will avoid major difficulties. Always remember that oil and grease affect rubber; therefore keep the tracks free from petroleum products. During hot weather avoid as much as possible continuous operation for long periods. Excessive heat can cause blocks or bogie

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wheels to 'blow' off. Inspect tracks for worn, broken, or loose end connections. Wedges, nuts, and sprockets should be checked for wear. The bottom of the wedge should be a specified distance from the connector face for correct adjustment.

Adjustment of the track to the proper tension will eliminate many maintenance problems. If too tight, it may damage the rubber blocks and bogie wheels, increase power loss, loosen track pin bushings, and result in support roller and idler bearing failure. A loose track may be thrown off, or it may whip or vibrate, in which case the connector lugs or guides may gouge the bogie wheel tires. Lag is measured by laying a straight edge on the track from roller to roller. Measure from the lowest sag to the bottom of the straight edge. For clearances, check the appropriate training manual.

ACCESSORIES

Power Winches

The proper operation and maintenance of power winches located on the front of Army vehicles or on the rear of recovery units can not be overemphasized. The winches are utilized to either recover the vehicle itself or to recover other vehicles that have been mired or disabled.

The winches, as discussed, will deal with those which are found on the Truck, Cargo, 2½ Ton, 6 x 6, and lighter vehicles. The principles utilized on these vehicles with minor exceptions would apply to the winches used on all types of Army vehicles.

The subject will be covered in the following sequence; familiarization, operation, cable precautions and service.

The winch on a military vehicle is a windlass that operates on power furnished by the vehicle's engine. It is geared in such a way that it can pull on a steel cable by winding it around a drum supported between the side rails of the vehicle's frame.

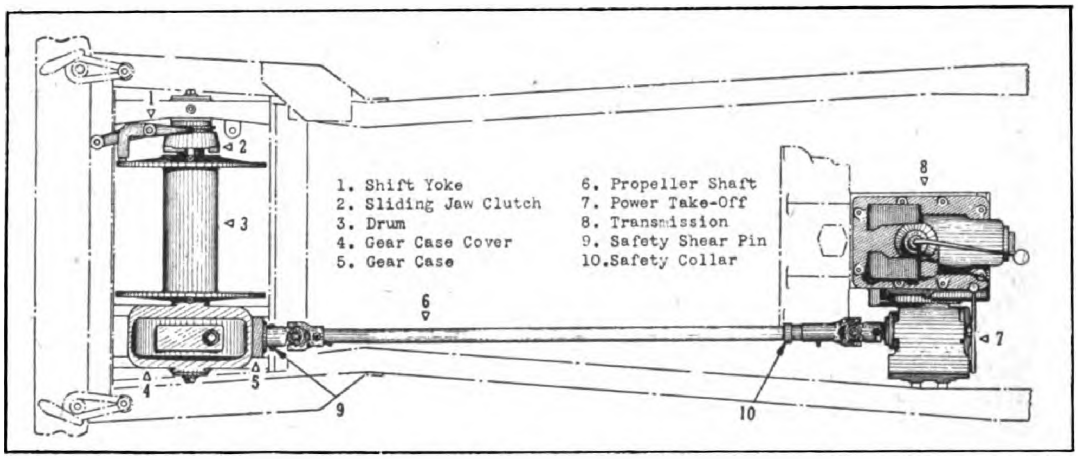

Figure 136. Winch and Power Take-Off Installation.

The power for operation of the winch comes directly from the engine, necessitating the utilization of an additional gear box or small auxiliary transmission located on the left side of the main transmission. This gear box is called a 'power take-off' or P.T.O., and receives its power from a positive connection to the main transmission of the vehicle. This positive connection is obtained by a sliding gear which engages or disengages the power coming from the transmission. There is a lever in the cab of the truck, so that the operator can engage or disengage the P.T.O. at any time.

In the case of the winch, the P.T.O. unit fulfills a function similar to that of the transmission gears in the case of the power train. The unit has two gear ratios to reel in the winch cable and a reverse position to reel out the cable. In addition it has a neutral position.

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The power take-off is connected to a propeller shaft which finally transmits the power to the winch gears. This shaft is similar in all respects (except size), to those found in the power train between the transfer case and the front and rear axles. Located in the yoke of the universal joint of this shaft is a small soft metal pin called a shear pin. It is this pin that determines the load value that can be pulled by the winch. If an attempt is made to pull a load that exceeds the capacity of this pin, the pin will break and the winch will stop operating. The shear pin capacity will never exceed the rated load capacity of the steel cable, providing the cable has no weak spots. It is mandatory that only specified shear pins be used as replacements.

There are two very definite reasons for having a shear pin located in the winch power train, both of which relate to safety in operation: To prevent a cable from snapping due to overload, thus protecting the operating personnel; to prevent overloading the winch gears.

The shear pin capacity is rated by a single line coming from the object of recovery to the winch. The weight of an object to be recovered can exceed the shear pin capacity if a block and tackle is used to gain a mechanical advantage.

For example, a force of ten pounds is required to lift a weight of ten pounds if the load is lifted by one rope. If a load is lifted by one rope the force exerted on the rope is ten pounds and the tension on the rope is ten pounds. If it is lifted with an equal force by two ropes only five pounds is exerted on each rope, and the tension on each rope will be five pounds. Therefore, the purpose of the block and tackle in handling heavy loads is to increase the number of forces (ropes) applied to the load. The relation between the load and the force exerted is the mechanical advantage.

The propeller shaft terminates in the winch gear box located at the side of the winch drum. In the winch gear box is a worm gear which is in mesh with and drives a spur gear. The axle or shaft which turns with the spur gear drives the winch drum, thereby winding in or out the steel cable on the winch depending upon the selection the operator makes with the power take-off shifting lever.

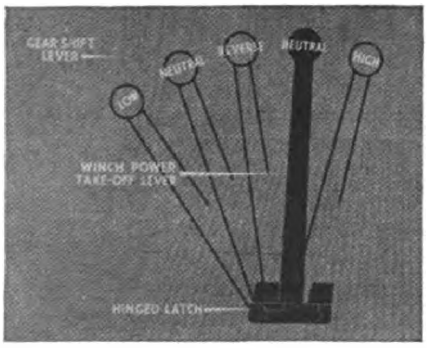

Figure 137. Winch Control Lever in Cab.

The operation of the power winch is relatively simple, and with observance of the following procedure, any vehicle operator can use the unit.

A. Reeling the winch out
   1. Transmission in neutral
   2. Start engine
   3. Disengage clutch
   4. Power take off selector lever in reverse
   5. Engage clutch
   6. Accelerate engine slowly.

B. Reeling the winch in
   1. Transmission in neutral
   2. Start engine
   3. Disengage clutch
   4. Place power take off selector lever in high or low

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5. Engage clutch
6. Accelerate engine slowly

Any time a load is pulled with the winch cable, it should be picked up gradually and slowly. The gear ratio selected through the power take-off will vary with the load of the object to be recovered. A sudden jerk on the cable places a great strain on both the cable and the winch gears.

The front winch on most vehicles can be power operated or 'free spooled'. Located on one side of the winch drum is a sliding jaw clutch which enables the operator to engage or disengage the power flow at the winch proper. The advantage of free spooling a winch is that the operator can run out the cable much faster than would be possible when operating under power. When using the winch under power, always be certain that the sliding jaw clutch is fully engaged.

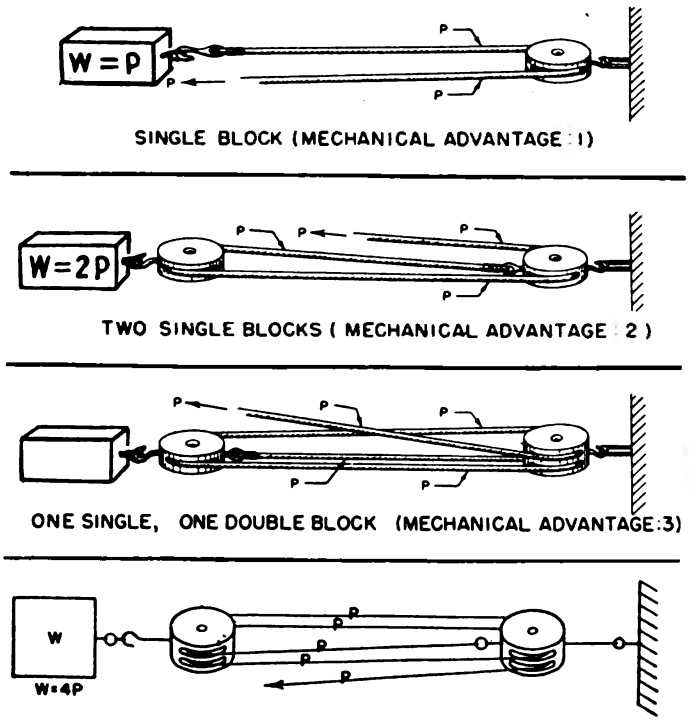

Figure 138. Mechanical Advantage in Tackle.

It can be seen that the tension on the cable of the winch drum can be substantially reduced in relation to the weight of the object to be recovered. The normal shear pin capacity of the winches on the Truck, Cargo, 2½ ton, 6 x 6 and on the half-tracks is 10,000 pounds. The large recovery units have much greater capacities. These capacities will vary with the size and type of steel cable utilized.

When using the power winch always:

1. Spool the cable properly;
2. Keep the cable clean and lubricated;
3. Inspect the cable for deterioration.

In winch operation, special precautions should be taken with the cable. A tension must always be maintained on the cable as it is being played out to prevent it from 'back-lashing' and getting tangled on the winch drum. Winding the first layer correctly is the most important step. Coils of the cable must be wound as close as possible against each other so that coils on the next layer will not jam between them as this jamming will injure and weaken the cable. Various methods have been devised to aid in spooling the cable properly across the face of the winch drum. The most common method is to use a crow bar as a guide. The crow bar should be padded with some soft material to prevent mashing or crushing the strands.

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Cleanliness and lubrication of the cable is of the utmost importance. Wire brushes should be used to remove all foreign elements that wedge themselves between the cable strands. The cable should be lubricated regularly to retard rust. The lubricant ordinarily used is old engine oil that has been strained. A piece of burlap saturated with the lubricant can be draped over the cable on the winch drum for added protection. This procedure is normally used when the cable will not be used for a prolonged period. The last method assures at all times complete and thorough protection for the cable.

The cable should be frequently inspected for signs of weaknesses caused by frayed strands or kinks. Any frayed strands should be clipped close to the cable with diagonal cutters. Kinks will materially weaken the cable if force is applied while the kink is present. A frayed cable can puncture a man's hand. A weak spot in the cable may cause that cable to break while under load and injure if not kill nearby personnel. When winches are in operation all but the necessary personnel should stand clear of the cable.

Proper lubricants should be used in the component winch parts. The power take-off requires gear oil of seasonal grade, the universal joints on the propeller shaft require chassis grease, and the worm gear box housing uses gear oil of a seasonal grade. Lubrication of the rest of the vehicle is as specified on the lubrication chart of the vehicle having the winch.

Description, operation, and lubrication of power winches have been discussed. The proper use of the winch can not be stressed too highly. Winches of the lighter and heavier types of vehicles are operated very much like the winch of the 6 x 6 and half-track which we have discussed. With proper operation, care, and service, the winch will operate indefinitely, and there isn't a more useful unit to have on any vehicle.

Recovery and Evacuation. The principles of Recovery and Evacuation will be found in Chapter 9 of Vol. I.

FIRE EXTINGUISHERS

Fire extinguishers as used in Army vehicles are generally one of two types; those which use carbon dioxide (CO_2) as an agent for fighting fire, and those which use carbon tetrachloride (CCl_4).

The carbon dioxide extinguishers are classified by weight, which, in turn, is an indication of the type and use. As an example, the four-pound extinguisher is a portable unit charged with four pounds (by weight) of carbon dioxide and equipped with a handle for carrying it to the scene of the fire. It is equipped with a squeeze grip valve which retains the gas and controls the discharge when the trigger is squeezed. It has a discharge horn fastened to the valve for directing the discharge on the fire. Another type is the fixed unit of the ten pound variety. This extinguisher is a fixed unit connected to a distributing system through a control head and tubing. Release handles marked 'fire pull' are located either on the inside or outside of the vehicle, or in both places.

Carbon dioxide gas has certain characteristics which should be known to all personnel. Carbon dioxide [not to be confused with carbon monoxide (CO)] is not poisonous, but suffocating. It is normally colorless except that when discharging it resembles a cloud of steam which is actually solidified carbon dioxide. The solidified particles, commonly known as dry ice, will produce a painful blister if applied with a slight pressure to the skin. The solid pieces will quickly vaporize into a gaseous state of carbon dioxide. After using this type of an extinguisher, thoroughly ventilate the space into which the gas has been discharged before entering. Should a person be overcome by carbon dioxide, it is essential that he be rescued from the space within a period of five minutes. To revive a person so overcome, apply artificial respiration and administer plenty of fresh air, as in the case of drowning in water.

As is the case in all equipment, a scheduled system of maintenance should be inaugurated. Every four months the control head must be removed from the cylinder. *Weigh* the cylinder to determine its state of charge—do *not* use a pressure gage. After long rough trips or after combat, examine the cylinder for dents or breaks. Check condition of valves, control heads, clamps, and, on the portable unit, the discharge horn. On fixed units the cylinder connections, tubing,

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nozzles and horns must be checked. Tighten all connections and replace any broken parts.

There are types of extinguishers and controls other than mentioned previously. Each have characteristics peculiar to the unit itself. Accordingly, any person charged with the responsibility of a vehicle should completely familiarize himself with the fire extinguishers on his vehicle.

The second type of extinguisher is the vaporizing liquid type using basically carbon tetrachloride (CC L_4) as an agent. The carbon tetrachloride is treated with other chemicals to make it harmless to the internal mechanism, and also to lubricate the moving parts. Commercial carbon tetrachloride should not be used in this extinguisher. Most of the extinguishers of this type have a double acting pump which expels the fluid on both the upstroke and the downstroke.

Carbon tetrachloride, which is the basic ingredient of this fluid, vaporizes easily. Personnel exposed to these fumes in a confined space are liable to get headaches, and continued contact with it over a longer period is likely to produce low blood pressure.

As in the other varieties of extinguishers, a preventive maintenance system should be organized. Frequent examinations should be conducted to be sure that it has not been tampered with, removed from its designated place, or damaged. It must also be checked to see that the handle is in a locked position, that it is full, and that the orifice of the muzzle is not clogged. Every four months a part of the contents of the extinguisher should be discharged into a glass container. If it is dirty, replace the fluid. Under no circumstances should water be added, as small amounts of moisture in the fluid cause hydrochloric fumes which is highly corrosive.

The fluid (CCL_4) is manufactured under a process that makes it a non-conductor of electricity. This feature is a protection for the operator when it is used on electrical fires. It may be well to remember that the freezing point of CCL, is 50 degrees below zero. Do not fill the extinguisher with ordinary commercial grades of CCL_4 as it may contain corrosive elements. Furthermore, such fluid will normally not contain sufficient lubricating ingredients to protect the mechanical part, of the extinguisher.

There are other types of fire extinguishers used by the Army but the discussion in this chapter has been limited to the types found in vehicles. Other information can be obtained from TM-9-1799.

BATTERIES

A storage battery is an electrochemical device for storing energy in chemical form so that it can be released in electrical form. Its purpose is to supply a source of electricity when the generator is not charging for starting, lights, and electrical accessories.

The storage battery, as it is known today, is made up of 'cells' composed of positive and negative plates insulated from one another by separators and submerged in an electrolyte solution. These units are all housed in a hard rubber case.

The material used in the plates and the type of electrolyte used will govern the voltage of the cell. In the storage battery used today the positive plates are made of lead peroxide (PbO_2), the negative plates are sponge lead (Pb), and the electrolyte is dilute sulphuric acid (H_2SO_4). This combination gives a terminal voltage of 2.1 volts (commonly called a 2-volt cell). In order to have a 6-volt battery, three of these 2-volt cells would be connected in 'series'. The common battery voltages are 6 and 12. The 12-volt also contains 2-volt cells but has twice as many as the 6-volt.

The capacity of a battery is governed by the number and size if the plates. The more area exposed to action of the electrolyte, the greater the capacity. Normally the lead acid storage battery will have 15, 17, 19, 21 or 23 plates per cell. The reason for an odd number of plates is that the positive plate is more active; therefore, an additional negative plate is used so that there will be a negative plate on both sides of all positive plates.

When connected into an electrical circuit, the battery delivers a current. This current is derived from a chemical reaction between the sulphuric acid (H_2SO_4) and the active material of both plates, during which lead sulphate is formed at

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both plates and the acid is replaced by water in the electrolyte. The chemical reaction which takes place is:

$$PbO_2 + Pb + 2H_2SO_4 \longrightarrow 2PbSO_4 + 2H_2O$$

When current is forced back into the battery the chemical reaction is reversed. That reaction is:

$$2PbSO_4 + 2H_2O \longrightarrow PbO_2 + Pb + 2H_2SO_4$$

There are several ways of telling the condition and state of charge of a battery. A way of telling the state of charge of a battery is by the specific gravity. This determines the percentage of acid in the electrolyte and the percentage varies with the state of battery charge as the specific gravity of sulphuric acid is 1.835 and water is 1.000. The electrolyte is tested with a hydrometer. Following is a list of specific gravity readings and corresponding states of charge at 80°F.

Gravity reading	*State of charge*
1.275-1.300	fully charged
1.245-1.270	three-fourths charged
1.215-1.240	one-half charged
1.180-1.210	one-fourth charged
1.150-1.175	barely operative
1.120-1.145	completely discharged

If the specific gravity varies 25 points between cells, that cell (or cells) is defective Since the specific gravity varies not only with percentages of acid, but also with temperature (increasing the temperature lowers the specific gravity, while decreasing the temperature increases the specific gravity) it is necessary to correct for temperature to determine accurately the condition of the charge of the battery. For every ten degrees of electrolyte temperature above 80°F, add four points to the gravity reading. For every ten degrees below 80°F subtract four points from the gravity reading. Examples:

1.250 at 100°F	Add 8 points. Corrected reading is 1.258
1.250 at 0°F	Subtract 32 points. Corrected reading 1.218

It is not necessary to make temperature corrections if only an approximate idea of the condition of charge is desired. A good way to tell the internal condition of the battery without tearing it down is by the high rate discharge tests. In this test a load is placed on the cells of the battery, so that they are delivering their approximate rated capacity. While the cell is delivering its rated capacity a voltmeter is placed across the terminals of the cell and a reading is taken. The voltage at this time should be 1.7 volts per cell. A variation of more than .2 of a volt indicates a defective cell. *CAUTION; the battery must be fully charged before making this test.*

Care must be taken when operating in cold climates to keep the battery fully charged. The higher the gravity the lower the freezing point, and the lower the gravity the higher the freezing point. Following is a table of specific gravities and freezing points:

Gravity reading	Freezing point
1.100	18°F
1.160	1°F
1.200	—17°F
1.220	—31°F
1.260	—75°F
1.300	—95°F

Consequently a battery should never be left out in cold weather after it has become discharged.

Batteries left sitting will discharge themselves because the chemical action never stops; therefore, a battery should be recharged or 'boosted' every 30 days. This is important because the lead sulphate which forms in the plates due to self-discharging is especially hard to break down and a sulphated battery which has been allowed to stand for a period of time may be ruined.

Some batteries are shipped for government use without electrolyte. Normally there is a tag on such batteries giving the details of the procedure for putting

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these batteries into service. Following are a few precautions for use when mixing electrolyte:

a. Use glass, china, earthenware, rubber, or lead vessels only. Never use a metallic vessel other than lead.

b. Carefully and slowly pour the acid into the water. *Never pour the water into the acid,* as this will cause an explosion which will throw the acid a considerable distance. Anyone standing near might be seriously injured. *Be careful.*

c. Stir thoroughly with a wooden paddle and allow to cool before taking a hydrometer reading.

d. Cool to a temperature below 90°F (but not below 60°F) before using.

An approximate table for mixing water and acid is given below.

Specific gravity	Using 1.835 sp. gr.		Using 1.400 sp. gr.	
desired	pts. of water	pts. of acid	pts. water	pts. acid
1.400	3	2	..	..
1.345	2	1	1	7
1.300	5	2	2	5
1.290	8	3	9	20
1.275	11	4	11	20
1.250	13	4	3	4
1.225	11	3	1	1
1.200	13	3	13	10

To prepare the battery for use, the steps to be followed are:

1. Remove the vent plugs and destroy the sealing devices. If the battery has the 'Electro-Level,' lift the lead valve and turn it clockwise until the valve rests on the shoulder in the cover. Fill each cell with electrolyte to a point ¼ to ⅜ inch above the separators.

2. Wait five minutes and then fill each cell again to the same height above the separators.

3. Allow the battery to stand two hours.

4. Fill each cell again, if necessary, to bring the electrolyte level up to a point ¼ to ⅜ inch above the separators.

5. The battery is now ready for service. If charging facilities are available, a charge at approximately 6 amperes until the specific gravity and counter voltage become constant (about 16 hours) will improve the initial capacity.

Most batteries today will be equipped with some type of device to prevent overfilling the battery. If the battery is not equipped with such a device, the correct electrolyte level is ¼ to ⅜ inch above the plates.

If a battery becomes corroded, the corrosion can be removed by using a solution of bicarbonate of soda and water or ammonia and water. After washing with this solution rinse with clear water and coat the terminals with terminal grease or a light cup grease.

Battery Charging. Batteries may be charged either by the constant current method or the constant voltage (constant potential) method.

Constant Current Charging. Constant current chargers usually are of the tungar rectifier type and operate from a source of alternating current. The rectifier changes the alternating current to direct current for charging the batteries. A rheostat must be incorporated in the circuit to adjust the flow of current to the batteries. Several batteries may be charged at one time on this type of charger by connecting them in series. However, the total voltage of the batteries must not exceed the output voltage of the charger. The charging rate is set and remains that way until changed. There is danger of overcharging the batteries with this type of charger.

Constant Potential Charging. Constant potential chargers usually consists of a motor or engine driven generator that has, incorporated in it, a rheostat for adjusting the voltage output. The voltage output of a constant potential charger is adjusted to approximately 7.5 volts for 6-volt batteries and 15 volts for 12-volt batteries. This voltage remains constant. If the batteries contain a low state of charge their terminal voltage is low; therefore, they will receive a high rate of charge. However, as the state of charge of the battery increases, its terminal voltage increases and offers more resistance to the flow of current from the charger. Since the voltage of the charger does not rise but is constant, the

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rate of charge is decreased. Thus, a constant potential charger may give a battery a high rate of charge at first, depending upon its state of charge, and taper off to a low charging rate as the battery reaches a completely charged condition.

When the state of charge of a storage battery is low it may receive a high rate of charge without damage as long as the temperature remains below 110 degrees F.; however, the rate of charge should be tapered off as the battery reaches a state of charge with a finishing rate of only a few amperes.

A storage battery should be charged until it is gassing freely and there is no further rise in specific gravity of the electrolyte for two hours.

The gas that escapes from batteries on charge is explosive and fires should be kept away from them, also do not remove clips from terminals while charging as this may cause an arc which will result in an explosion.

Charging Sulphated Batteries. When a battery has been allowed to stand for some time without attention, its plates may become sulphated to such an extent that it will not take a charge in the normal manner or they may have become completely ruined. In an attempt to save the battery it should be put on charge at a low rate (3 to 5 amperes) for about 60 hours to see whether the sulphation can be broken down so that the battery will take a charge. Sulphation takes more room than the active material; it swells and cracks or breaks the grids and, as a result, the battery can never be brought back to normal condition.

Battery Maintenance. Once a week (or mor often if necessary) storage batteries should be checked as follows:

a. By use of a hydrometer, take a specific gravity reading of all cells and compare the readings; charge or replace the battery if necessary.

b. By use of a cell tester (a voltmeter and a load shunt), test each cell under load and compare the readings.

c. Check the water level in each cell and replenish it to the proper level if necessary.

d. Clean top of battery, terminals, and cables using soda solution if necessary.

e. Clean battery carrier and paint if necessary.

f. See that battery is mounted solidly in the carrier with hold-down clamps tight.

g. Grease terminals and connections.

Battery Terminals. In order to install batteries properly it is necessary to be able to identify the positive and negative terminals.

The positive terminal of a storage battery may be identified as follows:

a. It is always larger.

b. It may be marked on top with P, POS, or +.

c. It may have P or POS marked on top of cover near terminal.

d. It may be painted red.

The negative terminal may be identified as follows:

a. It is always smaller.

b. It may be marked on top with N, NEG, or —.

c. It may have N, or NEG marked on top of cover near terminal.

For further information refer to TM 10-580.

GENERATORS

Function. A generator is a device for converting mechanical energy into electrical energy. It is used on automotive vehicles to generate electric current to charge the battery and supply current for lights and other electrical units on the vehicle.

Construction. Generators consist of four main subassemblies or components; namely, the frame and field, armature, commutator end head, and drive end head. The frame and field is composed of the pole shoes, the field coils, and the frame which supports the main components of the generator. There may be two, four, or more pole shoes. The field coils are wound around the pole shoes and supply the magnetic field which is necessary to generate electricity. The pole shoes and frame supply part of the path for the magnetic field. The armature consists of a laminataed iron core fixed to a shaft and the copper windings which are wound in slots in the core. The ends of the windings are connected to the commutator which consists of a number of copper segments that

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are insulated from each other and from the core and shaft. The commutator end head is a cast iron head that closes one end of the frame and supports one of the armature bearings. It also supports the brush holders and brushes that contact the commutator and carry the electricity from the revolving armature. The drive end head closes the drive end of the frame and also supports a bearing for the armature shaft. Both head assemblies have openings in them, and on the face of some drive pulleys are vanes which act as a fan to pull air through the generator for cooling. On the side of the frame and field assembly, or on the commutator end head, are insulated, shielded terminal posts, to which are attached the armature brush lead and field coil terminal.

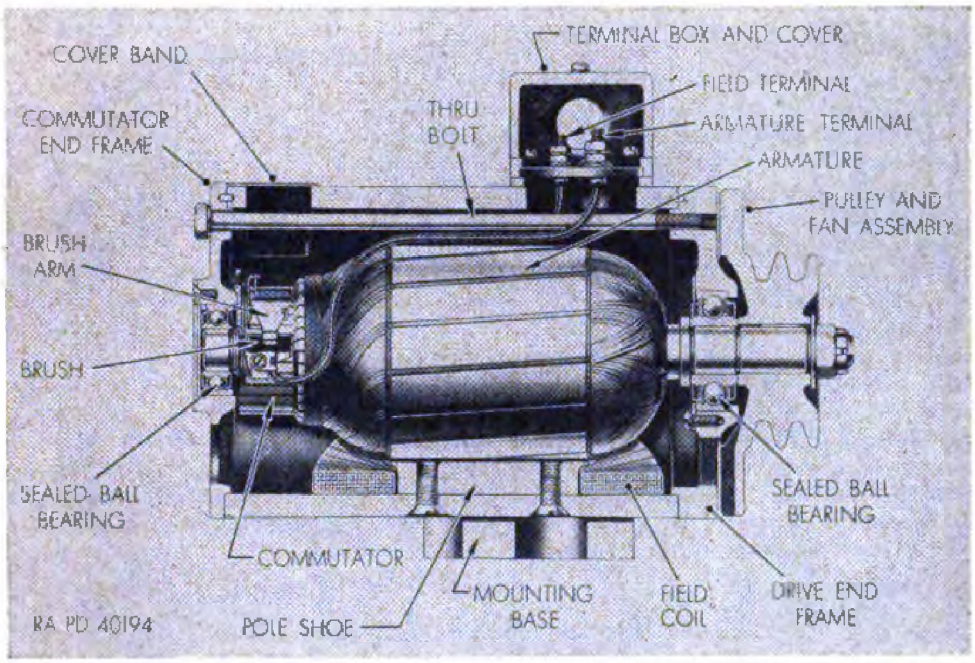

Figure 139. Section of Delco-Remy Generator.

General Description. Generators differ as to the design of the above parts due to the different electrical and mechanical characteristics desired for particular installations. Although the size, type of mounting, type of drive, or the voltage and current output may differ, all generators include the four components just described.

There are two types of generators; the third brush type and the shunt type.

The shunt generator is so called because the field is connected in parallel to the armature and current that flows through it is shunted from the main generator output through the field.

The field circuit of a standard duty generator is normally connected to the insulated brush inside the generator. The field circuit of heavy duty regulators is normally grounded inside the generator; therefore, two different checking procedures are required in checking the generators.

Operation. When the engine is started, it drives the generator by 'V'-belts or splined shafts. The armature coils rotate between the field coils which are wound around pole shoes that retain a small amount of magnetism (residual magnetism). This produces a small amount of electric current which is taken from the commutator by the brushes and passed through the field coils. This increases the strength of the magnetic field in which the armature is rotating, which in turn increases the voltage in the armature. This build up of electric voltage continues as the engine speed increases until it reaches the cutout relay closing voltage. The cutout relay points then close and connect the generator to the battery circuit. All electric energy not needed by the field coils is then passed through the generator regulator unit to charge the battery and furnish electric

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energy for the other electric units. The amount of current in the field of this generator is controlled by the generator regulator.

Third Brush Generator. The operation of the third brush generator is the same as that for shunt generators except that it uses a third brush to provide some means of controlling, within the generator, the maximum output of the generator. The field circuit is connected to the third brush so that the current fed to the field windings is taken off the commutator by the third brush. The two main brushes are located on the commutator at the two positions of maximum voltage. The third brush is placed in some position between the two, and consequently the third brush picks up less than the maximum available voltage. By moving the third brush toward the adjacent main brush, the voltage across

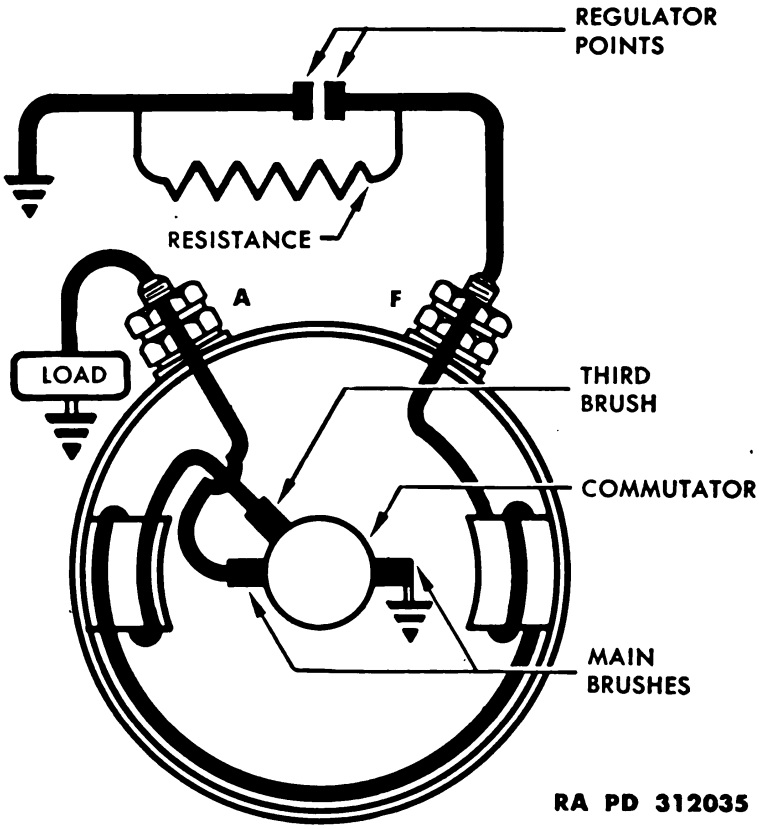

Figure 140. Third-Brush Generator Using External Regulation.

the field and the current through the field windings can be increased. This increases the strength of the magnetic field and causes a higher generator output. By moving the third brush away from the adjacent main brush the voltage across the field windings is reduced, less current will flow in the fields, and the output will be lower.

However, the third brush generator is not in very widespread use today because its output reaches a maximum at medium speeds and tapers off to lower values at higher speeds. To obtain high output at both low and high speeds, the shunt generator has been widely adopted.

CLEANING, INSPECTION, AND TEST OF GENERATOR

Cleaning. Wipe off excess grease and dirt with a clean cloth. Do not steam-clean or dip-clean the generator. Avoid getting any water or cleaner in the generator. Handle generators carefully to avoid battering or bending the terminal studs, cover band, relay, or control unit (where mounted on the generator).

Inspection. Inspect the generator for damage. Remove cover band and inspect for sticking or worn brushes, rough, out-of-round, dirty, or burned commutator,

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high mica on commutator, or thrown solder. Inspect all visible connections, screws, insulators, terminal studs, leads, and washers. Any apparent defect requires disassembly and correction.

CLEANING, INSPECTION AND TEST OF PARTS

General. After disassembling, clean and examine all parts and replace defective parts.

Armature. Do not clean the armature by any degreasing method as this would damage the insulation and ruin the armature. Wipe with a clean cloth slightly dampened with dry-cleaning solvent. If commutator is rough, out-of-round, worn, has high mica, filled slots, or is burned, it must be turned down in a lathe and the mica undercut. Check armature for grounds and open or short circuits as follows:

Ground. Use a test lamp and test points from the commutator to the armature shaft or lamination. If the test lamp lights (indicating a ground) and the ground is not readily apparent and repairable, the armature must be replaced.

Open. An open-circuited armature is easily detectable since this condition produces badly burned commutator bars. The bars connected to the open coils of the armature burn easily, because every time they pass under the brushes they interrupt a flow of current so heavy that arcing occurs. An armature may be tested for open circuit by use of a growler or low-reading ammeter.

The open circuit will usually be found at the commutator riser bars. If the condition is not too bad, repair by soldering the leads in the rising bars using rosin flux.

Short. An armature may be tested for a short by placing it on a growler, putting a hacksaw blade on the armature, and rotating the armature. If the armature is shorted the hacksaw blade will vibrate when the short circuited winding passes under it.

The armatures of Auto-Lite GDJ generators, Homelite auxiliary generators, and any others with parallel wound armatures cannot be tested in the above manner as this test would indicate nothing *but* shorts. Armatures of this type are tested for shorts by placing them on a growler and using a low reading ammeter, the leads of which are placed on two commutator bars that are separated by another bar, and rotating the armature until maximum reading is obtained. Test all windings in this manner.

Fields. Do not clean fields by any degreasing method as this would damage the insulation and ruin the coils. Clean by wiping with a clean, dry cloth. Be careful in handling the coil assembly to avoid breaking or weakening the connecting lead between the two coils. When field coils are removed from the generator, test for proper field current draw by connecting a battery and an armatures in series with the two field leads. Replace coils if they do not meet specifications. When the field coils are installed in the frame, test for ground and open circuit by use of a test light. If the field coil insulation is charred or worn away so that wire is exposed, it is sometimes possible to rewrap the coils.

Brushes. When brushes are worn so that they do not meet specifications, they must be replaced. Brushes may be seated by holding a seating stone against the commutator for a few seconds during operation, or by drawing No. 00 sandpaper under the brushes in the direction of commutator rotation.

Commutator. If the commutator is worn, rough, out-of-round, has high mica, filled slots, or burned spots, it should be turned down on a lathe just enough to true it. Undercut the mica 1/32 inch deep using a mica undercutter or hacksaw blade. Sand the commutator with No. 00 sandpaper and blow out particles with compressed air.

Bearings. Replace plain bearings if worn. If ball bearings appear to roll roughly or sloppily, replace them. Otherwise, clean ball bearings (if not the sealed type) in dry-cleaning solvent, dry with compressed air, and immediately relubricate with ball bearing grease. Never attempt to clean sealed ball bearings; replace them if they appear defective.

Miscellaneous. If brush holders, brush rings, screws, washers, insulation, etc., appear defective they must be repaired or replaced.

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GENERATOR TEST

To test the generator, place it on a test bench and test for maximum output in the prescribed manner.

In the absence of a test bench, the generator should be given a motoring test. If the armature does not turn in the proper direction of rotation it is an indication that field leads are improperly connected. A field expedient for testing generators when no other means is available is as follows: connect up the field, connect a lead to the A terminal, and hold the end close to the generator frame. Have someone wrap a rope around the generator drive pulley so that when the rope is pulled it will turn the armature in the proper direction of rotation. Give the rope a hard pull and observe if there is an arc between the end of the lead connected to the A terminal and the frame.

Flashing the Fields. When the pole shoes are first manufactured (and sometimes after overhaul) they do not have (or lose) their magnetism and have to be magnetized. This is done by connecting a battery to the field so that current will flow through the field in the same direction as when the generator is operating. This is called 'flashing the field'. If the pole shoes are not magnetized the generator will have no output.

GENERATOR TROUBLE CHART

Trouble		
A. Generator turning at rated r.p.m. but output low.	1. Dirty or pitted voltage regulator points.	1. Clean contacts and adjust regulator.
	2. Loose or high resistance connections.	2. Clean and tighten.
	3. Worn brushes.	3. Replace brushes.
	4. Dirty commutator.	4. Clean and polish in prescribed manner.
	5. Rough or pitted commutator.	5. Disassembly turn down on lathe, undercut mica, sand with No. 00 sand paper.
	6. Low brush spring tension.	6. Replace brush springs and brushes if necessary.
	7. Brushes binding in holders.	7. Remove and clean with cloth dampened with dry cleaning solvent.
	8. Shorted or grounded armature.	8. Disassemble, test and replace.
	9. Brushes not fully seated.	9. Reseat brushes in prescribed manner.
	10. Loose drive belt.	10. Tighten drive belt properly.
B. Generator operating at rated r.p.m. with no voltage output.	1. Generator field demagnetized.	1. Flash fields in proper direction.
	2. Generator field magnetized in wrong direction.	2. Flash fields in proper direction.
	3. Loose or high resistance connections.	3. Clean and tighten.
	4. Wiring not properly connected.	4. Check wiring and connect properly.
	5. Grounded field circuit.	5. Test and insulate or replace wiring or field coils.
	6. Open field circuit.	6. Test and replace coils, wiring or connections.
C. Excessive arcing of generator brushes.	1. Same as in "A" items 3-8 inclusive.	1. Same as in "A" items 3-8 inclusive.
D. Excessively high output.	1. Grounded field circuit, standard duty generators only.	1. Install new field coils, reinsulate field terminal or replace wiring.
	2. Improperly adjusted regulator.	2. Adjust regulator to specifications.
	3. Ground in brush holder.	3. Install new insulation.
E. Commutator burned at even places around the commutator.	1. Open circuit or high resistance in armature winding.	1. Resolder risers, test armature and replace if defective.

GENERATOR REGULATOR

General. When the possible output of the generator is greater than that needed by the connected load and state of charge of the battery, some means of output regulation is required. The output of any generator is dependent upon the strength of the magnetic field and the speed with which the conductors cut through the magnetic field. The magnetic field of a generator varies directly

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with the amount of current flowing in the field coils. The most commonly used method of reducing the strength of the field, and thereby reducing the generator output, is to insert resistance in the field circuit.

The generator-to-battery circuit must be opened when generator voltage is lower than battery voltage (which is whenever the engine is running slow or is stopped), or the battery would discharge back through the generator. It is also necessary to close the generator-to-battery circuit whenever generator voltage is above battery voltage in order for the generator to furnish electric current for electrical accessories and charging the battery.

The above conditions are accomplished automatically by the generator regulator. The most commonly used generator regulator consists of three units, namely; cutout relay (circuit breaker), current regulator, and voltage regulator.

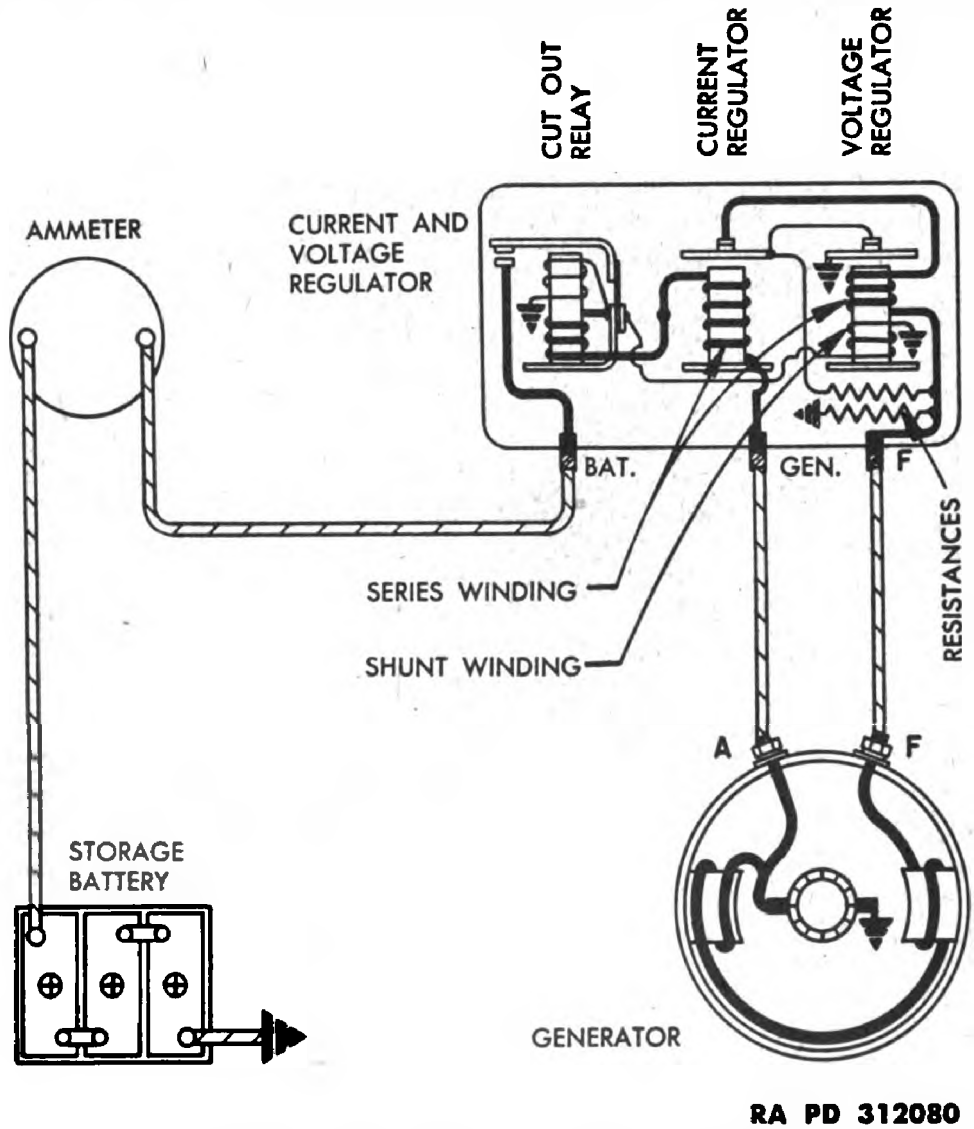

Figure 141. Schematic Wiring Diagram of Current and Voltage Regulator.

Cutout Relay. The cutout relay opens and closes the circuit between the generator and the battery. It closes the circuit when the generator operates to charge the battery, and opens the circuit when the generator is not operating to prevent the battery from discharging back through the generator.

Operation. The cutout relay consists of two windings; a shunt winding and a series winding. They are assembled on a single core above which is positioned

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an armature. The shunt winding consists of many turns of fine wire and is connected across the generator. The series winding consists of a few turns of heavy wire designed to carry full generator output and is connected in the charging circuit. The armature, which is positioned above the winding core, carries three contact points which are positioned above matched stationary contact points. When the generator is not operating, the armature is held away from the winding core by spring tension and the points are separated. As soon as the generator begins to operate at a speed sufficient to produce enough voltage to charge the battery, this voltage, which is impressed on the relay windings, creates enough magnetism to overcome the armature spring tension and closes the contact points connecting the generator with the battery. As long as the generator is charging the battery the contact points are held closed. When the generator slows up or stops so that current flows from the battery to the generator the points open. The flow of current from the battery to the generator reverses the magnetic field of the series winding and it no longer helps the magnetic field created by the current through the shunt winding, but weakens it, allowing the armature tension spring to separate the contact points.

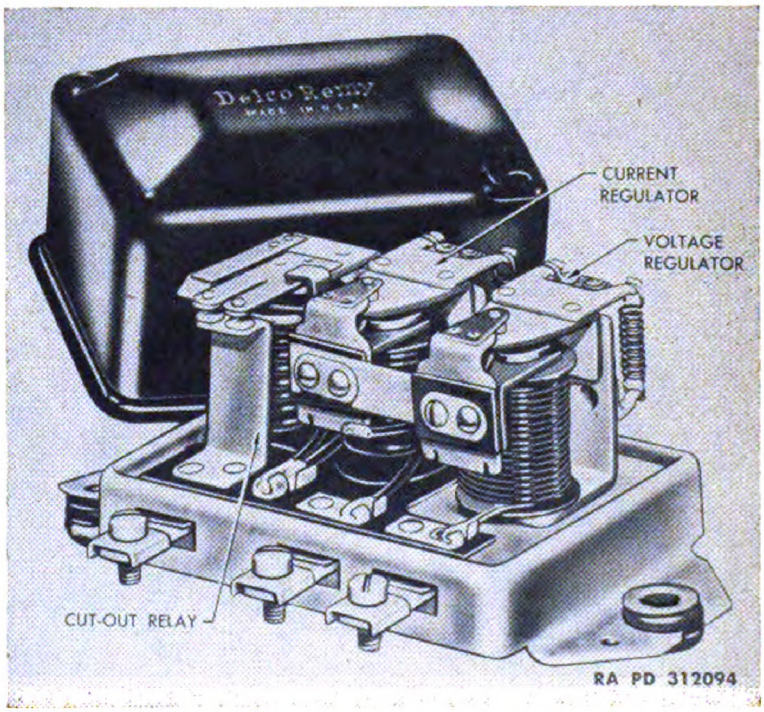

Figure 142. Current and Voltage Regulator for Type One Shunt Type Generator.

Voltage Regulator. The voltage regulator prevents the line voltage from exceeding a predetermined value, thus protecting the battery and other electrical accessories in the system. One characteristic of batteries is that, as either the specific gravity of the electrolyte or the charging rate increases, other conditions being the same, the battery terminal voltage increases. If the terminal voltage is held constant as the battery comes up to charge (specific gravity increases), the charging rate will be reduced. The voltage regulator does this job of holding the voltage constant and, consequently, protects the electrical system from high voltage and the battery from overcharging.

Operation. The voltage regulator consists of a pair of contact points (one positioned on an armature, the other stationary) and regulator windings assembled on a single core. As the voltage in the system increases because of increased generator output, or the battery approaches a charged condition, the magnetic attraction of the winding on the armature increases. The armature spring tension normally holds the regulator contact points closed and the gen-

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erator field circuit is connected through these contact points. With the contact points closed in this manner, the generator output can increase to a high value and can cause, under the above-mentioned conditions, a high voltage. When, however, the voltage reaches a predetermined value the magnetic attraction on the regulator armature is sufficient to overcome the armature spring tension and pull the armature toward the core. This opens the contact points, causing a resistance to be inserted in the generator field circuit. This decrease in the generator field circuit immediately causes a reduction of the generator output, with a consequent reduction of voltage. Reducing the voltage, however, reduces the magnetic pull on the armature so that almost at once the armature is released and the spring tension closes the regulator contact points. This permits an increased output and voltage, so that the points are again opened. This cycle is repeated very rapidly so that the voltage is held to a constant value and the output is reduced to just what is required by the connected load and the condition of charge of the battery.

Current Regulator. The current regulator limits the generator output to a safe value. It is in effect a current limiting device which operates when the generator output has reached its safe maximum, preventing the generator from exceeding this value.

The current regulator consists of a pair of contact points (one positioned on an armature, the other stationary) and regulator windings assembled on a single core. As the current output of the generator reaches the value for which the current regulator is adjusted (the maximum specified for the generator), the magnetic strength of the current regulator windings is sufficient to overcome the spring tension holding the points closed. They open and cause the same resistance as the voltage regulator used to be inserted into the generator field circuit. This increase of resistance in the generator field circuit causes a reduction in the generator output. However, as soon as the output falls below the value for which the regulator is adjusted, the magnetism becomes insufficient to hold the points open. They close, and permit the generator output to again increase. This cycle is repeated very rapidly so the current output of the generator does not exceed its specified maximum.

Resistance. The resistance is used to increase or decrease the generator field circuit. Increasing the external resistance of the generator field circuit decreases its output; decreasing the external resistance, increases output. When both the voltage regulator and current regulator contact points are closed, this resistance is shorted out of the field circuit; the opening of either set of contact points places this resistance in the generator field circuit.

Summation. Either the current regulator contact points or the voltage regulator contact points operate at any one time, both can never operate at the same time. When the battery is low and the load requirement is high (many accessories in use) the current regulator contact points operate to prevent the generator from exceeding its specified maximum and the voltage regulator contact points do not operate because the voltage does not reach a value sufficient to cause its operation. When the battery begins to come up to charge and the electrical accessories are not in use, the voltage begins to increase and reaches a value at which the voltage regulator contact points begin to operate. The generator output consequently begins to taper off so that it is below a value at which the current regulator contact points would operate. Consequently, only the voltage regulator contact points operate under this condition.

Cleaning, Inspection, Repair, and Testing. Clean by wiping off excess dirt with a clean cloth. Do not wash, steam or dip-clean. Remove cover and blow out dirt or dust with compressed air, being careful to avoid directing air stream against leads, resistors, windings or other parts that could be damaged. Inspect for burned contact points, resistors, windings, leads, or insulation. Inspect for loose connections, loose nuts, loose contact points, and bent or distorted armature springs. Dress contacts if necesary. Repair or replace any defective parts.

Adjust clearance of all core-armature air gaps and all contact points according to specifications.

Electrically test and adjust cutout relay, voltage regulator, and current regulator according to specifications.

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Maintenance on Vehicle. A periodic inspection of the generator regulator will prevent failure in the field. All inspections and adjustments of this unit in the vehicle must be by ordnance personnel. Before inspecting the generator regulator, perform inspections as listed below.

1. Inspect wiring from generator to generator regulator for proper connections and open or short circuits.
2. Inspect for loose, corroded, or high resistance connections in the circuit between the generator regulator and battery.
3. Inspect the battery.
4. Check the regulator to see that it is the proper one for the generator being used.
5. Inspect and test the generator for proper operation.
6. Clean, inspect, repair, test, and adjust the regulator as prescribed above, making replacement of the unit if necessary.

CRANKING MOTORS

Construction and Function. Cranking motors are designed to crank engines electrically. They consist of an armature, a field frame with field coils, a commutator end head, a drive end head or drive housing, and a drive arrangement to transmit the cranking effort from the armature to the engine flywheel. The commutator end head supports a bearing (either plain or anti-friction), brush holders, and brushes. The drive is protected by a cast iron or bronze drive housing. All cranking motors are similar in general design and operation, differing mainly in the type of drive used.

Operation. When the cranking motor switch is closed, current flows from the battery to the cranking motor. It passes through the positive brushes, armature windings, negative brushes, field windings, and back to the battery. Since armature is connected in series with the field, all current that passes through the armature windings also passes through the field. The magnetic field set up by the current flowing through the armature windings opposes the field set up by the current flowing through the field coils. Because the armature is supported freely on bearings, this opposition forces it to rotate. Rotation of the armature causes the cranking motor drive pinion to rotate; when the drive pinion is meshed with the flywheel teeth, the flywheel cranks the engine.

The cranking motor is of a special type designed to operate under great overload and produce a high horsepower for its size. It can do this, however, only for short periods of time, since in order to produce sufficient power, a high current must be sent through the cranking motor. This high current creates considerable heat within the unit. If the cranking motor operation is continued for any length of time without pause to allow for cooling, the accumulating heat will cause serious damage to the cranking motor. It should never be used for more than thirty seconds at one time without a pause of at least two minutes to permit the heat to escape before renewed operation.

Cranking Motor Drives. *General.* The cranking motor drive is a vital part of the cranking motor, since it is through the drive that cranking torque is transmitted to the engine. The drive mechanism has the following functions: (1) engaging the flywheel, (2) transmitting torque to the engine being cranked while the cranking motor is being operated and (3) disconnecting the cranking motor from the engine when the engine has started. The drive mechanism must also provide a gear reduction between the cranking motor and engine, so that there will be sufficient torque to turn over the engine at cranking speed.

The three types of drive mechanism most commonly used today are the Bendix, the overrunning clutch, and the Dyer drives. Each provides a means for meshing the drive pinion with the engine flywheel for cranking, and for disengaging the drive pinion from the flywheel when the engine starts.

Bendix Drive. The Bendix drive consists of a threaded sleeve fastened to the armature shaft through a drive spring and a pinion mounted on the threads of the sleeve. When the starting circuit is closed, the armature revolves, turning the sleeve within the pinion and forcing the gear toward the flywheel where it meshes with the flywheel gear. The sudden shock of meshing is absorbed by

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the spring. When the engine starts, the pinion is driven faster than the sleeve and is forced back along the threads, automatically demeshing it from the flywheel.

Overrunning Clutch Drive. The overrunning clutch type drive consists of a pinion connected by a roller clutch to a sleeve. The sleeve has internal splines that match splines on the armature shaft. To engage the flywheel the whole clutch is shifted along the armature shaft either by cranking motor pedal linkage or by solenoid action. The cranking motor switch is designed to close when the meshing is nearly completed. When the motor cranks the engine, the clutch binds the pinion of the sleeve in a firm grip and transmits the torque to the flywheel. When the engine starts, the clutch is released permitting the pinion to turn faster than the sleeve. This prevents spinning the armature. When the cranking motor pedal or button is released, spring action disengages the pinion from the flywheel.

Dyer Drive. The Dyer drive which combines some of the principles of the Bendix and the overrunning clutch drives, is used on heavy-duty gasoline and Diesel engine applications. It has the advantage of providing complete and positive meshing of the drive pinion and the flywheel teeth before the cranking motor is connected to the battery.

The Dyer drive is operated by a shift lever, which forces the shift sleeve, pinion guide, and pinion endwise along the spirally splined armature shaft. The pinion guide fits snugly. As the assembly moves along the shaft, the pinion guide and the pinion rotate, owing to the spiral splines on the shaft. If the relative position of the pinion and flywheel teeth is such that the teeth align, meshing will take place immediately. Further movement of the shift lever closes the cranking motor switch, and cranking takes place. If, however, the teeth butt, the shift sleeve continues to move the pinion guide along the shaft. Because the pinion guide fits the shaft splines snugly, while the pinion fits loosely, the pinion rotates without any forward movement until the teeth align and meshing can take place. Cranking is then accomplished as described above.

As soon as the armature begins to rotate, the shift sleeve is spun back out of the way. The pinion is held in mesh as long as power is transmitted from the armature through the pinion to the flywheel. The instant the engine begins to operate, however, it spins the pinion faster than the armature is rotating, with the result that the pinion is disengaged from the flywheel.

Cleaning, Inspection and Testing Parts. At each major overhaul of the engine, or oftener if necessary, the cranking motor should be removed and overhauled.

Cleaning, inspection and testing of parts is done in the same manner as prescribed for generators.

Lubrication. Cranking motors should be lubricated in the prescribed manner. Caution: Over-lubrication should be avoided. A great deal of cranking motor trouble is due to over-lubrication, as grease gets on the commutator and prevents proper operation of the unit.

The Bendix drive should be oiled lightly with light oil only. Excess oil and heavy oil will result in failure of the drive mechanism when dirt gets in the oil and makes it gummy.

Testing Cranking Motors. Cranking motors should be tested as follows:

No Load Test. Connect the cranking motor in series with a battery of the specified voltage and an ammeter capable of registering several hundred amperes. Check the current draw and armature RPM with unit running free speed or no load, and compare with specifications.

Torque Test. The starting motor should be set up with the proper equipment and given a stall torque test. The torque developed, current draw, and voltage are checked together when making this test, and should be within specifications.

Malfunctions and Causes. Rated torque, current draw, and no-load speed indicates normal condition of the cranking motor.

Low free speed and high current draw with low developed torque may result from tight, dirty, worn bearings, loose field poles which allow armature drag, grounded armature or field, or shorted armature.

Failure to operate, with high current draw, may result from a direct ground in the switch, at terminal or brushes, or frozen shaft bearings.

Failure to operate, with no current draw, may be caused by open field circuit, open armature coils, broken or weakened brush springs, worn brushes, high com-

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mutator mica, or other conditions which would prevent good contact between brushes and commutator.

Low no-load speed, with low torque and low current draw, indicates open field or high internal resistance due to worn brushes, dirty commutator, weak or worn brush springs, defective leads and connections, or other causes of poor contact between commutator and brushes.

High free speed, with low developed torque and high current draw, indicates shorted fields.

For further information refer to TM 9-1825A or TM 9-1825B.

DIRECT ELECTRIC CRANKING MOTOR, HEAVY DUTY TYPE FOR RADIAL ENGINES

General. This cranking motor is a heavy duty type designed for cranking radial engines. It is a direct cranking, four-pole, four brush electric motor that mounts on the accessory case of the engine. This cranking motor has incorporated in it a friction clutch of which the adjustment is such that the clutch will slip in case of a hydrostatic lock in the engine, thus preventing damage to the engine or cranking motor.

Construction. The motor comprises a field frame and a laminated rotatable armature within the frame. Four field coils encircle the pole shoes in the frame (also known as yoke). The field coils are connected to the armature windings through the brushes at one end and are connected to a ground at the other end. All four brushes are insulated and are an equal distance apart.

The end frame has window openings closed by a removable cover band so that the commutator and brushes may be examined.

The hand crank assembly bolted to the other end of the field frame supports the hand crankshaft in antifriction bearings. A ratchet is contained in this assembly which allows cranking rotation of the crankshaft but prevents rotation in the opposite direction.

The drive consists of an internal reduction gear train which includes the armature shaft gear, intermediate gear, sun gear, annulus gear, planetary pinions, friction clutch consisting of drive and driven clutch plates that are held under pressure by springs, baffle assembly and meshing jaw which is mounted on and splined to a screw shaft in such a manner that they can move slightly towards and away from each other.

These cranking motors are designed for 12- and 24-volt applications. To convert from 12- to 24-volt operation requires replacement of brushes, field coils, and armature.

Operation. The operation of the electric motor is the same as for other cranking motors.

When the cranking motor switch is closed, the electric motor drives the engine by means of the internal reduction gear train beginning at the armature gear and ending at the meshing jaw. The baffle assembly friction seal ring bears upon the circumference of the meshing jaw and prevents for an instant the rotation of the jaw by the screw shaft when the motor begins to revolve. When the clutch and screw shaft first begin to turn, the meshing jaw is forced outward to engage the engine jaw. The meshing jaw then begins to turn with the screw shaft, clutch, and other parts to crank the engine. Power is transmitted through gearing within the accessory case to the engine to rotate the crankshaft in a clockwise direction.

When the engine starts, the cranking motor meshing jaw is turned faster than the screw shaft upon which it is mounted, hence it travels up the screw shaft away from the engine. This disengages the cranking motor meshing jaw from the engine.

Maintenance. In addition to the standard tests for the cranking motor (those used for generators), the meshing jaw location and the clutch action must also be tested.

Meshing Jaw Location. The meshing jaw, in the retracted position, must be 1 19/32 inches from the mounting flange of the cranking motor, with the baffle plate in position. Adjust by turning the meshing rod nut in or out as required.

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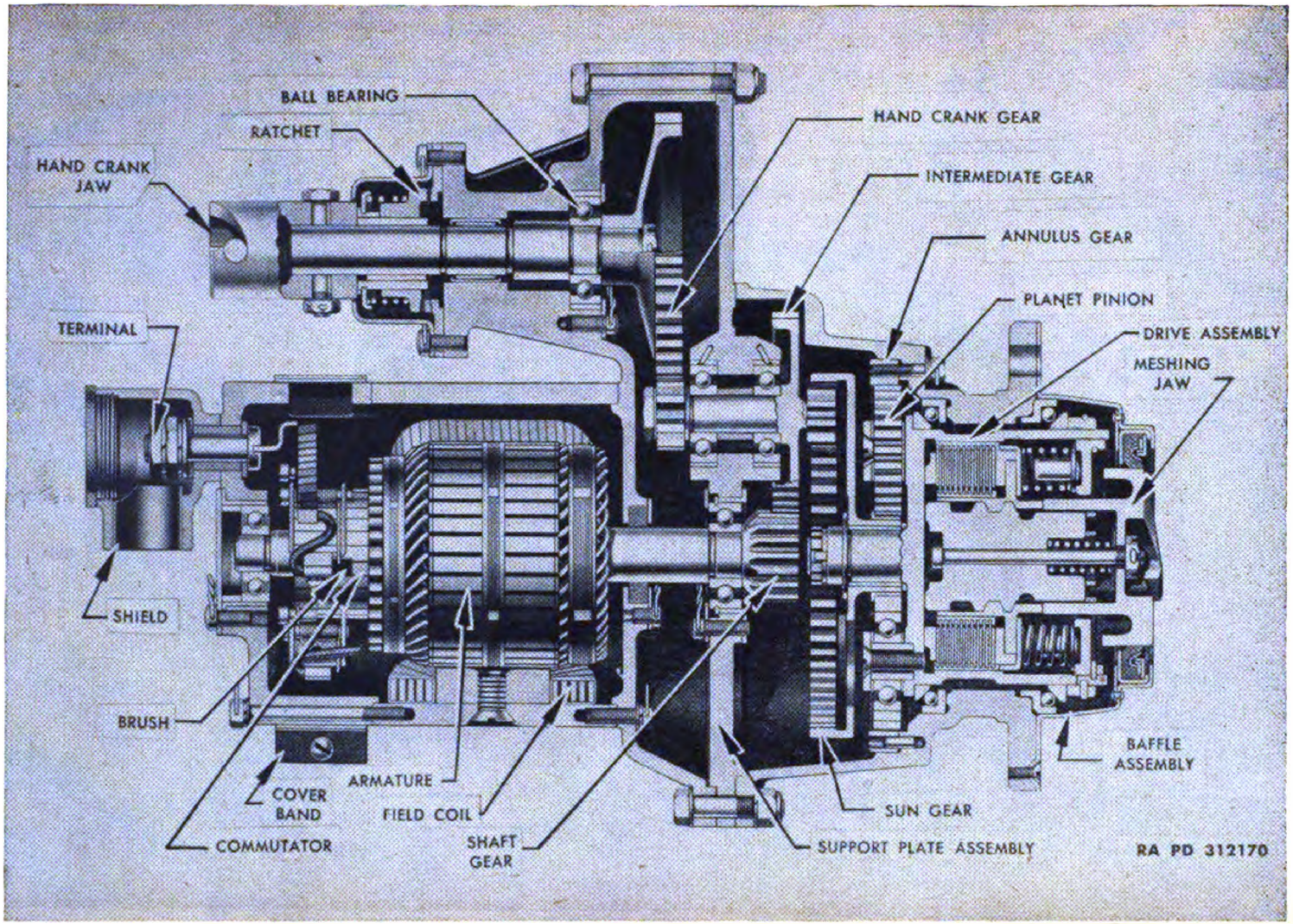

Figure 143. Sectional View of Heavy-Duty Cranking Motor With Internal Gear Train.

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Secure nut with cotter pin after adjustment. Meshing jaw travel from the retracted position must be 11/32 inch.

Clutch Check and Adjustment. With the baffle plate removed, mount cranking motor on test stand, lock brake drum, and operate cranking motor for a period of five seconds. Repeat five times at intervals of one minute. If the torque reading on the scale remains constant at 550 foot-pounds within plus or minus 20 foot-pounds, clutch adjustment is satisfactory. To adjust, screw clutch adjusting nut out to lower torque, and screw it in to raise setting. After the correct setting has been attained, place snap ring in position to lock the nut and allow cranking motor to cool to room temperature. Then operate cranking motor five consecutive times to determine if setting remains constant. Caution: Do not allow cranking motor to overheat.

For further information refer to TM 9-1825A, TM 9-1825B, TM 9-1726A, and TM 9-1950D.

DIRECT CRANKING MOTOR

Trouble Chart

Trouble	Possible Cause	Remedy
A. Motor operating cranking motor fails to crank engine.	1. Friction ring spring tension too low.	1. Test and replace friction ring.
	2. Slipping clutch.	2. See Item "D" in this paragraph.
	3. Starter rotation incorrect.	3. Replace starter.
	4. Discharged battery.	4. Recharge or replace battery.
B. Cranking motor fails to operate or operates at too low speed.	1. Low voltage due to discharged battery.	1. Check and recharge battery.
	2. Loose or corroded battery terminals.	2. Clean, tighten, and coat with vaseline.
	3. Wiring not properly connected.	3. See wiring diagram and connect properly.
	4. Loose or high resistance connections.	4. Clean and tighten connections.
	5. Brushes binding in brush boxes.	5. Remove and clean with cloth moistened with dry cleaning solvent.
	6. Worn brushes.	6. Replace brushes.
	7. Brushes not properly seated.	7. Reseat brushes.
	8. Excessive brush side play.	8. Replace brushes.
	9. Dirty commutator.	9. Clean with No. 000 sandpaper.
	10. Rough or pitted commutator.	10. Disassemble, turn commutator down on lathe, if 24 volt under cut mica, sand with No. 000 sandpaper.
	11. Shorted, grounded or open motor armature.	11. Replace armature.
	12. Grounded or open field coils.	12. Replace field coils.
	13. Foot or push switch inoperative.	13. Test and replace if necessary.
C. Excessive arcing.	1. Same as "B" items 5-11 inclusive.	1. Same as "B" items 5 to 11 inclusive.
D. Slipping clutch.	1. Engine oil leakage.	1. Disassemble clean, lubricate, and replace worn oil seals.
	2. Worn or scored clutch disks.	2. Replace and test.
	3. Clutch adjusting nut not locked.	3. Adjust, test, lock.
	4. Improper lubrication.	4. Disassemble, relubricate, assemble, and test.
	5. Clutch not properly adjusted.	5. Test and adjust.

CRANKING MOTOR SWITCHES

General. Cranking motors may draw several hundred amperes from the battery during cranking. In order to prevent the motor from being overheated or damaged, special switches with heavy contacts must be used.

These switches vary in size and form depending upon the different applications, and several types of controlling devices may be used to close and open them. One controlling device is merely mechanical, with linkage from the cranking

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motor switch (mounted on the cranking motor) to a pedal in the driving compartment. Other applications make use of a magnetic switch, or a solenoid switch and shift combined with a relay to provide an automatic switch control system.

Magnetic Switch. The magnetic switch consists of a winding wrapped around a hollow core and a cylindrical iron plunger placed part way in side the hollow core. By closing the circuit so current will flow through the winding, a magnetic field is set up which pulls the plunger farther into the core. A contact disk is attached to the plunger and the plunger movement forces this disk against two other contacts. This closes the circuit between battery and cranking motor.

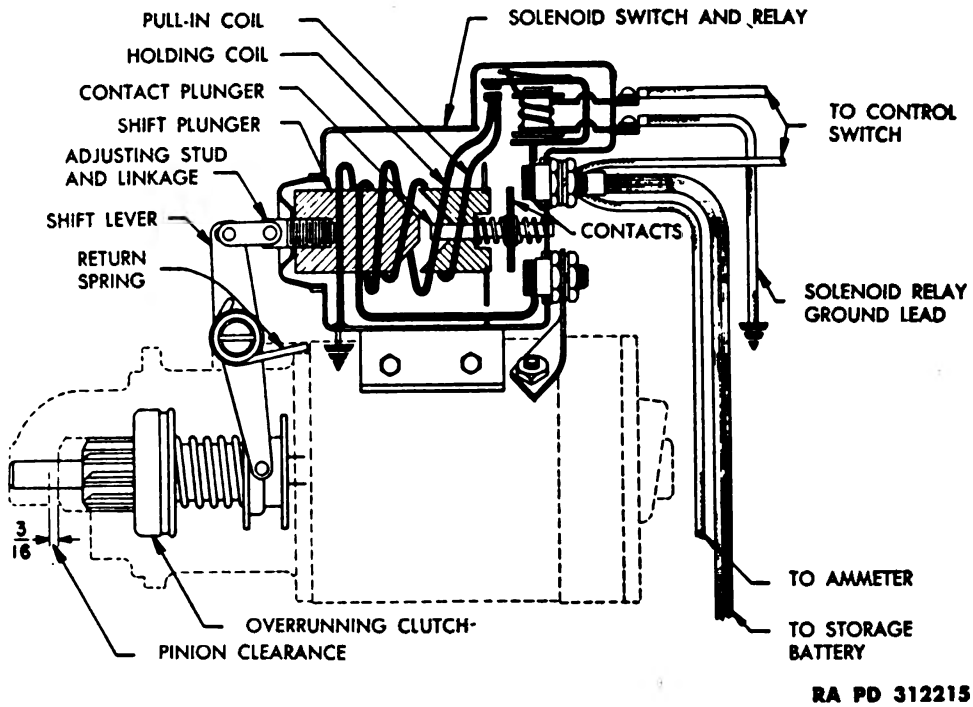

Figure 144. Solenoid Relay and Solenoid Wiring Circuit.

Many magnetic switches have two windings, as shown in figure 144. One is a pull-in winding and consists of a few turns of heavy wire; the other is a hold-in winding consisting of many turns of fine wire. When the control switch is closed, current flows from the battery through both of these windings. The current through the hold-in winding returns directly through ground. The current through the pull-in winding goes through the cranking motor before returning through ground to the battery. When the pull-in coils and hold-in coils are energized, the magnetic field pulls the plunger and contact disk forward. The contact disk comes to rest against the cranking motor circuit contacts. This shorts out the pull-in winding and only a very small amount of current continues to flow through this winding. The hold-in winding remains energized and continues to hold the contact disk against the cranking motor circuit contacts. The reason for the above hookup is that more energy is required to pull the plunger and disk forward than is required to hold them in the forward position. This hookup gives positive operation with no lagging.

Some magnetic switches use only one winding instead of two. The single winding operates to pull in the plunger, and the winding remains energized as long as the external control circuit is closed.

The magnetic switch is normally mounted on the cranking motor and used with cranking motors of the Bendix type only. It permits use of a short cable between battery and cranking motor which gives a minimum of resistance. The remote control is conveniently located on the dash.

With this system the ignition switch must be turned on before the cranking

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motor switch can be pressed to put the remote control circuit in operation.

Solenoid Switch and Shift. When the overrunning clutch type of cranking motor is used, the magnetic switch may be given an additional job to do, and it is then called a solenoid switch and shift (figure 144). It is made somewhat larger and linked to the overrunning clutch shift lever so that, when it operates, it first shifts the drive pinion into mesh and then closes the circuit between the battery and cranking motor. The solenoid has two windings, a pull-in winding and a hold-in winding, which operate in the same manner as in the magnetic switch.

For further information refer to TM 9-1825A and TM 9-1825B.

SERIES-PARALLEL SWITCH

General. The series-parallel system provides a means for connecting two batteries in series during cranking to provide increased voltage, and after the engine has been started, for reconnecting the two batteries in parallel for normal operation of the equipment. For example, if two 12-volt batteries are connected in series they produce 24 volts but when connected in parallel they produce 12 volts. Similarly, two 6-volt batteries produce 12 volts when connected in series and 6 volts when connected in parallel.

When the engine is stopped, the two batteries are connected in parallel through two sets of contacts inside the switch. Both batteries deliver current to any lamps which may be switched on.

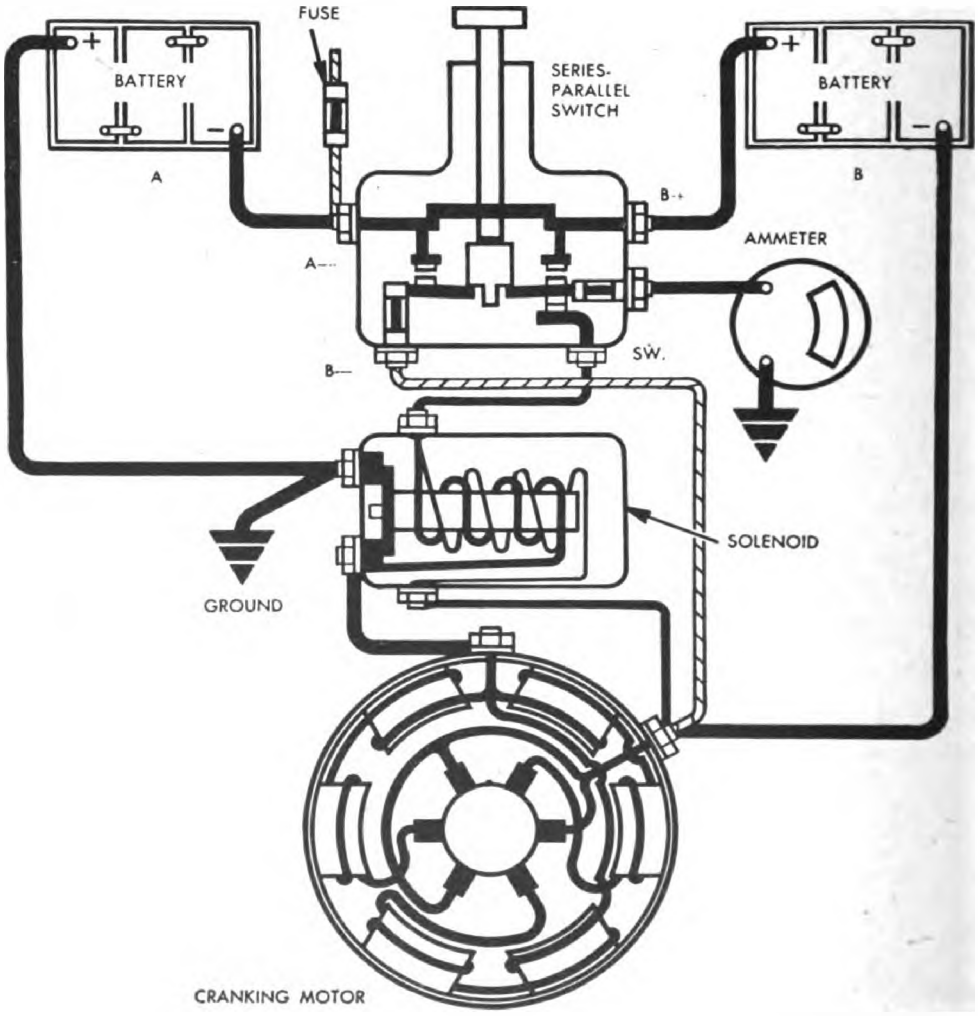

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Figure 145. Series-Parallel Switch Circuit With Switch in the Cranking Position and Series Connections Completed.

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When the engine is to be started, the ignition switch is turned on, then the series parallel switch knob is depressed. The first part of this movement opens the two sets of contacts, thus breaking the parallel connection of the batteries. Further movement closes the heavy contacts inside the switch, thus connecting the batteries in series. The final portion of the plunger movement closes the set of contacts "SW" which connects one side of the cranking motor solenoid switch to ground or to the plus terminal of battery "A." The other side of the solenoid winding is connected to the minus terminal of battery "B." This imposes 12 volts across the coil and causes current to flow through it. The magnetic field produced by this current reacts on the plunger inside the solenoid switch, pulling it in and closing the contacts, thus completing the circuit from the batteries to the cranking motor. As the solenoid plunger is pulled in, it forces the cranking motor drive pinion out of mesh with the engine flywheel. As soon as the contacts are closed, the cranking motor begins to operate, thus cranking the engine.

The diagram in figure 145 shows the series-parallel switch contact position and the circuit with the two 6-volt batteries connected in series for cranking. Since two 6-volt batteries are connected in series through the heavy contacts of the series-parallel switch, 12 volts are thus imposed on the cranking motor.

As soon as the engine fires, pressure on the switch should be released, allowing the switch to return to its normal position.

When the switch returns to normal, first open the circuit to the solenoid switch coil. This allows the contacts to open the cranking motor circuit. Next, the series connection between the batteries is opened, and then the two sets of contacts inside the switch close again, placing the batteries in parallel for charging.

The batteries in figure 144 are positively grounded. To charge them, current from the generator flows through the frame of the vehicle. Half of the current enters battery "A" through B-plus terminal at the ground connection of the solenoid, goes to terminal A-minus, up through the fuse, and back to the generator. The other half of the generator output enters the ammeter ground connection, goes through the auxiliary ammeter, the contacts inside the switch, B-plus, the battery, to the cranking motor terminal, up through the lead to B-minus on the switch, through the switch contacts to A-minus, up through the fuse, and back to the generator.

The purpose of the auxiliary ammeter is to indicate the amount of charge that battery "B" receives. There is also an ammeter in the generator circuit that registers the total charging current.

To prevent burning the points inside the series-parallel switch, some circuits contain circuit-breakers. These open the circuit when the flow of current through the contacts becomes too great, which might happen if the batteries were improperly connected.

Maintenance. The series-parallel switch should be removed and disassembled at each 6,000-mile inspection of the vehicle, or oftener if necessary. Clean contacts and connections, replace any worn or defective parts, test insulation, assemble, and test operation of the unit. Any high resistance in the switch circuit will prevent proper operation; therefore, all terminals, contacts and connections must be kept clean and tight.

For more information, see TM 9-1825A.

LIGHTING SYSTEMS; WHEELED AND HALF TRACK VEHICLES

General. The lighting system consists of a source of electric current (the storage battery or generator), the necessary switches, wiring, and protective devices (fuses or overload circuit breakers which prevent excessive discharge of the battery and burning of the wiring in case of short circuits), and the lights. Lights include the headlights, signal lights (tail lights, and blackout lights), and interior lights. Trouble lights for repair work, spot lights and fog lights for better illumination of the road, fender lights to show the width of the vehicle, and others may also be installed.

The wiring circuits illustrated in figure 146 are of the single wire type. A single cable connected to the positive terminal of the battery runs directly to the terminal on the cranking motor switch, ignition switch and ammeter. From

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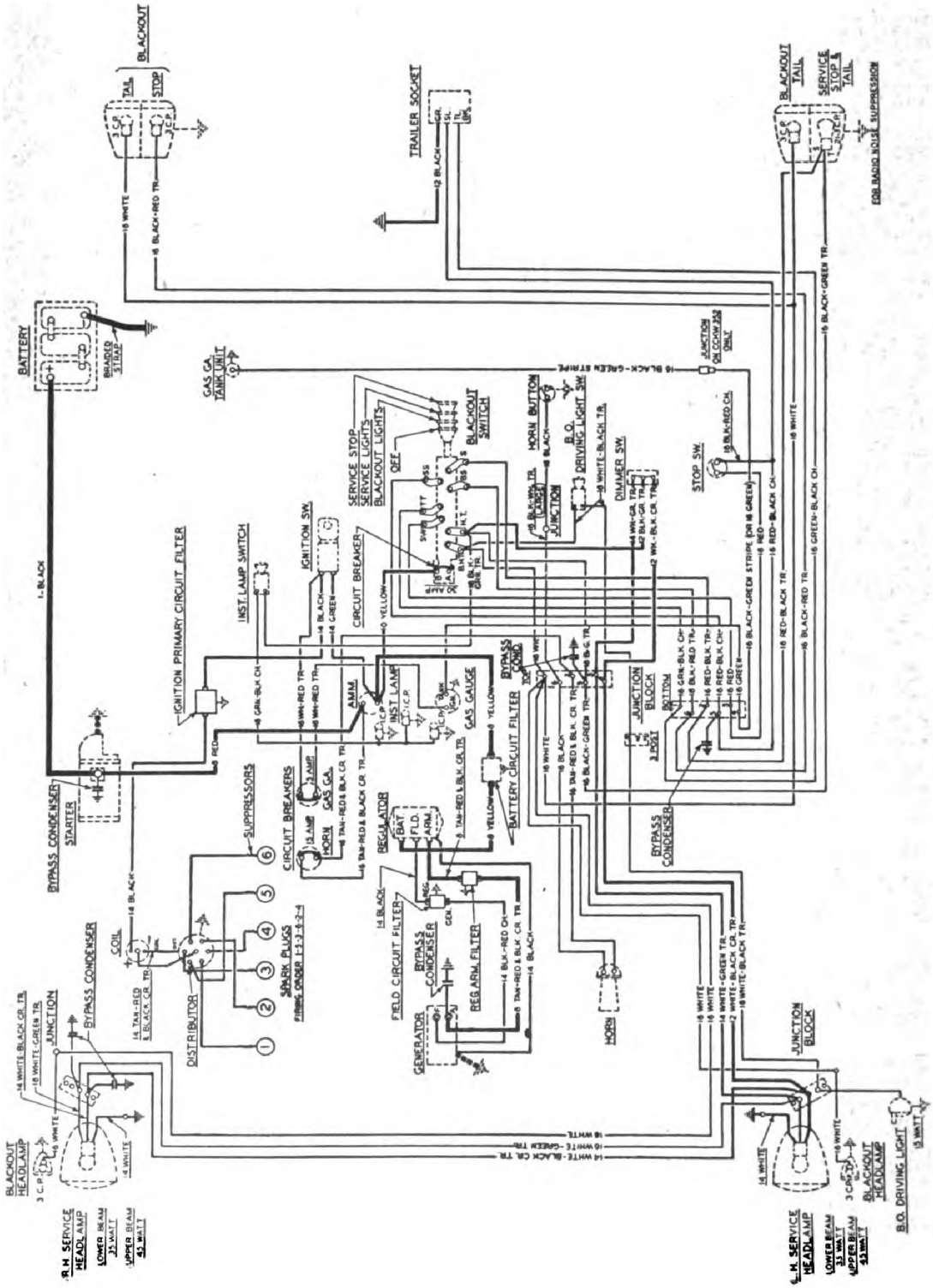

Figure 146. Wiring Diagram.

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the ammeter, single feed wires which are built into assemblies run directly through switches to all electrically operated units except the cranking motor. When the engine is not operating, the switch which controls any electrical unit except the starter is closed, current flows from the battery through the ammeter, fuze, or circuit breaker, through the switch and single wire into the wiring assemblies, and then through the unit to ground.

When the engine is running, current will be furnished by the generator for any electrical units that may be turned on. Any current not required by the units goes to the battery to charge it. If more current is required by the electrical units than the generator puts out, additional current is drawn from the battery.

Light Switch. The exterior lights on most vehicles are controlled by a four-position push-pull switch. Starting from the 'off' position, pulling the knob of the switch out to the first notch provides current for the blackout headlights, tail light, and stop light. A safety button must be depressed before the switch can be pulled beyond the blackout position. This is to prevent any lights visible from the air to be accidentally turned on during a blackout. As the main light switch is placed in the various operating positions, other light switches such as instrument panel, stop light, and dimmer, are operative and will control their respective lights.

Head Lamps. In head lamps of the older type, means are provided for focusing and directing the lamp. (Focusing means bringing the filament of the bulb to the focal point of the reflector; directing means aiming the lamp properly.)

Later developments brought into general use a two-filament or 'pre-focused' bulb. Its position is fixed with respect to its mounting socket at the rear of the reflector so that the filaments remain at the proper focus. To improve the lighting of the roadway, it is necessary only to 'direct' the lamp.

Bulbs. Bulbs are of various sizes depending upon their use. The head lamp bulb contains two filaments; a larger filament is placed close to the focal point to obtain a good beam for driving on the highway, while a second filament is placed just off the focal point so that a depressed beam is obtained for passing other approaching cars. Depressing the beams is accomplished by a foot-operated dimmer switch that switches the circuit from one filament to the other.

Sealed Beam. A superior head lamp that has recently been adopted is the 'sealed beam'. In this lamp the lighting elements, reflector, and lens are assembled as a sealed unit. The lighting elements (filaments) may or may not be enclosed in the conventional glass bulb within the unit. Failure of a lighting element requires replacement of the sealed unit.

Stop Lamps. The function of the stop lamp is to warn any following vehicle that the driver intends to stop. The stop lamp is designed to go on whenever brakes are applied to slow down or stop the vehicle.

Two types of stop lamp switches are in use, one for use with mechanical brakes and the other for use with hydraulic or air-operated brake systems.

The operation of the stop lamp switch must be coincidental with the operation of the brake pedal. In the mechanical switch, the contacts are closed by a linkage connection to the brake pedal. The hydraulic switch unit is connected directly to the master cylinder so that when the brakes are applied the fluid pressure will operate the switch. The stop lamp switch on the air brake systems is operated from the air pressure of the system.

Blackout Lamps. Blackout lamps are designed to furnish a diffused light beam of limited illumination when driving under blackout conditions and to keep these rays of light from being visible to air observers.

Instrument Lamps. Ordinarily, indirect lighting is used for the instrument lamps, which light whenever the lighting switch is in any of the 'on' positions. Many vehicles are equipped with an instrument lamp switch so that the instrument panel lamps can be turned off when desired.

The brilliancy of some instrument panel lights is controlled by a rheostat.

Spot Lamps. These lamps are similar in construction to the head lamps. They are designed to project a beam for a great distance ahead and are constructed so that the light can be aimed by the vehicle operator (in tanks, by the car commander).

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LIGHTING SYSTEM; TANKS

The operation of the lighting system is basically the same for tanks as for wheeled and half track vehicles; however, the location and manner of installation vary.

Head Lamps. A socket is provided above each front fender for installation of the combination driving and blackout position lights. The lights should be kept in the tank except when they are to be in operation. A plug is provided to weather seal the socket and should be kept in the socket when the lights are not installed. The plug is chained to a protective housing which is attached to the head lamp guard and in which the plug is stored when not in use.

The driving lights are focused by means of a focusing screw on the back of the lights.

A special blackout hood is provided for each driving light.

Tail Lamps. The tail lamps are combination lamps: The rear left is a combination stop, service, and blackout lamp; the upper lens is the blackout light. In the rear right lamp, the lower lens is the blackout light and the upper lens is the blackout stop light. Both stop lights are controlled by switches connected with the steering hand levers. No stop signaling will be seen until both hand levers are pulled, indicating a slowing down or a full stop.

Protective Devices. Because of heavy drain on the storage battery by lights and electrical units and the damage from short circuits, overload circuit breakers and fuses are used as protective devices.

The overload circuit breaker is designed to open the circuit when a current in excess of what it is designed to carry passes through it. Circuit breakers are of various types, namely; vibrating type, thermostatic, and thermostatic-magnetic.

If a short occurs in the circuit, all of the above type circuit breakers have a pair of contacts that are caused to open and close rapidly, either magnetically or thermally, or by a combination of both depending upon their construction. After the contacts start operating, approximately 5 amperes of current flows which keeps the contacts vibrating. This causes a buzzing sound which continues until the trouble is eliminated. Thus the battery is prevented from rapidly discharging or causing any damage to the system.

Overload circuit breakers in use on tanks are operated thermally; but once the circuit is open the contacts stay open until they are closed by pushing on the reset button. An adjusting screw is incorporated in this type circuit breaker for adjusting the contacts whenever necessary. If this circuit breaker continues to throw out after being reset, the circuit under its control must be checked for an overload or a short circuit.

Fuze. A more common method of protection is to use a fuze in the circuit. Whenever there is an excess current through the circuit, the fuse will burn out and open the circuit. The short circuit should be removed before the fuse is replaced.

Maintenance of Lighting Systems. All wiring and connections in the lighting system should be checked periodically. The wiring should have good insulation and be free from oil and grease; the connections should be clean and tight. The most common troubles experienced with the lighting system are; insufficient illumination, frequent burning out of bulbs, and incorrect adjustment of light beams. The difference of a few degrees in the aiming adjustment of head lights will determine the effectiveness of the head light beam. The aiming adjustment of the head light should be checked periodically or whenever the light beam is ineffective.

Insufficient illumination is usually caused by blackened bulbs, dirty lenses, a low state of charge of the battery, or high resistance in the lighting circuit. Frequent burning out of bulbs usually is caused by excessive voltages due to an improperly adjusted generator regulator.

Dirty lenses absorb a large amount of light and therefore decrease light output. Lenses are easily cleaned with water. Inside sealed beam unit lenses cannot be cleaned because they are sealed to the reflector.

A sprung or bent reflector will distort the light beam and make it impossible to correctly dim or direct the beam. The only remedy is to replace the unit.

The electrical condition of the wiring and connections can be tested by checking for voltage drop in the system with a voltmeter.

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ELECTRICAL INSTRUMENTS AND ACCESSORIES

The instrument panel is usually placed so that the instruments may be easily read by the driver. They inform the driver of the approximate speed, engine temperature, oil pressure, rate of charge or discharge of the battery, amount of gasoline in the supply tank, and distance traveled. Controls such as the choke, extra sockets for plugging in trouble lamps, electric fans, and starter and heater switches may be mounted on the instrument panel.

Ammeter. The ammeter is used to indicate the amount of current that is charging or discharging the battery. It does not give an indication of the total generator output because other electrical units in the electrical system besides the battery are supplied by the generator.

At low engine speed the ammeter may show a negative or discharged reading. If the ammeter consistently indicates discharge during normal operation when little or no current is being used, either the generator regulator or the generator itself is not functioning properly. In either case the battery is not receiving current and will quickly discharge unless the trouble is eliminated.

Voltmeter. The purpose of the voltmeter is to indicate the condition of the battery. In vehicles containing radios, during standby radio operation when the engine or auxiliary generator is not operating, it is important that a frequent check on battery voltage be made to prevent discharging. Whenever the battery voltage of a 12-volt system drops to 11½ volts the battery should be charged by the auxiliary generator, or, in the absence of one, by the engine generator.

Horns. The most common type of horn is the vibrating type in which the general principle of operation is the same as that of a vibrating coil. A vibrating diaphragm is operated by the coil which also operates the contacts that break the circuit. Magnetism from the coil pulls the diaphragm toward it when the contacts are closed. The contacts are then pulled open by the coil, reducing the magnetism and allowing the diaphragm to return to its normal position. When the contacts are closed again a new surge of current induces magnetism in the coil and starts a second movement of the diaphragm. This cycle is repeated rapidly. The vibrations of the diaphragm within an air column produce the note of the horn.

Tone of the horn is changed by turning an adjusting nut.

If dual horns are used, one horn with a low pitch may be blended with another horn of higher pitch.

Inasmuch as the total current required to operate a horn is approximately 12 amperes, dual horns are operated by a relay switch and controlled by the horn button.

Sirens. On tanks and large prime movers, sirens are used instead of horns for traffic signaling. The siren is operated by a foot switch. The siren is turned by a small electric motor.

Fuel Gages. Most fuel gages are electrically operated and are composed of two units: the indicating unit which is mounted on the instrument panel and the tank unit which is mounted on the fuel tank.

In vehicles having more than one fuel tank, manipulation of a toggle switch will enable the gage to indicate the fuel in the right or left tank.

Oil Pressure Gage. An engine oil pressure gage consists of an indicating unit mounted on the dash and an operating unit mounted in the oil system of the engine. It indicates the pressure of the engine lubricating oil. The pressure may vary according to operating conditions but should be within the specified limits for that vehicle. However, if oil pressure should fall to zero while the engine is running, stop the engine immediately and determine the cause. This gage does not indicate the amount of oil in the crankcase.

Mounted near the oil pressure gage on the instrument panel of some vehicles is a red jewel-type light to signal the driver when the oil pressure drops below 8 pounds.

Engine Hour Meter. The hour-meter used on some tanks indicates the total number of hours that the engine has been in operation. The meter is installed with a pressure switch. When the required pressure is reached, the meter will start operating and will continue to operate whether the engine idles or is under full load until it is stopped.

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The pressure switch is installed in the oil pressure system by means of a 'T' connection near the oil pressure gage behind the instrument panel.

Warning Signals. A set of warning signals may be incorporated on the instrument panel to call the driver's attention to low oil pressure in the engine, transmission, or transfer unit or to warn of engine overheating.

Compass. A compass is mounted on some vehicles. Necessary illumination, controlled by a toggle switch on the instrument panel, is provided by a small lamp. The bulb is accessible for replacement by removing the upper knurled plug.

A means of compensation for the attraction of nearby metal parts is provided within the instrument. For compensation instructions see TM 9-731A.

NON-ELECTRICAL INSTRUMENTS, SPEEDOMETER

Speedometer. The speedometer indicates road speed of the vehicle in miles per hour. It is operated by means of a flexible cable and records the total miles operated by the vehicle and 'trip' miles. The trip indicator can be cleared by turning a knurled button located on the under side of the speedometer head.

Tachometer. The tachometer registers the revolutions per minute of the engine. It is driven by a flexible cable. It can be used to check carburetor idle speed adjustment and governor adjustment for maximum engine speed.

RELAYS

Construction and Function. Relays are similar in construction to the cutout relays used in generator regulators. They are used to open and close circuits electrically. Horn relays connect horns through the relay points to the battery; lighting relays connect the lights through the relay points to the battery; solenoid relays connect the solenoid through the relay points to the battery. Note relay in figure 144. In each case, extra wiring is eliminated and a more direct connection is possible with the battery, so that less voltage drop is obtained. All relays are adjusted in a similar manner. No disassembly is possible; any defect requires complete relay replacement.

Test and Adjustment. Connect relay in series with a battery and a variable resistance. Apply increasing voltage and note relay closing voltage. Adjust air gap, point opening, and closing voltage to specifications.

For further information, refer to TM 9-1825A or TM 9-1825B.

Radio Interference Suppression. *General.* When the engine of a vehicle is running, the electrical system of that vehicle is a source of radio interference. This is because of radio waves of varying frequencies and wave form being broadcast, due to high voltage surges in various circuits. These radio waves interfere with the radio equipment in that vehicle and any other nearby radio equipment. In order to reduce such interference vehicles are equipped with a suppression system consisting of various types of suppression units connected throughout the electrical system.

The high voltage surges of the ignition system cause interference in two ways. First, some of their energy is radiated from the high tension leads, is picked up by the radio aerial, and produces interference. Second, some portion of the energy (in the form of high current surges) is sent from the coil primary back into the battery. If the same battery supplies power to a radio receiver, these high current surges will cause interference.

The generator is a source of radio noise. As each commutator bar passes under a brush, a tiny arc occurs which causes interference in radios by radiation and by being conducted to the battery and then to the radio of the vehicle. The generator regulator is also a source of radio interference.

Shielding and Filters. The above mentioned radio interference may be eliminated or reduced by the use of shielding and filters.

(1) *Shielding.* Shielding is accomplished by incasing wires of the electrical system in a metal braid or solid shielding, and grounding them at both ends so that none of the interfering radiation can escape. Shielding should be inspected regularly. All connections should be kept clean and tight. Any holes should be filled or the shielding replaced.

(2) *Filters.* Filters consist of an induction coil and one or more condensers

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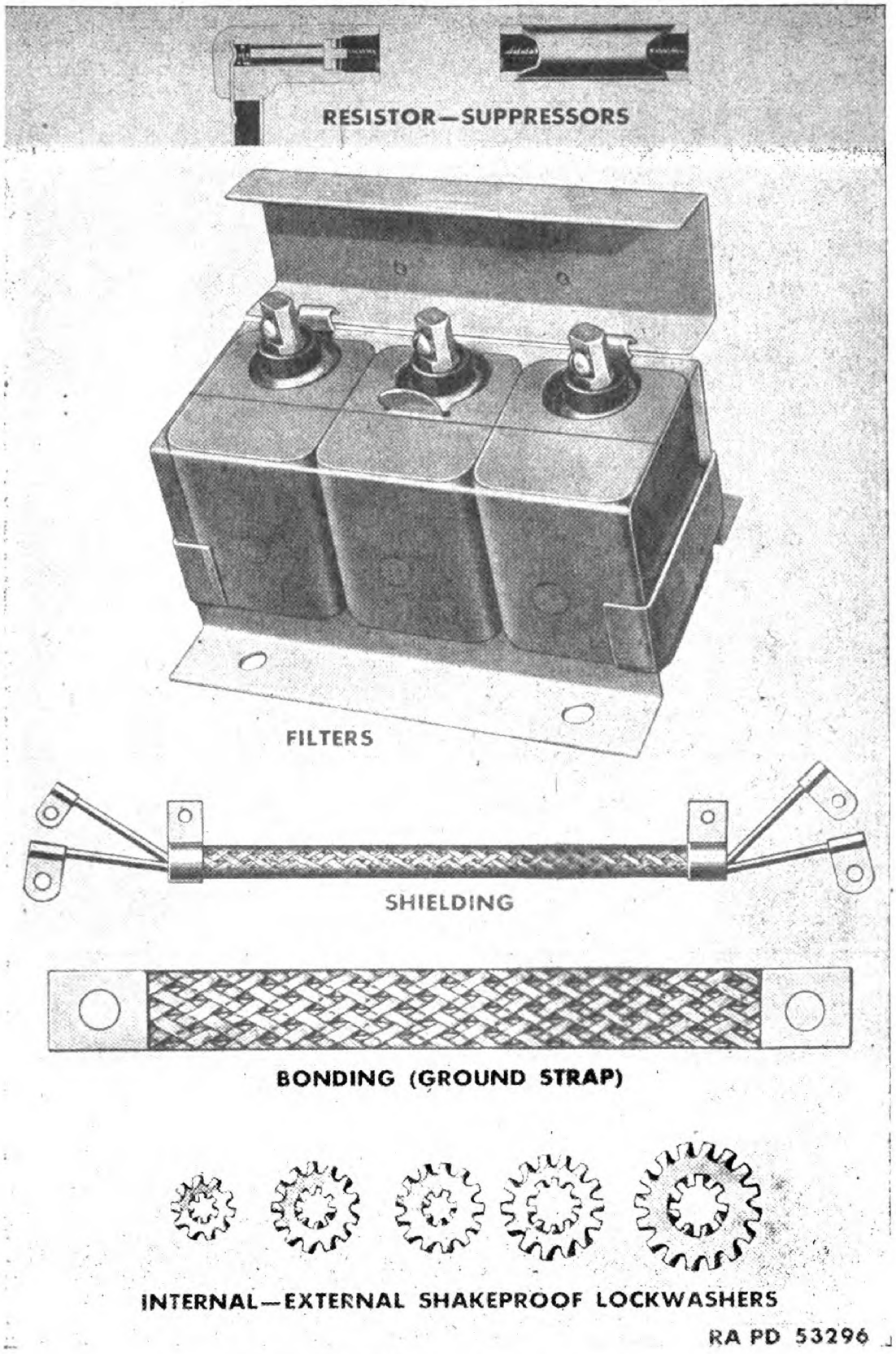

Figure 147. Radio Interference Suppression.

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incased in a metal shield and so constructed that when connected in the circuit the coil is in series with the circuit and the condenser connects between the circuit and ground. The filter should be connected as near the source of interference as possible. The induction coil passes low frequency currents readily but opposes high frequency currents and will not pass direct current. This results in smoothing out the flow of current.

Filters should be checked for continuity and defective condensers.

Suppression Type System. On some vehicles wires are not shielded between electrical units, but instead, filters as described above are placed at various points in the electrical system, where they operate to prevent radio interference.

(1) *Suppressors.* A suppressor, which is designed to suppress radio noise, may be used at each spark plug and at the distributor center high tension terminal.

(2) *Bonding.* Bonding is an electrical contact of extremely low resistance between two or more metal parts. Various points of the vehicle are bonded by means of tinned copper braid ground straps. These straps are fastened to their respective points by cadmium-plated bolts and nuts or screws and internal-external shakeproof lock washers. Fenders, shields, and other sheet metal parts are fastened together by means of cadmium-plated fastening bolts and internal-external shakeproof lock washers; these lock washers, when drawn up tight, bite into the metal surface which they contact and form a good ground. The purpose of bonding is to insure that metal parts have a good ground for grounding the radio waves picked up by them instead of radiating them off into space.

(3) *Servicing and Replacing Bonded Parts.* Before replacing bonded parts, clean off all paint and dirt from the mounting surfaces, tops and bottoms of both ends of bonds, and their placement position on the vehicle. Replace any broken or frayed bonds. Exercise special care when replacing bonded parts to be sure they are installed in exactly the same manner as they were before removal. Install shakeproof lock washers in their original sequence.

AUXILIARY GENERATORS

Homelite Auxiliary Generator, Models HRUH-28 and HRH-28. The Homelite auxiliary generator models HRUH-28 and HRH-28 are used in medium tanks for charging batteries when the engine is not running, and to supplement or aid the battery during periods of heavy current draw.

The Homelite auxiliary generator is an integral, gasoline-engine driven, direct current power plant with a capacity of 1,500 watts at 30 volts. It consists of an electric generator with control box attached, directly coupled to, and driven by, a gasoline engine. This assembly is mounted on four shock absorbing feet. On some installations, a metal duct containing the muffler is included for the purpose of carrying off engine heat from the crew compartment in hot weather and as an aid in preheating the main engine compartment in cold weather.

This unit has a two stroke cycle engine. Homelite auxiliary generator models HRH-28 and HRUH-28 are the same except that model HRH-28 has an inverted cylinder while model HRUH-28 has an upright cylinder.

The ignition in the Homelite engine is by a high-tension flywheel type magneto mounted as a complete assembly at the end of the magneto shaft.

The heating ducts vary according to installation.

The generating unit is compound wound. It has a series winding for starting and a shunt winding for generating. The generator output is controlled by a generator regulator.

Lubrication. Lubrication of the entire engine is obtained by mixing oil with the gasoline. It is extremely important that the oil be thoroughly mixed with the gasoline by stirring before pouring it into the fuel tank. Mix fuel in the following manner: Pour ⅜ pint of oil, engine, SAE 30, into a 1-gallon measure. Pour 1 to 2 quarts of fuel into the measure and stir with a clean stick until it foams. Then fill the measure with fuel, stir again, and pour it into the fuel tank. If oil, engine SAE 30, is not available, SAE 20 to 50 may be used. It is important that the oil and fuel be mixed in the proper proportions, as excess oil will cause a fouled spark plug and excess carbon. Insufficient oil will cause heating of the engine and eventual sticking of the piston in the cylinder. Containers for handling fuel must always be clean.

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Starting and Stopping. Before starting (the fuel tank supplied with fuel mixed in the prescribed manner), open the shutoff cock on the fuel filter. In cold weather, close the carburetor choke. The choke is open when the lever is against the stop pin. Depress the starting button on the control box or start manually with a rope. Release the button as soon as the engine starts and immediately open the choke partially, easing to full open position as the engine warms up. If the engine does not start within 10 seconds or about 12 pulls with the rope, it may be flooded. To relieve this condition, open the drain cock on the bottom of the crankcase and turn the engine over several times to expel raw fuel.

In warm weather do not close the choke throttle. The automatic governor keeps the engine operating at proper speed at all loads.

To stop the engine, press the red stop button and hold it firmly until the engine stops.

Maintenance. At each major overhaul of the vehicle (or whenever necessary) the auxiliary generator should be overhauled in the prescribed manner, inspecting all parts and repairing and replacing any parts that may be necessary.

The most important things to insure proper engine performance are proper ignition, carburetion, and compression. If trouble develops look for it in this order.

Spark Plug. The spark plug should be removed, inspected, cleaned, and adjusted every 50 hours of operation.

Magneto. The high-tension magneto should be inspected every 100 hours of operation, and the breaker points cleaned and adjusted Inspect the condition of the leads and parts and repair or replace any parts necessary.

Carburetor. Keep strainers and fuel system clean. The carburetor should be kept properly adjusted as too rich a mixture uses excessive fuel, tends to foul the spark plug, and causes excess carbon.

Carbon Removal. It is important that the cylinder ports be kept free of carbon since an excess will reduce the engine power to a marked degree.

Governor. The governor is set at the factory for that particular unit and requires no adjustment.

Generating Unit. The generating brushes should be inspected for wear every 300 hours of operation. Inspecting, testing of parts, and maintenance of this generating unit is the same as previously prescribed for generators except that the armature can not be tested for shorts by use of a growler and hacksaw blade as it would show shorts in all windings. It must be tested with a growler and a low reading ammeter by placing the ammeter leads on No. 1 and No. 3 bars. Test all of the windings in this manner.

For further information refer to TM 9-1731K.

Homelite Auxiliary Generator Models HRA and HRUA. The HRA and HRUA model Homelite auxiliary generators are the same as Homelite models HRH-28 and HRUH-28 except that the generating unit is of the alternating current type with rated output of 1,500 watts and 115 volts.

These power plants are used on shop trucks to furnish power for lights and for operating electric drills and equipment.

Generating Unit. The generating unit has two slip rings for AC output and a commutator for DC for self-exciting the fields. Generator output is adjusted by means of a rheostat in the field circuit.

Maintenance. Maintenance is the same as for other generators.

Delco Auxiliary Generator. The Delco auxiliary generator is a self-contained, direct current engine generator for charging the battery when the engine or engines are idle, and to supplement or aid the battery during periods of heavy current draw. It is used in M5 light tanks and motor gun carriages having 12 volt electrical systems. It consists of an electrical generator and controls which is directly coupled to, and driven by, a one-cylinder 4 stroke cycle gasoline engine. The generating unit has a rated output of 12 volts and 750 watts. The engine develops 1.6 horsepower at 2300 rpm. It has battery ignition and uses engine oil of seasonal grade in the crankcase. The generating unit is compound wound. It has a shunt winding for generating and a series winding for starting. A cutout relay and voltage regulator are used in the generator-battery circuit to control voltage output. Whenever a heavy load is applied to the generator, it causes engine speed to decrease which results in decreased generator output, eliminating the need for a current re

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Starting and Stopping. In tanks and motor gun carriages the starting button is located in the fighting compartment. Press the starting button and hold it down until the engine cranks, begins to fire, and gains generating speed. As soon as the engine gains generating speed release the starting button. The engine is equipped with an automatic choke to facilitate starting in cold weather. There is no ignition switch. Ingition current is supplied by the battery during the cranking period.

In extreme cold weather, if improper lubricating oil or a too nearly discharged battery prevents the engine from cranking, it should be assisted with the cranking rope as follows: Wrap the cranking rope around the cranking pulley after anchoring the knotted end of the rope in the slot in the pulley. Press the starting button and at the same time give the cranking rope a quick pull. It may be necessary to repeat this procedure several times. *Caution:* The starting button must be depressed to establish the ignition circuit during the rope cranking procedure.

Occasionally, the battery may be discharged to the point where it does not have enough output to crank the engine but it does have enough energy to supply ignition current. In this case, it is necessary to 'isolate' the ignition circuit so that no battery current will feed back into the generator, and to crank the engine with the starting rope. Do not press the starting button during this procedure. After the engine starts, allow it to run long enough to charge the battery for a normal start.

When the battery is completely discharged, an outside source of ignition current must be provided. Twelve volts of storage batteries or 'hot shot' dry cells may be used.

To stop the auxiliary power plant generator, press the stopping button and hold it down until engine stops.

Maintenance. At each major overhaul of the vehicle (or whenever necessary) the unit should be overhauled in the prescribed manner. Trouble shooting, repair, and servicing of units on the Delco auxiliary generator should be performed in the same manner as on conventional type units.

For further information on the Delco auxiliary generator refer to TM 9-1727 F.

GYRO-STABILIZER

Purpose. The gyro-stabilizer is installed on tank guns to keep the gun in the aimed position *only while the tank is in motion.* When the tank gun is fired from a standstill, there is no need for a stabilizer for the weapon then takes on the characteristics of a field piece and is treated as such.

Before the gyro-stabilizer was installed on tank guns the pitching of the tank while in motion disturbed the gunner's aim. This was because the gun and sighting equipment followed the tank's motion, making it necessary for the gunner to constantly reaim his piece. The addition of the gryo-stabilizer reduces the gunner's operation of the elevating handwheel to a minimum.

During the tank's progression, it will deviate from the fixed position due to elevation and depression of terrain, making it necessary for the gunner to make very slight corrections to compensate for them. These corrections are so slight in comparison with the reaiming of the unstabilized gun that it is possible for a good gunner to keep his piece aimed on the target at all times while the tank it pitching over average or average rough terrain.

The gun is freed from the tank turret as much as is practicable, so that the motion of the tank will not carry through to the gun. The gun and gun mount is suspended from the trunnion bearing which is the only fixed linkage between the gun and the turret. The gun is balanced on the trunnion bearing, and if it were possible to eliminate all friction in the bearing and keep the gun balanced, there would be no need for a gyro-stabilizer. The gun would remain in a fixed position in relation to the earth's surface regardless of the motion of the tank. *The gyro-stailizer only compensates for the friction in the trunnion bearing and unbalancing forces on the gun.*

Operation. A cylinder and piston, one end attached to the gun and the other fastened to the turret, serve as a *flexible* linkage between the breech end of the gun and the turret. If a force tends to push downward on the breech end of

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the gun, an equal hydraulic force is exerted upward against the piston holding the gun in place. If a force pushes upward on the gun, hydraulic force will push downward on the piston holding the gun in position.

Two pumps are required to supply pressure to the cylinder and piston, one pump supplying pressure downward on the piston and the other applying pressure upward on the other end of the piston. These hydraulic pressures must operate independently of each other. A dual, gear-type, oil pump driven by an electric motor supplies hydraulic pressure to the cylinder and piston. The pressure is delivered to the cylinder and piston in the correct amount by magnetically controlled valves.

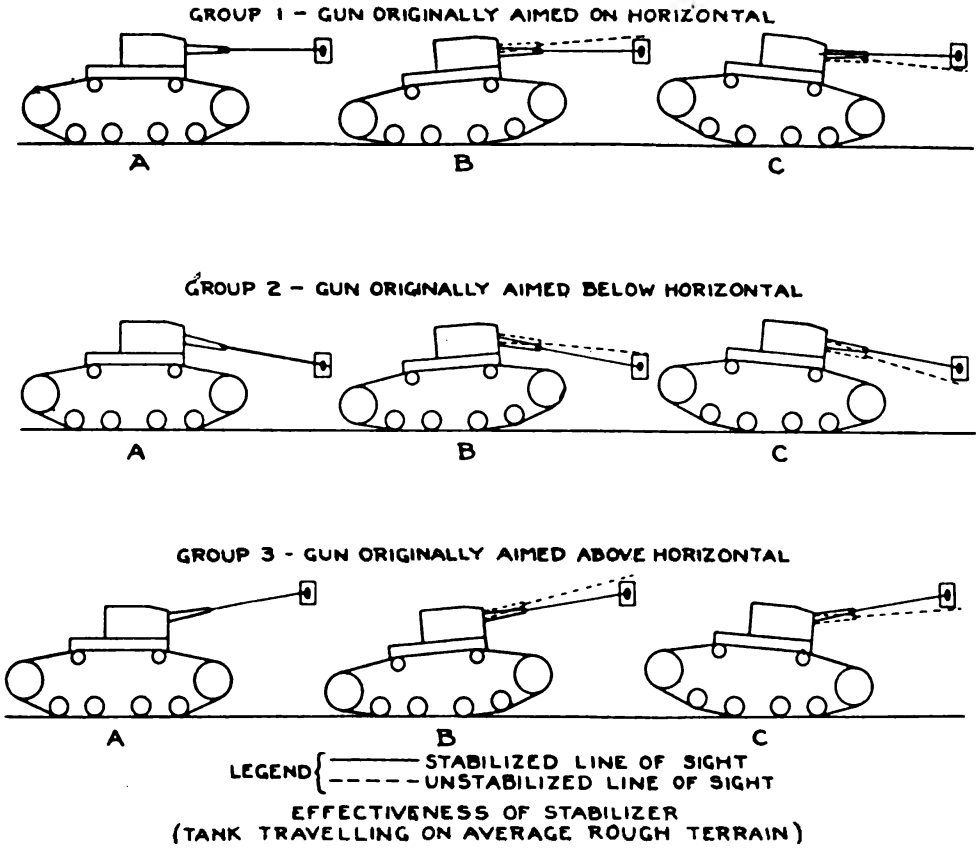

Figure 148. Effectiveness of Stabilizer.

The apparatus that determines how much pressure should be exerted against the proper end of the cylinder and piston is the gyro control mounted in the gun mount. Within the gyro control there is an electrically driven gyro which tends to maintain a set position in relation to the earth's surface. Movement of the gun off the aimed position will apply a force to the gyro and cause it to move into a set of silverstats, which control the amount of current flowing through the magnetic valves in the oil pump. If the force applied to the gyro through the gun is slight, the movement of the gyro will be slight, closing only a few of the silverstat leaves and permitting a small amount of current to flow through to the magnetic valve. With increasing force, the movement of the gyro is greater, closing more silverstats and allowing additional current to flow through to the magnetic valve.

There are two sets of silverstats, one controlling current to the magnetic valve which supplies pressure to the top of the piston, and the other controlling current to the magnetic valve which supplies pressure to the bottom of the piston. If the unbalancing force is exerted downward on the breech end of the gun, the gyro will move in one direction, contacting one set of silverstats. If the force of unbalance is exerted upward on the breech end of the gun, the gyro will move

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in the opposite direction, contacting the other set of silverstats. The gyro is adjusted to move only enough to compensate for the force exerted against it. The gyro control is so sensitive that it takes very little movement of the gun to operate it. The gyro-stabilizer controls the gun only in the vertical plane.

In order to elevate or lower the gun it is necessary to change the angular position of the gyro control in relation to the gun. This is done through the gear box, which is attached to the gyro control and is connected to the handwheel through a flexible shaft. The gunner merely turns the elevating handwheel, which changes the position of the gyro control, putting it into operation. When elevating the gun in this manner, there is no direct gear linkage between the gun and the elevating mechanism that is used to elevate the gun in manual operation.

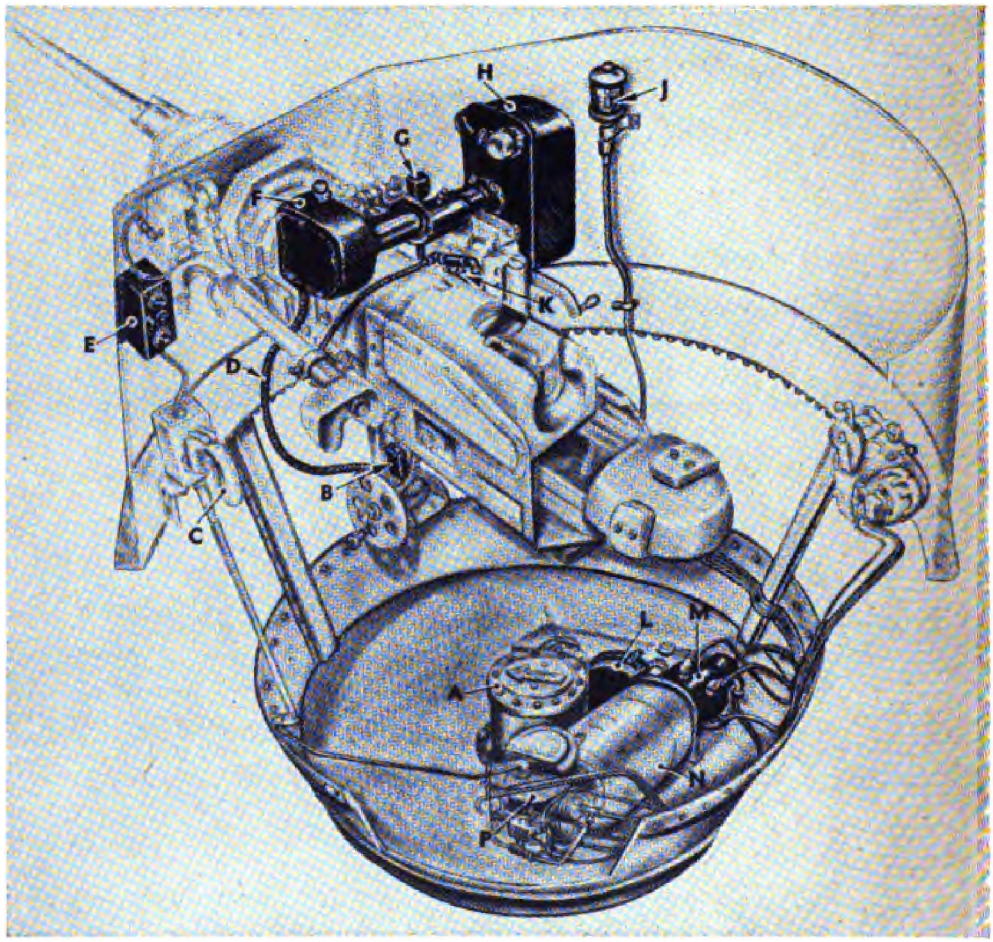

Figure 149. Complete Stabilizer—Installation.

A—Ring, Collector, Turret
B—Switch, Disengaging
C—Handle, Control, Traversing
D—Shaft, Flexible
E—Box, Control
F—Gear Box and Mounting Bracket
G—Cylinder and Piston
H—Gyro Control
J—Reservoir
K—Switch, Recoil
L—Switch, Master
M—Pump, Oil
N—Motor, Electric
P—Pump, Hydraulic Traverse

Sensitivity of stabilizer action is controlled by the stiffness rheostat located in the control box. The stiffness rheostat permits a variable choice of current to flow through the silverstats. The gunner selects the proper amount of current to operate the gyro-stabilizer at its maximum efficiency and leaves it at that setting.

When the gun fires, there is a great amount of unbalance due to the tube moving back in recoil. To aid the gyro-stabilizer in keeping the gun on the aimed position during firing, a separate circuit has been added that operates independently of the gyro control. When the gun starts into recoil, it automatically closes a recoil switch. This sends current directly to a separate coil on the magnetic valve which controls pressure exerted against the bottom of the piston. During gun

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recoil the breech end of the gun has a tendancy to move down. The closing of the recoil switch controls pressure pushing upward on the piston and holding the gun in place until the breech of the gun contacts the recoil switch at the end of its counterrecoil travel and opens the circuit.

There is a recoil rheostat similar to the stiffness rheostat that controls the gyro control circuit. It is located in the control box. The gunner turns the recoil rheostat, selecting the proper amount of current flowing through the coil to keep the gun on the aimed position during firing. This selection is made through trial and error and once made is left at that setting.

Naturally the tank gun is not always fired when the tank is in motion. Therefore there is no need of a gyro-stabilized gun when firing from a standstill. The simple, mechanical gear elevating mechanism is best suited to the gun fired from a stationary position. The tank gun is equipped with a mechanical gear elevating mechanism that can be engaged and disengaged at will by a simple clutch lever. In order that the gyro-stabilizer and the manual elevating mechanism cannot both be in use at the same time a disengaging switch has been installed on the elevating mechanism that opens and closes automatically when the clutch lever is operated. When the gun is engaged in the manual elevating position, the switch is in open position cutting out the current flowing through to the silverstats and making the gyro-stabilizer inoperative. The pump and gyro can be in operation during manual elevating position without applying controlled pressure to the cylinder and piston. This enables the gunner to switch from manual to gyro-stabilizer action quickly by merely operating the clutch lever.

Operation Instructions:

1. The oil level reservoir must show at least two-thirds full of oil at all times.
2. Take the hand elevating gears out of mesh and turn the hand wheel so as to place the gyro control unit in a vertical position.
3. Be sure the multi-prong plug is connected to the gyro unit.
4. Set the stiffness adjuster knob on the control box to zero.
5. Start the pump motor and the gyro unit by operating the necessary switch or switches. (If control box includes a push-pull switch, pull out to start gyro unit.)
6. Turn the stiffness adjustment to the right as far as possible. If the gun vibrates, decrease the setting slightly until vibration stops. (It may be necessary also to change the stiffness adjustment slightly from time to time during operation.)
7. The gun is elevated or depressed by turning the elevating handwheel.
8. Set the recoil adjuster knob on the control box to No. 5 position.
9. After firing, change the recoil setting if necessary to keep the gun on the target. If the breech drops, increase the setting, and if it rises, decrease the setting.

Cautions. Observe the following precautions:

1. Never push the gun up and down rapidly by hand as this may cause air to be drawn into the system around the piston rod.
2. The purpose of the stabilizer is to stabilize the gun while the tank is in motion. While standing still, the gun should be controlled manually.
3. When controlling gun elevation, avoid turning the hand wheel after the gun has reached its limits of elevation or depression. Continued turning of the hand wheel will cause an overload on the tank battery.
4. Keep all stabilizer parts greased.
5. Keep all stabilizer mounting parts tight.
6. To get best results the speed of the tank should be constant. This is best obtained by using the proper gear and running against the engine governor.
7. For further operating details, refer to instruction book and maintenance manual.

OILGEAR HYDRAULIC TURRET TRAVERSING MECHANISM

Purpose. The hydraulic turret traversing mechanism enables the tank gunner to rotate the turret at variable speeds in either direction with a minimum of effort. The tank turret is primarily a protective gun mount with the gun fixed to the turret in regard to traverse. To traverse the gun the entire turret must turn, carrying the gun crew around with it. This makes it unnecessary for the

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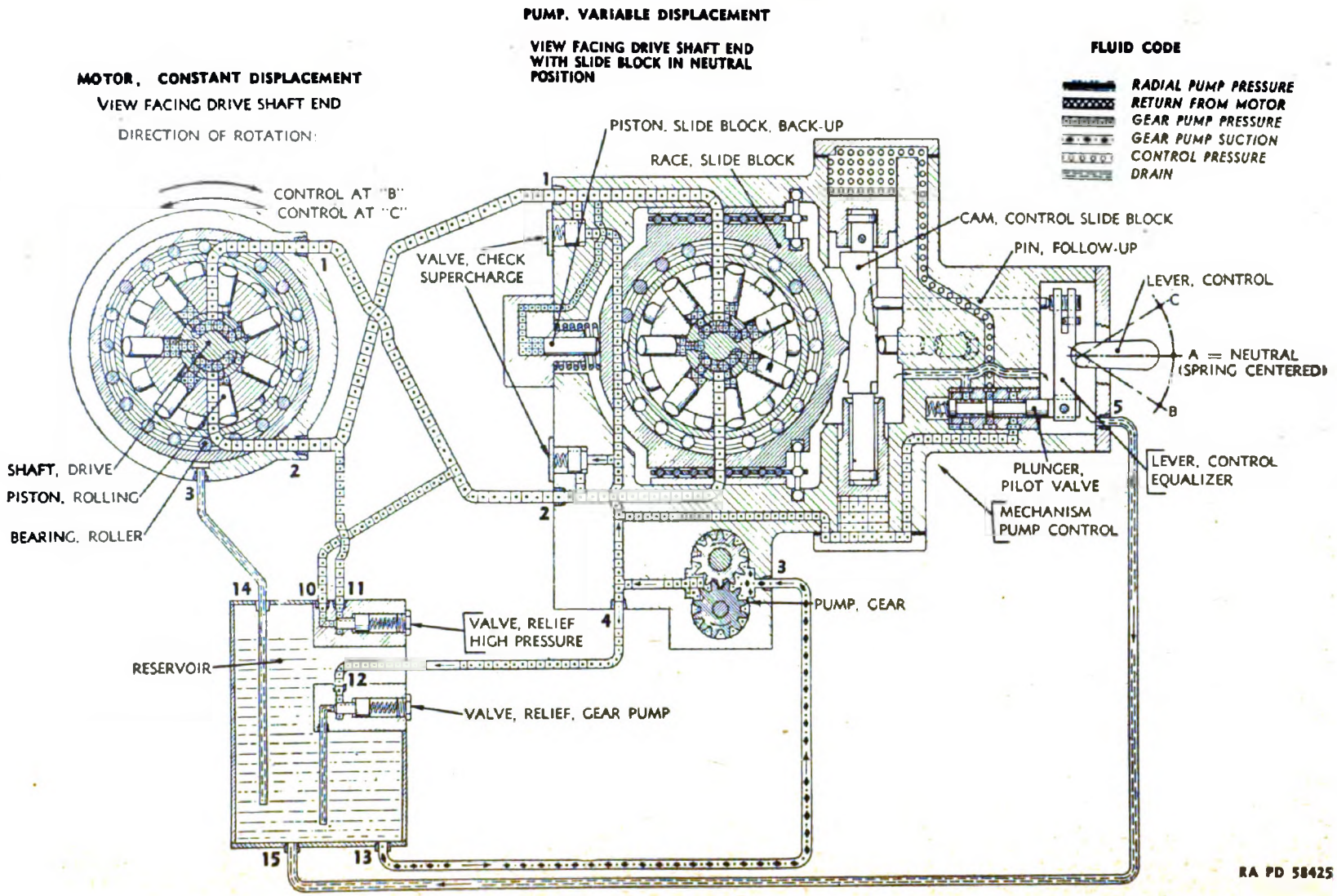

Figure 150. Hydraulic Turret Traversing Mechanism Oil Circuit (Neutral).

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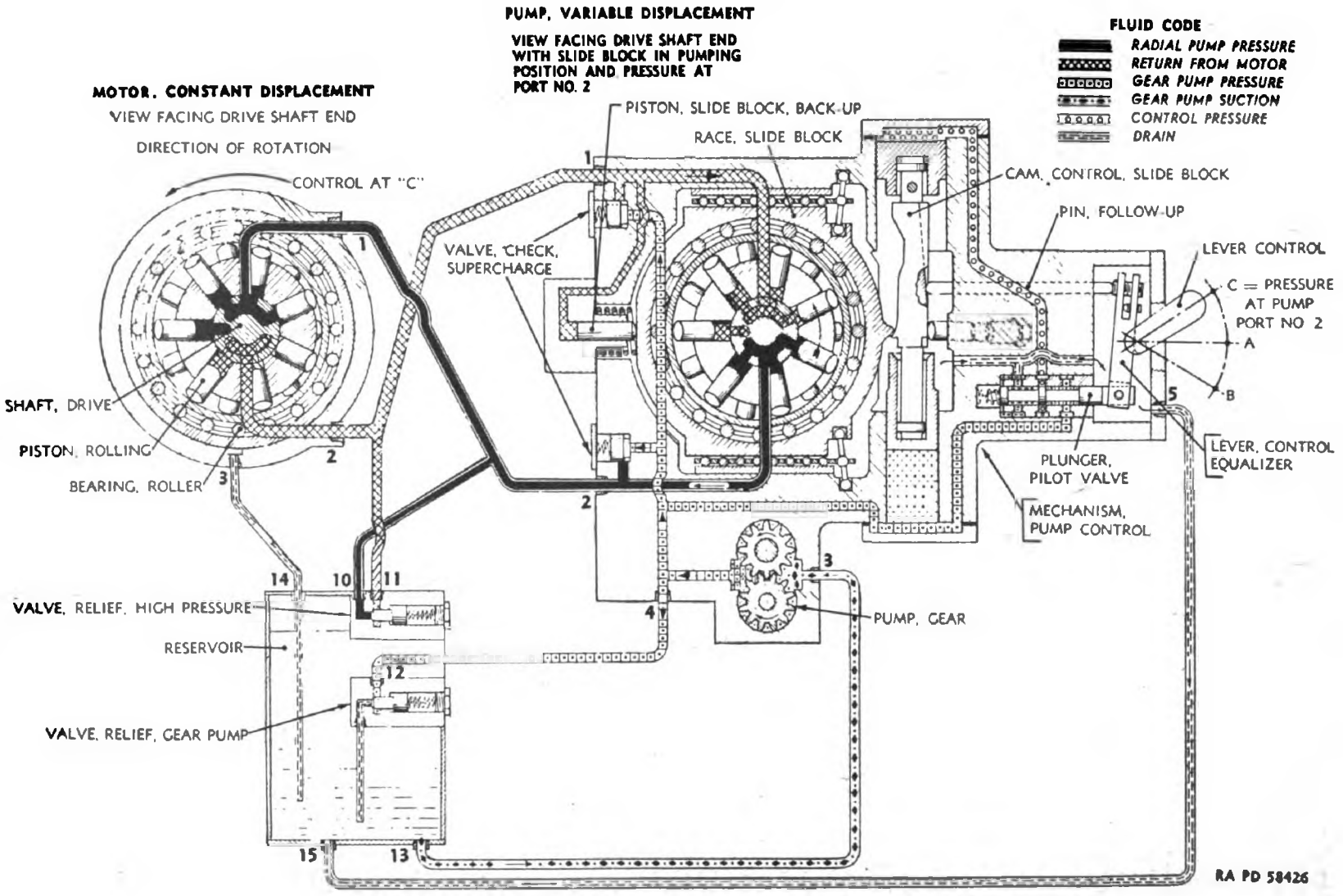

Figure 151. Hydraulic Turret Traversing Mechanism Oil Circuit (Counterclockwise Rotation).

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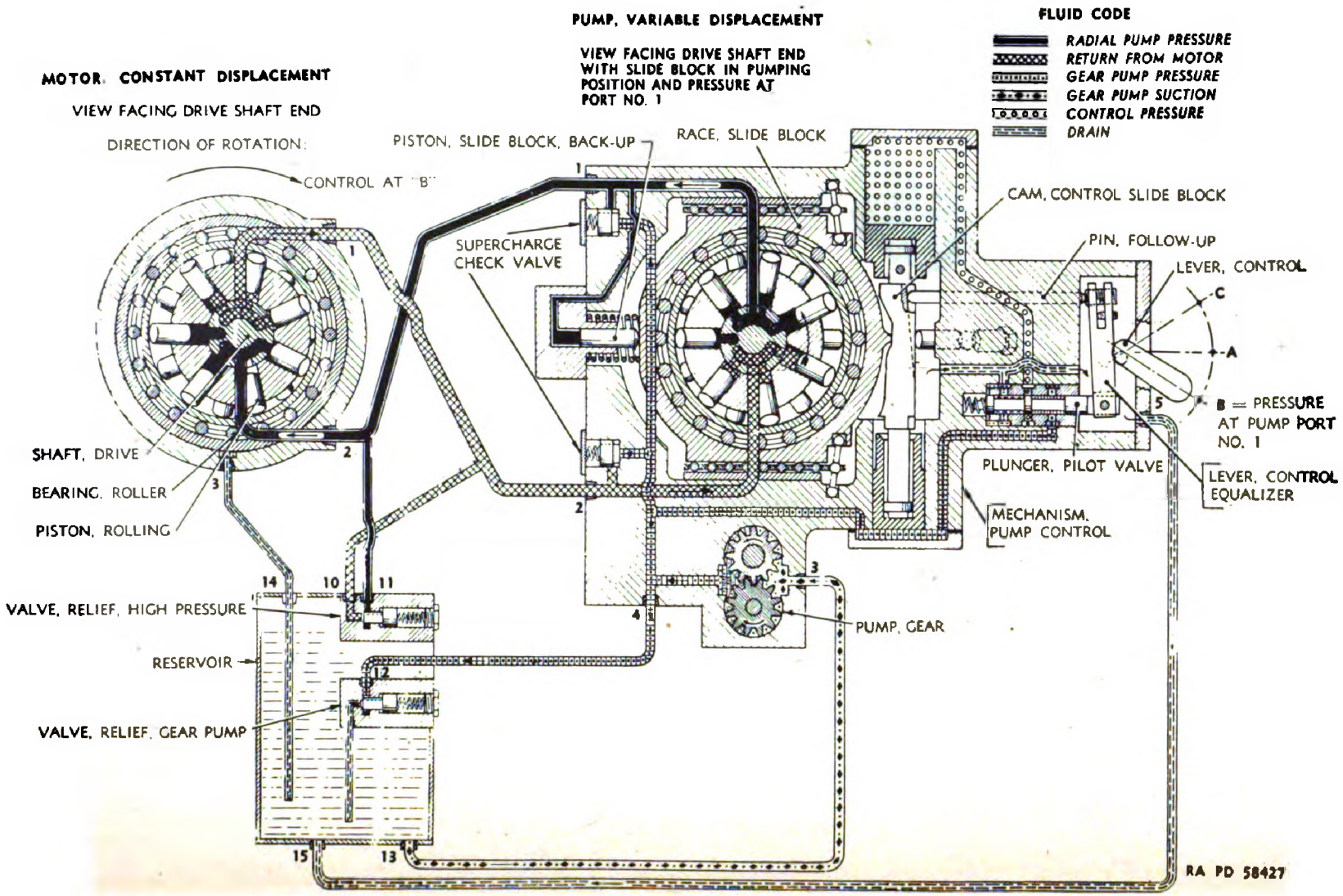

Figure 152. Hydraulic Turret Traversing Mechanism Oil Circuit (Clockwise Rotation).

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gun crew to change position during tracking and firing at a target. The turret can be traversed 360° in either direction either hydraulically or manually.

When tracking a target it is essential to traverse the turret smoothly without any disturbing influences to slow or speed the motion. At times, rapid acceleration is needed to bring the gun on a target. The hydraulic traversing mechanism rotates the turret smoothly, at the required speed, and is capable of rapid acceleration and deceleration.

The gunner traverses the hydraulically driven turret by moving a control handle slightly. He is able to select any speed, up to maximum, by moving the control handle off the neutral position in one direction until the desired speed is obtained. The further 'off' neutral he positions the control handle the faster the turret will rotate. To turn the turret in the opposite direction, he turns the control handle to a position on the other side of neutral.

The turret can be traversed manually, but not as efficiently as with the hydraulically operated system. With the hydraulic turret traversing mechanism in operation the gunner can bring his gun around quickly onto a target and follow it accurately while the tank, or his target, or both are in motion.

Operation. The principal parts of the oilgear turret traversing mechanism are: the variable displacement pump, the contant displacement motor, the traversing gear mechanism and manual drive, the gear box adaptor, the oil reservoir, and the electric motor.

The electric motor drives the gear pump in the variable displacement pump housing. Oil is sucked from the oil reservoir by the gear pump which supplies hydraulic fluid to the piston cylinder radial pump and the pilot valve. Once the hydraulic system is charged with oil a gear pump relief valve, located in the oil reservoir, opens and discharges the surplus oil back into the reservoir until the radial pump or the pilot valve requires replenishing.

The piston cylinder radial pump, which is driven off the same shaft that drives the gear pump, is set within a movable race. When the race is set in an eccentric position it forces pistons into cylinders as the pump rotates. The pistons are forced out of the cylinders by centrifugal force where clearance between the pump body and the race permits. When the pistons are forced out of the cylinders oil is sucked in through a stationary port, and as the pump rotates the oil is carried around in the cylinders until the pistons are forced into the cylinders through gradually decreasing clearance between the pump body and the eccentric race. The piston on entering the cylinders force the oil out under pressure through another stationary port and carry it to the constant displacement motor. The constant displacement motor is a piston and cylinder radial assembly as is the radial pump except that it has a fixed eccentric race. Pressure entering one stationary port of the constant displacement motor forces the pistons out of the cylinders causing the motor body to rotate. When the pistons are out to their maximum travel, the oil in the cylinders leaves through another stationary port, allowing the eccentric race to bring the pistons back into the cylinders. The hydraulic fluid leaving the constant displacement motor is carried back to the entrance port of the radial pump to circulate through the system again.

The pistons in both the radial pump and motor are set at an angle so that the flat end of the piston will not contact the eccentric race. This angular position eliminates excessive friction and permits the free pistons to roll on the race without rubbing.

To reverse the direction of rotation of the constant displacement motor the position of the eccentric race within the variable displacement pump is changed so that the flow of oil is reversed (compare figures 151 and 152). The eccentric race within the variable displacement pump is called the slide block race.

The amount of pressure delivered to the constant displacement motor is governed by the distance of eccentricity of the slide block race. The further on eccentric, the more pressure delivery to the hydraulic motor. If the radial pump is centered within the slide block race, no circulation of hydraulic fluid will travel between the variable displacement pump and the constant motor because the pistons will not travel in and out of the cylinders. Gear pump pressure will open the supercharge check valves and keep the system supplied with hydraulic fluid. (See **Fig. 150.**)

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Positioning of the slide block race is obtained by a hydraulically operated pilot valve. The slide block race engages the graduated surface of the slide block control cam. Movement of the control cam will change the position of the slide block race through the graduated surface of the control cam. The slide block race is held firmly against the control cam by a back-up spring and piston.

Movement of the control cam is controlled by hydraulic pressure exerted against pistons on either end of the control cam. Pressure to these pistons is supplied by the gear pump. Constant gear pump pressure is applied to the smaller piston at all times. The hydraulic fluid behind the large piston is captured, and because oil is not compressible, the pressure against the smaller piston will not move the control cam. To move the control cam toward the large piston, oil must be metered out from behind the large piston allowing the pressure exerted against the small piston to move the control cam. To move the control cam toward the small piston, oil is metered in behind the large piston at gear pump pressure. Thus, pressure behind both pistons is equal, but because the large piston has a greater pressure area, the control cam will move toward the small piston.

Pressure metered to and from the large piston is controlled by the pilot valve. Manual movement of the control handle operates the equalizer control lever which moves the pilot valve plunger. The pilot valve plunger opens and closes ports which permit oil to be metered from behind the large piston when the control handle is moved in one direction off the neutral position. When the control handle is turned in the other direction off neutral position oil will be metered in behind the large piston under gear pump pressure.

When the control handle is held in one position the turret must maintain a constant speed. To obtain a constant speed while the control handle is in a set position, it is necessary to capture the oil behind the large piston to keep it from traveling further and increasing the speed of the turret. The control cam is stopped in an operating position by the follow-up pin contacting a grooved surface in the control cam and one end of the equalizer control lever. Movement of the control cam will operate the follow-up pin which equalizes the operating position of the equalizer control lever, moving the pilot valve plunger so that the ports leading to the large piston are closed, thereby capturing the oil and holding the control cam in a set position. Further movement of the control handle will put the pilot valve plunger in operation. The gunner is able to move the control handle slightly and maintain a smooth, steady, turret rotation as long as he holds the control handle in a set position.

There is a high pressure relief valve located in the oil reservoir. Two oil lines connect from the valve to the two high pressure lines leading to the constant displacement motor. If the hydraulic system becomes overloaded, the high pressure relief valve will open, allowing the hydraulic fluid to pass from one line to the other and by-passing the constant displacement motor. The oil will circulate through the variable displacement pump but will *not* flow back into the reservoir.

The moving parts of the variable displacement pump and the constant displacement motor are lubricated by the hydraulic fluid. Two drain lines return the excess oil back to the oil reservoir; one from the variable displacement pump and the other from the constant displacement motor.

The constant displacement motor is mounted on a traversing gear mechanism and manual drive and gear box adaptor. The hydraulic motor drives the turret pinion gear through a gear train within the gear box unit. The hydraulic motor can be disengaged from the gear train by a shift lever and the turret can then be turned manually.

The electric motor which drives the variable displacement pump also drives a stabilizer pump on the other end of the armature shaft. Both the turret traversing mechanism and the stabilizer depend on hydraulic fluid for lubrication of the units, therefore, care should be exercised before operating the electric motor. Both the turret traversing oil reservoir and the stabilizer reservoir should be inspected to see if there is sufficient oil in them.

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VEHICLE CHARACTERISTICS

A prime requisite when designating a military vehicle is to give the complete and correct nomenclature for that vehicle. Without standardized nomenclature, endless confusion would result from different individuals using different terms for the same unit. Standard nomenclature means a greater saving of time, a minimum of errors, and much less misunderstanding.

The term 'motor vehicle' includes all track laying, wheeled, and combination wheeled and track laying vehicles with chassis designed for cross country or road use. The vehicle derives power from a self-contained internal combustion engine. All trailers and trailed loads towed by motor vehicles are to be included in this term. It excludes vehicles designed for use on railroads or other trackage, and bicycles.

Vehicle Designation. When an expected need or existing requirement develops, automotive equipment must pass through various stages of development before it can be issued and used in the different services. Equipment that is being developed to meet approved military characteristics is classified as experimental, service test, or limited procurement.

Experimental types include equipment that is under development but has not progressed to the point where extensive tests have indicated that the unit has sufficient satisfactory military characteristics to warrant further tests as service test equipment.

Service test equipment includes units that have progressed beyond the experimental stage, have operated satisfactorily in engineering tests, seem to possess the desired military characteristics, and have been approved for issue in limited quantity to further service test the unit.

Limited procurement units of equipment have passed service tests but are not ready for classification as an adopted type until used by troops to determine their suitability and bring to light additional refinements in design.

Equipment in development stages is designated by naming the unit and following the name with the letter 'T', a definite number, and possibly the letter 'E' with a following number. The combination 'T3E1' indicates that the particular unit is in the development stage, is the third unit of the particular type, and has been modified one time. In the same manner most equipment that has been adopted and is in general use is designated by the letter 'M' followed by a number, a second letter 'A', and another number. The combination 'M5A1' indicates that it is the fifth adopted model with one modification. In the case of medium tanks, the letter 'A' and the number following it indicate the type of engine and the hull construction.

Army motor vehicles that have been adopted are classified into four main groups: general purpose vehicles, special equipment vehicles, special purposes vehicles, and combat vehicles.

General purpose vehicles are all-wheeled vehicles intended for the movement of supplies, personnel, ammunition, or equipment, or towing of guns, trailers, or semitrailers, and which are used by more than one service. They are used without modification to body or chassis to satisfy the general automotive transport needs of the various components of the ground and air forces, technical services, and other War Department agencies. This does not mean that a vehicle manufactured for civilian use has the same characteristics as an Army motor vehicle classed as a general purpose vehicle.

GENERAL PURPOSE VEHICLES

General purpose vehicles are designated by carrying capacity, model, chassis, cab, and body type.

The term 'chassis' is used to designate (as an assembly) the frame, springs, wheels, axles, transfer case, transmission, engine, and other units which contribute to the actual operation of the vehicle. Not included are the cab, fenders, body, winch, and other accessories and equipment mounted on or built into the chassis.

The chassis with which a motor vehicle is equipped is designated by giving the total number of wheels (dual wheels being considered as a single wheel for this purpose), with 'by' (x) inserted between th enumbers. Example: 6x6 (six by six), designating a vehicle with a total of six wheels, all of which are driving wheels.

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Trailer chassis types are designated by giving the total number of wheels on the vehicle and then adding the letter suffix 'W'. Example: 4W, designating a trailer with four wheels. The number of dual tires and wheels on a vehicle is designated by their number followed by 'dt', both in parenthesis. Example: (4dt) designates a vehicle with four dual wheels and tires.

Cabs may be designated as a conventional open or closed cab, or, open or closed cab-over-engine (C.O.E.). The term 'conventional' designates a cab mounted on the chassis at the rear of the engine with a removable hood to cover the engine. An open cab is a steel structure, with or without doors, with a fabric collapsible top often called a 'soft top'. The windshield may be folded flat. The conventional open type cab allows better visibility with the top off and the windshield down, dismounting of personnel is instantly accomplished, and the silhouette is lower. The closed cab is a fully enclosed cab, with the top as an integral part of the structure.

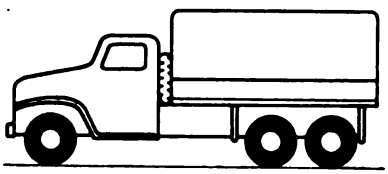

Figure 153. Six Wheels—All Wheels Drive.

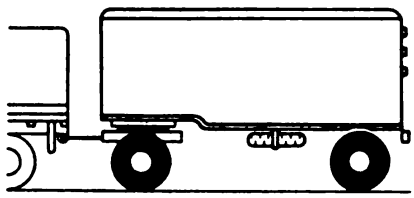

Figure 154. Four Wheels—Two at Front and Two at Rear of Trailer.

The cab-over-engine denotes a cab which is mounted over the engine in such a manner that the cab, windshield, and engine radiator are approximately in line with each other. An open or closed cab-over-engine type is the same general construction as the conventional cab.

The type of body with which a vehicle is equipped is designated by the general character of the body or the use for which the vehicle is designed. Example: SEDAN, passenger; TRUCK, cargo.

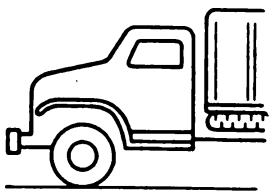

Figure 155. Conventional Cab-Closed.

The carrying capacity or payload capacity of trucks, truck-tractors, semi-trailers, and trailers is their capacity in tons expressed to the nearest half ton, except for the ¼ ton and ¾ ton types. Passenger capacity is the number of passengers the vehicle is designed to carry, including the operating personnel.

Model designation and make is carried on a nameplate which is generally attached to the instrument panel or front panel in a conspicuous place. Typical plates have the serial number, specific data on fuel and oil, road speed, gear shift arrangement, and identification of manuals pertinent to the vehicle.

Typical example of a general purpose vehicle would be: TRUCK, 2½-ton, 6 x 6, cargo. This designation indicates a conventional cab on a cargo truck having a two and one half ton carrying capacity with six wheels on the ground with all wheels driving.

All cargo trucks, passenger cars, trailers, and semi-trailers (when used for hauling cargo), motorcycles, and some amphibian vehicles are general purpose vehicles.

Special equipment vehicles are wheeled vehicles, the chassis of which are basically identical to those used in general purpose vehicles except for a special body with special equipment mounted in it. Special equipment vehicles are designated in the same manner as general purpose vehicles. The carrying capacity, model, chassis, cab, and body type are indicated in the same manner. Thus: TRUCK, 2½-ton, 6 x 6, machine shop, M-16, designates a machine shop truck,

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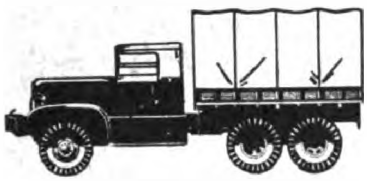
model M-16, a carrying capacity of two and a half tons with six wheels on the ground and all wheels driving. All types of repair shop trucks, wreckers, reproduction trucks with van body, and ambulances are considered special equipment vehicles.

Special purpose vehicles are wheeled, track-laying, or a combination of wheeled and track-laying. The chassis are designed or adopted for a special purpose and do not necessarily incorporate the standard chassis of general purpose vehicles. Special purpose vehicles utilize standard parts and assemblies unless they will not perform the required function. Special purpose vehicles are designated in the same manner as general purpose and special equipment. The fundamentals of design are different and specifications must meet definite characteristics for a particular purpose. Spceific example of a special purpose vehicle is a TRUCK-TRAILER, 40-ton, tank recovery, M-25, which is made up of the TRUCK-TRACTOR, M-26 and SEMITRAILER, M-15. Typical special purpose vehicles include tractors, mobile cranes and shovels, and amphibious trucks.



Truck, 4-ton, 6 x 6, Cargo

Car, Scout, M3A1

Truck-Tractor, 4- to 5-ton, 4 x 4

Car, Armored, Light, M8

Truck, 2½-ton, 6 x 6, Amphibian

Car, Half-track, M9

Semitrailer, 6-ton, gross, 2-wheel, Cargo

Tank, Medium, M4

Figure 156. Eight Types of Vehicles.

Combat vehicles can be classed in the general designation to include armored cars, scout cars, cargo or personnel carriers, combat cars, tanks, and gun motor carriages. Armored cars are used primarily for reconnaissance while scout cars are used as personnel carriers and reconnaissance. Cargo or personnel carriers are either track-laying, half-track, or convertible vehicles designed for combat. Gun motor carriages are track-laying and half-track vehicles used for self-propulsion of artillery in combat.

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DESIGN FUNDAMENTALS

The purpose for which the vehicle is needed is the most important consideration in its design. Certain fundamental requirements must be met and certain fundamental limitations must be observed to insure a vehicle of acceptable performance characteristics. In all types of vehicles the perfect set of specifications is difficult, if not impossible, to obtain; but by a compromise of two or more specifications, the best vehicle for a particular mission is obtained.

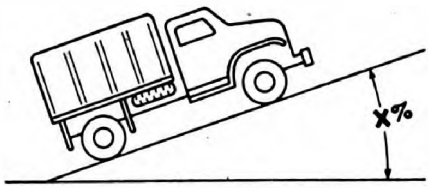

Figure 157. Gradeability.

Maximum allowable gross weight applying to any type of vehicle or combination of vehicles is a factor of prime importance because it affects the over-all performance attainable. Gross weight is the weight of the vehicle, fully equipped and serviced for operation, plus the maximum allowable payload and the weight of all operating personnel.

The type of terrain over which a vehicle is to operate is another important consideration in its design. Most general purpose, special equipment, special purpose, and all combat vehicles are designed to operate cross-country. In traveling over good roads the most desirable feature is high road speed, while cross-country it must have a high degree of gradeability, good ground clearance, maximum floatation, and a maximum of gear reduction. High road speed is sacrificed for high performance off the road; a combination of these is desired in most military vehicles. To obtain this result they are usually powered by a large engine or engines and are provided with a wide range of gear reductions.

Figure 158. Angle of Approach.

Other design requirements and limitations applying to vehicles are those which affect the chassis. Some of the more important are discussed in the following paragraphs.

Maximum road speed is the maximum speed at which a vehicle will travel in high gear over hard-surfaced roads with the engine turning at maximum governed revolutions per minute.

Gradeability is the maximum grade, expressed in per cent, that a vehicle will negotiate while carrying the payload for which it was designed. Maximum gradeability is obtained with the lowest gear in the transmission case and transfer case. Most trucks and truck-tractors are designed to negotiate a 65 per cent grade, grade being defined as the number of feet of vertical rise in 100 feet of travel.

Wheelbase is the dimension, expressed in inches, between the center of the front wheels and the center of the rear wheels. The wheelbase of a six-wheel vehicle is the distance from the center of the front wheel to the center of the rear axle bogie.

The angle of approach and departure is expressed in degrees from the horizontal and is the angle of the maximum grade which a vehicle can approach or depart from without any part of the vehicle coming in contact with the grade.

Turning radius is the radius of the circle in which a vehicle can completely turn through 360 degrees.

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Ground clearance is the distance between the ground and the lowest point of the vehicle chassis. Fordability is the depth of water that a vehicle can negotiate without stalling the engine.

Floatation is the ability of a vehicle to traverse soft terrain without becoming mired. Floatation is determined by the number of pounds of load per square inch of supporting contact area on the ground, and varies with tire size or total area of track on the ground.

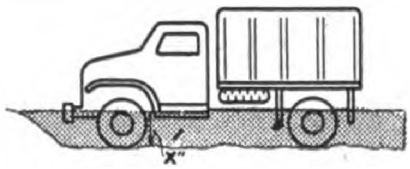

Figure 159. Fordability.

Detailed chassis specifications may be obtained in TM 9-2800.

Vehicle characteristics and a tie-in of the various mechanisms described herein, grouped as they pertain to specific equipment, are furnished in charts for wheeled, half-track and full track vehicles at the end of this chapter.

ARMOR

The choice of armor to be used in a combat vehicle must be made on the basis of its ability to withstand the type of attack which is expected against the vehicle. Face-hardened armor is most commonly used for protection against small arms attack because of its high resistance to penetration (especially against impacts of relatively small caliber projectiles); homogeneous armor (rolled or cast) tends to be more tough and ductile and affords greater protection against the shock of impacts of relatively large caliber projectiles and blasts of high explosive missiles.

Homogeneous Rolled Armor is the cost common type of armor in use. It has the same characteristics throughout the metal. It is usually used as flat plate, furnishing conveniently flat walls for the inside of the vehicle. It can be formed into limited shapes for some sections which can be substituted for a more costly and more vulnerable welded joint. It can be welded more readily than face-hardened armor in the fabrication of a structure. This plate has a tendency to shatter under repeated impact. In thinner sections or gages it offers less resistance to bullets than face hardened armor.

Face-Hardened Rolled Armor is generally 'carburized' or 'nitrided' in the manufacturing process. It is considerably more expensive and more difficult to manufacture than is homogeneous armor. Its greatest advantage lies in the tendency of its hardened face to shatter attacking projectiles and it is employed primarily to gain the advantage of a higher resistance against penetration by relatively small caliber projectiles than is afforded by an equal weight of homogeneous armor. It is used principally in light fast combat vehicles and in shields for mobile artillery pieces as protection against small arms attack.

Homogeneous Cast Armor can be cast into any shape within the limitations of good steel casting practice and must be heat treated to give greatest protection. The curved surfaces of a casting can furnish armor walls of desired thicknesses at average obliquities greater than those which may be obtainable with an assembly of rolled plates, thereby eliminating the necessity for welding joints between flat plates; however, since the effect of heat treating depends upon the thickness of the section, it is impractical to use castings which contain too great a variation in thickness as optimum ballistic properties cannot be maintained throughout. Welded assemblies of flat plates or welded assemblies of castings of different thicknesses are preferable in such cases. Because they can be cast into almost any desired shape, castings are most practical in gun shields and housings and in doors and port covers.

There are three ballistic properties required of armor plate: resistance to penetration, resistance to shock, and resistance to 'spalling.'

Resistance to Penetration is measured in terms of the velocity of an attacking

* See Chapter 2, Vol. III for further information on armor plate.

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projectile upon striking the armor. It is determined by causing the projectlie to strike the armor at the maximum velocity which will *not* result in penetration far enough to cause a hole which permits the passage of light through the armor; this velocity is essentially what is called the 'ballistic limit.' The true definition of ballistic limit is as follows: The ballistic limit is the average of the velocity to give complete penetration and the velocity to give partial penetration.

There are several types of ballistic limits. The most common of these is the 'Army ballistic limit,' which is that described above. Another common one is the 'Navy ballistic limit' which is essentially the maximum striking velocity at which the attacking projectile will not pass completely through the thickness of the armor.

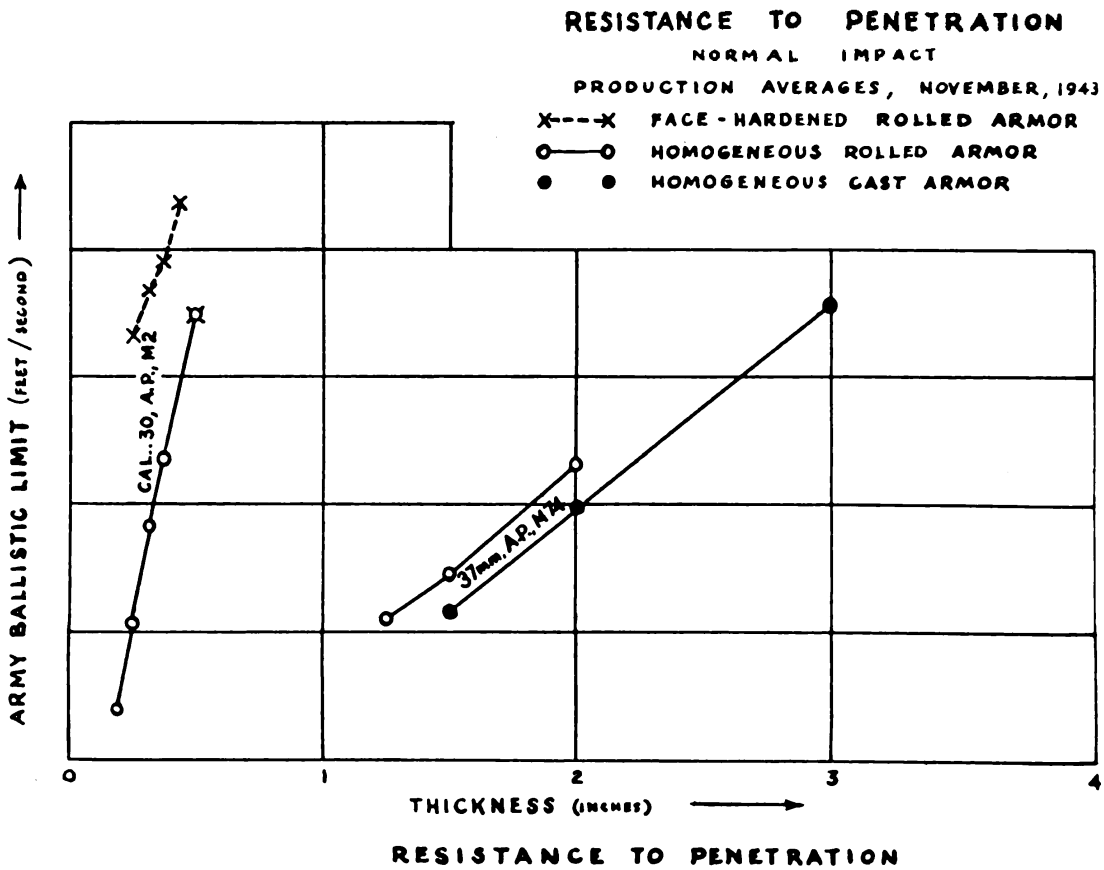

Figure 160. Resistance to Penetration.

In almost all ballistic tests of armor, armor structures, and components of armor structures, the severity of the test is controlled by controlling the velocity of the attacking projectile, and the performance of the material under test is evaluated according to the velocity of the projectile upon striking the material. On the other hand, some tests are conducted by determining the amount of damage which can be caused by a specific projectile, fired at service muzzle velocity from a standard gun at specific ranges. Because it contains a reference to the range from the gun to the target, the data obtained in the latter type of test readily can be applied to tactical considerations. The data obtained in the former type of test can be applied to tactical considerations only after the 'striking velocities' are converted to appropriate ranges for the particular projectile and gun concerned.

A graph showing typical resistance-to-penetration data of production armor at normal impact is illustrated in Figure 160.

Resistance to Shock is that property of armor which enables it to absorb with-

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out cracking or general rupturing the energy expended against it by an attacking projectile of relatively large caliber, or the explosion of a high explosive projectile. Because of the very high speed at which projectiles travel and at which explosions take place, this energy absorption must occur in an extremely short

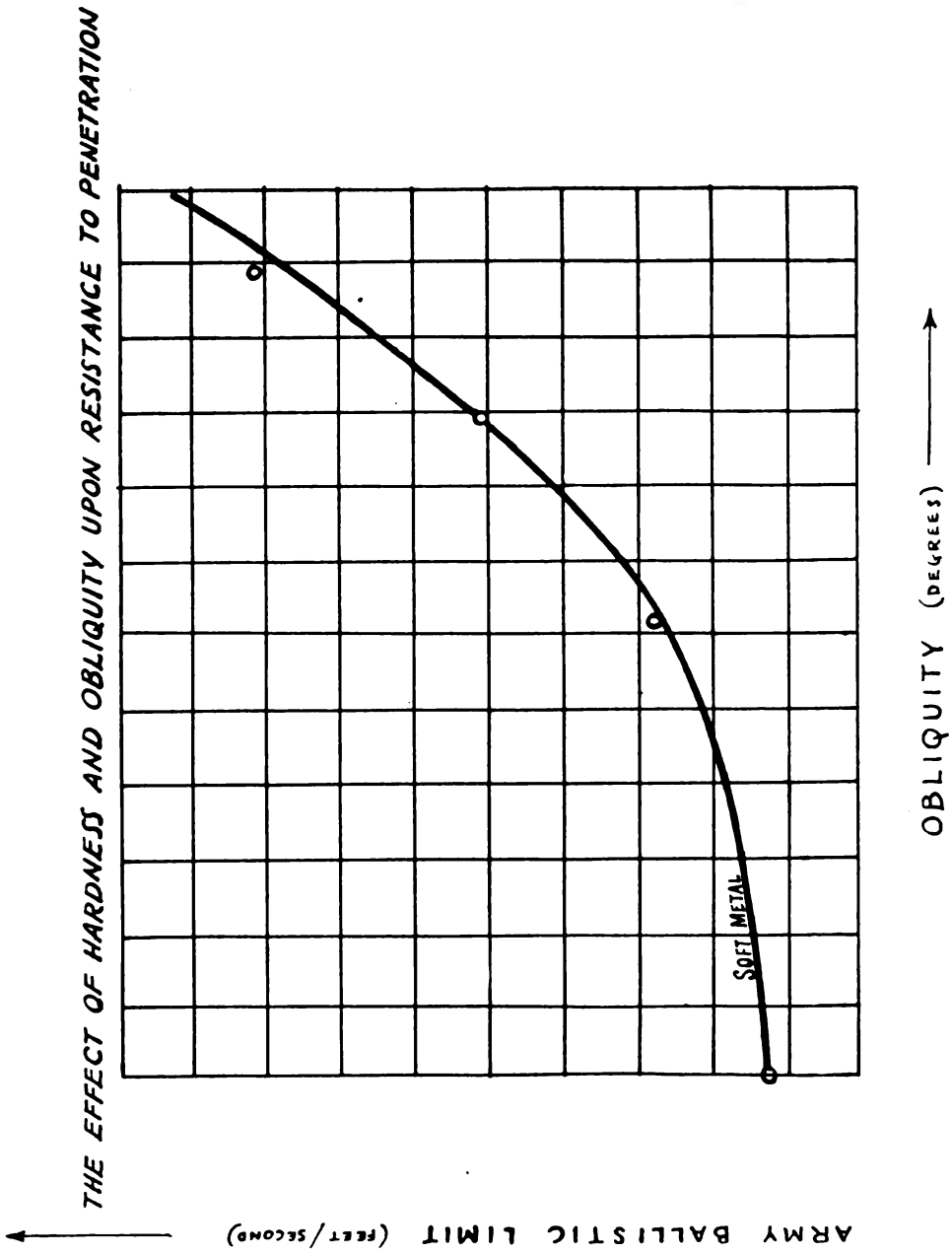

Figure 161. Resistance to Penetration and Obliquity.

space of time. Shock tests are intended to reveal the manner in which armor will react under the blast of the explosion of the piercing projectile at obliquity. Tests with high explosive projectiles are conducted at obliquity to utilize the maximum effect of the blast, which is in a plane perpendicular to the axis of the projectile. Shock tests with inert shot are generally conducted at normal impact with soft, flat-nosed projectiles (which stress the armor as they deform against it) rather than with armor-piercing projectiles at obliquity. By testing in this manner much better control can be exercised over the test, much more consistency occurs from round to round, and the results produced are comparable to those which would be produced by an armor-piercing projectile at obliquity.

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Resistance to Spalling. The basic purpose of the resistance-to-spalling test is to expose any defects which indicate inferior steel quality or improper heat treatment. It is conducted by causing a projectile to pass completely through the thickness of the armor. The performance of the armor is measured in terms of the size of the opening in the rear surface, the tendency of the armor to spall (chip or crumble), and the type of metallurgical structure revealed.

The Effects of Obliquity and Hardness upon Ballistic Properties of Homogeneous Armor. The ballistic properties of armor depend upon several factors: the type and thickness of the armor, the type and caliber of the projectile used in the test of the armor, the hardness of the armor, the obliquity of impact, and the ratio of the thickness of the armor to the caliber of the projectile.

The term 'obliquity', as it is applied to impacts upon armor, is defined as the angle between the trajectory of the projectile and a line normal to the surface of the armor at the point of impact. 'Normal impact' is equivalent to an obliquity of zero.

The Effect of Obliquity upon Resistance to Penetration. Naturally, as the obliquity of impact against a given thickness of homogeneous armor is increased, resistance to penetration increases, and (all other conditions remaining unchanged) the basic relationship between resistance to penetration and obliquity is given by a set of curves such as is shown in figure 161. Basically, little or no change in resistance to penetration occurs as the obliquity begins increasing from zero until somewhere in the range of from 10° to 40° when the curve begins to rise more and more rapidly. The location of the beginning of the rapid rise and the steepness of the curve at any particular obliquity depends upon the several factors already mentioned: the thickness and hardness of the armor, the type and caliber of the projectile, and the ratio of the thickness to the caliber.

The Effect of Hardness upon Resistance to Penetration. An increase in the hardness of a given thickness of homogeneous armor may result in an increase, a decrease, or in no change at all in the resistance to penetration, depending upon the type of projectile concerned and the ratio of its diameter to the thickness of the armor.

For projectiles smaller in diameter than the thickness of the armor plate, an increase in hardness introduces an increase in resistance to penetration. Projectiles having a diameter equal to the thickness of the armor plate usually introduce an increase in resistance to penetration up to a certain hardness range, at which point the resistance to penetration begins to decrease fairly rapidly. Generally, for projectiles having a diameter greater than the thickness of the armor plate, little or no increase in resistance to penetration is realized and a decrease in resistance to penetration is noted in the higher hardness range.

In general, armor of the higher hardnesses tends more readily to cause the shattering of attacking projectiles of relatively small calibers, thereby affording greater resistance to penetration. On the other hand, projectiles of relatively large caliber tend to remain intact and tend to penetrate more readily the brittle armor of higher hardnesses.

The Combined Effects of Obliquity and Hardness upon Resistance to Penetration. Increases in obliquity also tend to cause the shattering of attacking projectiles of relatively small caliber; the obliquity at which shattering occurs is marked by a sharp rise of several hundred feet per second in the resistance-to-penetration-obliquity curve. The basic shape of the set of resistance-to-penetration-obliquity curves is essentially the same as that of the curve of figure 161, and, in addition, the sharp rise due to the shattering of the projectile is clearly evident in each curve. The effect of the hardness of the armor upon the shattering of the projectile is shown by the variation in the obliquity at which the sharp rise occurs for each hardness. The resistance-to-penetration-hardness curves show the protection which is afforded at each obliquity over the entire hardness range.

Because of the magnitude of the effect of increased obliquity upon resistance to penetration, every advantage should be taken of the effect of obliquity in the design of all combat vehicles, gun shields, and other armor structures. Wherever possible, armor surfaces presented to attack by enemy fire should be inclined at the highest obliquities permissable within the limitations of other design considerations.

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The Effect upon Resistance to Shock and Resistance to Spalling. The resistance-to-shock test being a measure of the ability of the armor to absorb energy, the obliquity of attack has little effect upon the performance of the armor under test. However, the hardness of the armor has a definite effect upon its shock resisting properties. Armor of the higher hardnesses tends to be more brittle and to crack under severe shock, while armor of the lower hardnesses tends to be more tough and ductile and to withstand greater shock; however armor of too low a hardness cannot meet sufficiently high resistance to penetration requirements.

The hardness of the armor and the obliquity of attack have little effect upon the resistance-to-spalling test which is essentially a measure of the soundness of the steel and the quality of its heat treatment.

Additional data on armor will be found in the chapter on Shop Theory and Practice and in the chapter on Ammunition and Terminal Ballistics.

SUSPENSION

The suspension system on any vehicle can be defined as the unit or units used to support the weight of the vehicle and provide the mechanism on which the vehicle moves.

Generally, suspension systems can be divided into three types: the relatively simple system with the wheels of the vehicle either mounted on a spring suspended axle or suspended independently on springs, the bogie suspension system, or a combination of the bogie and the wheel and spring suspension. The exceptional suspension systems used are the torsion bar and the torsilastic systems.

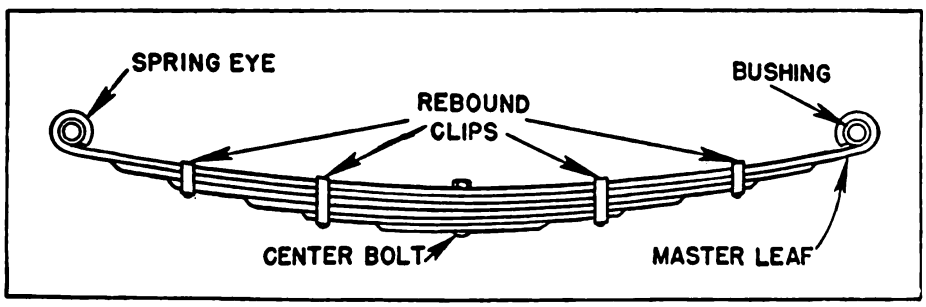

Figure 162. Laminated Leaf Spring.

Leaf Springs. A spring, whether it is of the laminated, volute, spiral, flat, or disc type, is used to absorb or redistribute enery and act as a flexible connection between the wheels and the frame or hull. Springs can not be designed to successfully meet all requirements but a compromise must be made in designing a spring for a particular vehicle. Springs are designed to assume their proper shape under normal load, which for the semielliptic or laminated leaf spring is almost flat. The load definitely limits the load rating since a spring must not allow too great a vertical movement of the wheels. Vehicles carrying heavy loads require a stiffer spring which results in sacrificing good riding qualities.

If the front spring deflection on a vehicle is too large, erratic steering will result; it is purposely kept small. Large rear springs with a high load rating are used on trucks because they must carry most of the load placed on the vehicle. At the same time they must not be so rigid that the energy of road jars or blows will be transmitted to the body of the vehicle.

When a spring is set vibrating it is deflected from its normal position and absorbs the energy from the road shock. This energy then causes the spring to rebound and to pass through its normal position and deflect in the other direction.

General purpose, special equipment, and special purpose vehicles almost extensively use laminated leaf springs suspending a live axle at the rear of the vehicle and a dead or live axle at the front of the vehicle.

The laminated leaf spring is built up of a number of spring steel strips or leaves of different lengths placed one above another. Each end of the longest or master leaf is usually rolled into an eye to serve as a means of attaching the spring to the frame. To make the strain substantially uniform in all parts of the spring, the

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leaves usually decrease uniformly with their distance from the master leaf. Truck springs are sometimes provided with elongated eyes, or box eyes, which slide on rollars on the spring mounting. They are also made without eyes at either one or both ends; the ends then slide on bearing plates or guides.

The leaves are fastened together by a center bolt or by bands or clamps. One objection to the center bolt is that the hole through the spring weakens the spring at that point.

When the leaves are assembled they are placed under a small initial stress by the bent or 'nipped' arc of each leaf. This also prevents dirt and water from getting between the leaves.

Nipping or bending each leaf decreases the stress in the master leaf and increases the stress in the shorter leaves. Within certain limits this is desirable because it tends to make the shortest leaf the weakest leaf. A large difference in the stresses on different leaves is undesirable because some of the spring material is not utilized to full advantage. To prevent large differences, the leaves are 'graded'; that is, the shorter leaves are made thinner so that with a given deflection under load the stress is not increased on the shorter leaves as much as it is increased on the master leaf.

When a leaf spring is depressed the stress is resisted by all the leaves, but when the rebound occurs the direction of the stress is reversed. This may separate the leaves, throwing most of the stress on the master leaf. To provide for a distribution of stress on rebound, rebound clips are added in the form of straps which surround all the leaves at two or more points along the spring. The clips allow the leaves to slide but keep them from separating on the rebound.

Two forces are at work on a deflected spring: the force due to the load carried and the force due to the internal strains of the spring material. The load force is constant for any one load, but the internal strain force increases with the spring deflection and reaches a maximum at the maximum deflection point. When a laminated spring is deflected, one leaf slides over another, which introduces friction and opposes the deflection, thereby assisting the internal forces. Spring deflection ceases when the frictional resistance plus the internal strain equals the force due to the load on the spring.

When suspension is obtained by use of laminated springs, the general practice is to use single semielliptic springs which have a maximum deflection when the spring is straight. Spring camber is defined as the distance from a line joining the centers of the spring eyes, to the center of the outside of the master leaf. Under normal load a semielliptic spring should have no camber; when unloaded, a moderate postive camber, and when under rated shock load a negative camber.

When springs are mounted lengthwise on the vehicle, the ends are usually attached to the frame by spring hangers through the eyes and are clamped to the axle on a spring seat.

Bushings are provided in the spring eyes and lubricated by a drilled hole in the shackle pin.

The spring shackle is a swinging support which permits the spring to vary in length as it flexes. It is mounted between the spring and the hanger by bolts or pins.

Volute Spring Suspension. The volute spring suspension assembly consists of the bogie wheels, supporting arms and levers, volute springs, and a suspenion bracket to connect all the moving members.

Volute springs differ from the conventional leaf spring in that they are made from one flat bar to form a conical spring. Each coil partially overlaps the next adjacent coil with the smallest coil on the weakest end. The deflection of a volute spring is similar to the action of the spring on a simple shears used to trim the garden hedge. Hedge shears generally have a double conical spring but the action is the same.

Volute springs are desirable when a heavy load must be supported and when space limits the type of conventional spring to be used. Volute springs are small for the load rating obtained, easy to design and manufacture, and are sturdy for their size. For these reasons heavy duty volute springs are used on tanks, half-tracks, and other vehicles having a bogie suspension.

If the one flat bar in a volute spring is unrolled as a flat strip the bar would

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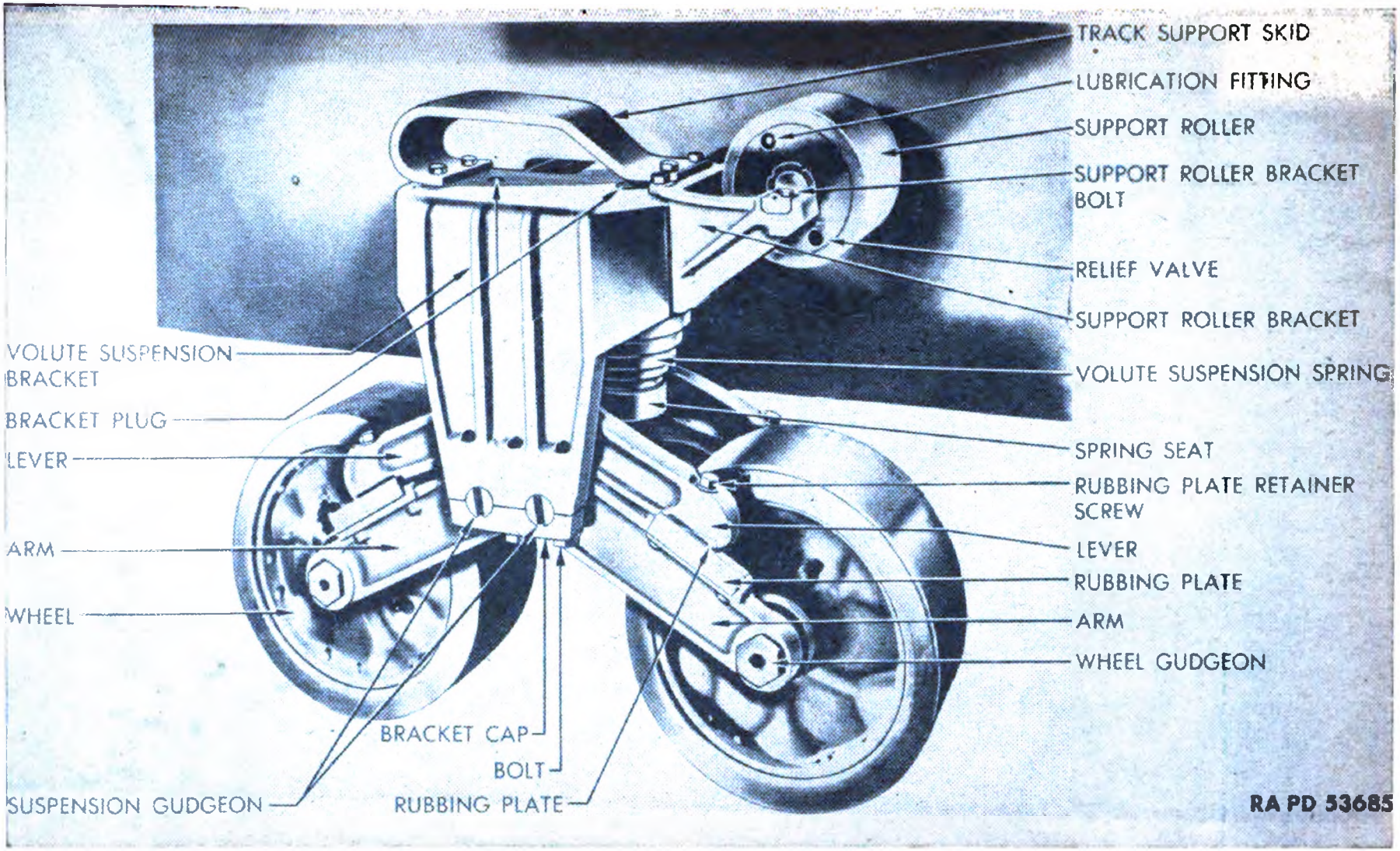

Figure 163. Volute Spring Suspension Assembly.

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resemble a wedge which is tapered in two dimensions. The width and thickness is tapered from one end of the bar to the other end, and when the coil is wound up the largest coil is made of the thickest and widest portion of the bar stock. In this way the slight deflection is absorbed by the small coil which is made of the narrow and thin end of the bar. As the deflection increases the smallest coil moves inside the next larger coil which is wider and thicker and can absorb a greater shock.

Heavy duty volute springs used on tanks, half-tracks and other vehicles using bogie suspension systems are placed in a horizontal position, vertical position with the small end of the spring down, or inclined from the vertical.

Vehicles having volute springs placed in a vertical position require two bogie wheels, arms and levers, and a suspension bracket. The bogie arm is connected to the suspension bracket. When the bogie wheel which is fastened to the other end of the bogie arm, moves in a vertical direction the arm acts as a cantilever. The lever rests on the bogie arm at a point approximately half way between the suspension gudgeon and the wheel gudgeon, the wheel gudgeon being the connecting member between the bogie wheel and the bogie arm. The lever extends from one bogie arm to the other with the spring seat located in the center of the lever. One end of the volute spring rests on the spring seat and the other rests on the top of the suspension bracket. When the bogie wheel moves up, the lever is free to move up and at the same time to slide on the bogie arm. As the lever moves up the springs are compressed and absorb the shock.

Horizontal volute spring suspensions are similar to the volute springs placed in a vertical position in that the assembly consists of two bogie wheels, two bogie arms, and spring seats and springs. Instead of the suspension bracket acting as one spring seat the bogie arm is connected to the suspension bracket and the bracket connection becomes the stationary point of the bogie arm. The bogie arm is constructed in the shape of a triangle with the bogie wheel at one end of the leg, the spring seat at the end of the remaining leg, and the hinge pin connecting the bracket and bogie arm at the vertex of the triangle. As each bogie wheel moves in a vertical direction the spring is compressed from each end, absorbing the shock.

Volute springs inclined from the vertical use bogie arms similar to the arms used on horizontal volute spring suspensions, except that the springs each have a spring seat and are not compressed from each end.

TORSION BAR SUSPENSION

A relatively new type of suspension on Army vehicles is the torsion bar suspension system. Each track wheel assembly rotates on a spindle at the rear end of a support arm, which pivots on an integral axle shaft mounted upon roller bearings in an axle shaft housing attached to the hull. A steel torsion bar is splined to the axle shaft on one end and anchored to the opposite axle shaft housing on the opposite side of the vehicle. The bar functions as a spring to resist the upward movement of the track wheel and support arms, thereby supporting the weight of the vehicle.

The support arm assembly consists of a heavy steel forging into which a tubular axle shaft is splined and welded at the front end. A solid steel wheel spindle is pressed and swaged into the rear end. The axle shaft is supported in the axle shaft housing by two large diameter roller bearings separated by a tubular spacer. A cap bolted to the outer end of the housing and a retaining nut screwed into the inner end of the housing position and hold the bearings in place. The axle shaft is retained in the housing by a nut at its inner end which bears against the inner bearing race. Oil seals are located in the housing cap and bearing outer retaining nut to retain the lubricant and exclude dirt and water from the bearings. The housing incloses a torsion bar spacer and a splined torsion bar retainer into which the splined end of the torsion bar from the opposite axle shaft is engaged. This retainer anchors the end of the torsion bar so that rotation of the opposite support arm and axle shaft causes the bar to twist and act as a spring.

The torsion bars are solid steel shafts of high carbon alloy steel serrated at each end. One end engages in the internally serrated axle shaft which is integral

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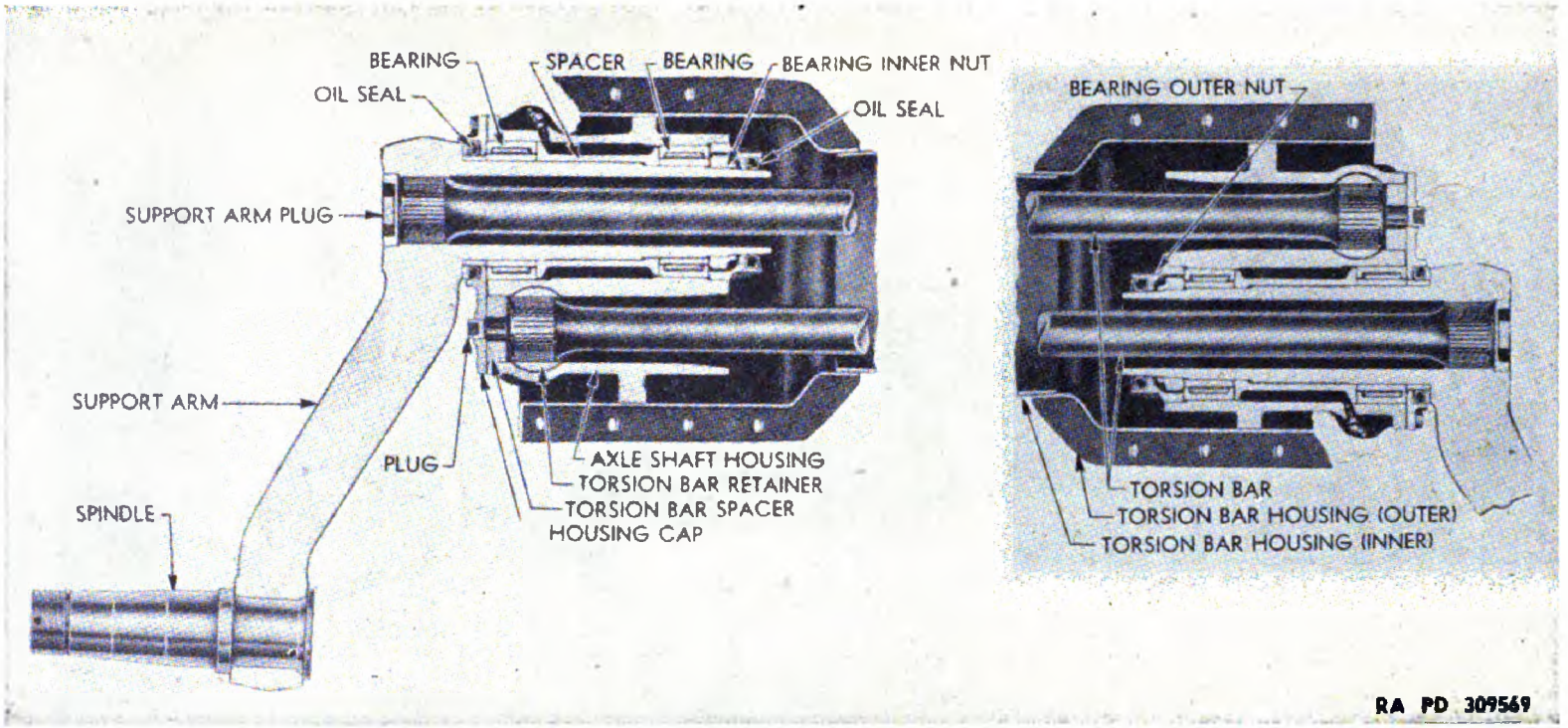

Figure 163A. Cross Section of Torsion Bar Suspension.

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with the support arm; the other end is anchored to the opposite axle shaft housing through engagement with the internally serrated torsion bar retainer inclosed in the housing. When manufactured, each bar is given a definite twist or 'set' in the direction that the bar will twist in supporting the vehicle. The twist of a soda straw is very similar to the 'set' in a torsion bar. Because of the twist, torsion bars are not interchangeable from left to right, and if installed on the wrong side will fail quickly. Bars may also be of different strengths from front to rear on the same side of a vehicle and should always be in the proper assembly.

TORSILASTIC SUSPENSION

While the leaf spring, volute spring, and torsion bar suspensions are the most common types of suspension systems, other suspension systems are used. One is torsilastic suspension in which the torsional effect of a shaft 'floating' in rubber is utilized to cushion and support the vehicle.

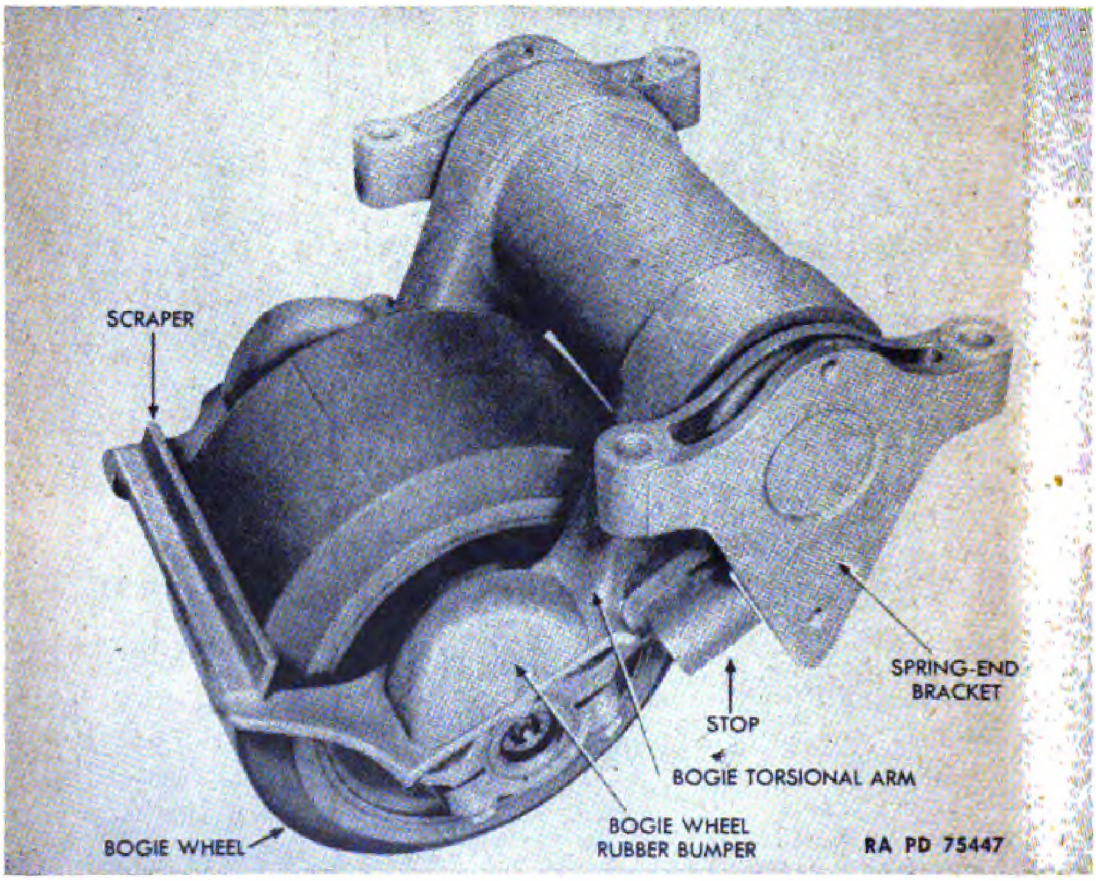

Figure 163B. Bogie Assembly—Torsilastic.

At present the torsilastic type suspension is used on amphibious vehicles. The assembly consists of a bogie wheel, bogie torsional arm, and spring end bracket. A hollow shaft is placed within another large hollow shaft, and rubber is vulcanized between them. Bogie wheel arms are welded to the ends of the outer shaft, and the bogie wheel is mounted between them. Spring end brackets are welded to the ends of the inner shaft, and these brackets are attached to the pontoon. As the vehicle travels over rough terrain, the outer shaft twists on the inner shaft, and the rubber cushions the movement of the bogie arm. If the vulcanized bond is broken on either shaft the twisting effects of the rubber is lost and no suspension results. To prevent excessive twist each torsional arm has rubber bumpers which act as a stop.

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BOGIE WHEELS

Bogie suspensions found on track-laying vehicles either have a single bogie wheel mounted on the suspension arm when the track uses outside guides, or has split bogie wheels when the track uses center guides. Split bogie wheels either have two separate bogie wheels mounted on the same gudgeon pin or have two wheels bolted together with a space in the center for the track guide.

Ball or tapered roller bearings are used to mount the bogie wheel to the gudgeon pin. Oil seals are provided to keep water and dirt out of the bearings and at the same time keep the lubricant in the wheel.

IDLERS

The term 'idler' is used to designate a unit that reverses the direction of rotation of gears or, as in the case of track-laying vehicles, the unit that keeps the proper tension on the track and reverses the direction of the track. Track idler wheels are of two types: the trailing idler type and the outboard idler type.

The trailing idler type, as found an light tanks and high-speed tractors, is located at the rear of the vehicle and keeps the track on the ground until it passes around the idler wheel. Tension is maintained on the track by means of a volute spring. Track tension is adjusted by moving the idler forward or backward on the idler arm.

The outboard idler is used on medium tanks, gun motor carriages, and half-track vehicles (See Fig. 135). This unit has no idler arm but is fastened to the hull. The track leaves the ground after passing under the last bogie wheel. Tension is adjusted on the track by an eccentric adjustment of the idler wheel and is maintained by coil springs or a lock.

SHOCK ABSORBERS

Experience has proved that satisfactory riding conditions cannot be obtained by using springs alone. To prevent excess rebound and dampen spring vibrations, spring control devices, called shock absorbers, are employed. Shock absorbers which only check the spring rebound are known as 'single acting,' while shock absorbers that in addition check spring compression are known as 'double acting'. There are many types of shock absorbers but the two types used on Army vehicles are direct-acting and double-acting.

The principle of the hydraulic shock absorber is fairly simple. Oil contained within a housing is forced through a restricted opening by a piston when the spring flexes. Since liquids are not compressible, the oil takes a certain time to flow through the restricted opening. The rate of piston travel, which controls the period of spring vibration, is determined by the opening through which the oil must flow.

The shock absorber, which is attached to the frame of the vehicle, contains a lever pivoted to a shaft in the housing. This lever is pinned to a link, the other end of which is usually attached to the spring seat or spring clip. Rubber grommets are used at either end of the link to prevent metal-to-metal contact.

The direct-acting shock absorber consists of an inner cylinder which is filled with a special shock absorber oil and divided into an upper and lower chamber by a double acting piston. The shock absorber is mounted by stud and rubber bushings inserted through the eye on each end so that it is directly acted upon by the action of the spring in deflection or rebound. The piston rod is forced up or down within the inner cylinder. A reservoir which contains a supply of oil surrounds the inner cylinder and is joined to it by a reservoir check valve.

When the vehicle spring is compressed, the piston is forced down and some of the oil below the piston is forced through compression valves inside the piston into the upper chamber. These valves operate only on the down stroke. Since the push rod moves into the cylinder on the down stroke, some of the oil in the lower chamber is forced through the reservoir check valve at the bottom of the cylinder into the reservoir.

When the vehicle spring rebounds, the piston is moved up, and oil from the upper chamber is forced into the lower chamber through spring loaded rebound valves inside the piston. These valves control the rebound of the vehicle spring.

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As the piston moves out of the cylinder, oil is drawn into the lower chamber from the reservoir through the reservoir check valve.

The cam operated double acting shock absorber contains an oil reservoir and two cylinders. The cam is inserted between two interconnected pistons, each contained within a cylinder. The double acting pistons may operate in opposed cylinders made from one bore or in side by side cylinders with a double arm cam.

The shock absorber arm, which is connected by a link to the wheel support arm, is moved upward when the wheel moves over an obstruction and this action rotates the shaft and cam. The cam pushes the piston toward the compression end of the cylinder and forces fluid out through the drilled passage and through the compression rleief valve into the rebound end of the cylinder. On a very slight or slow movement of the cam, the fluid flows only through the small orifice of the compression relief valve. On a rapid movement, the increased fluid pressure lifts the valve from its seat by compressing the spring, thereby

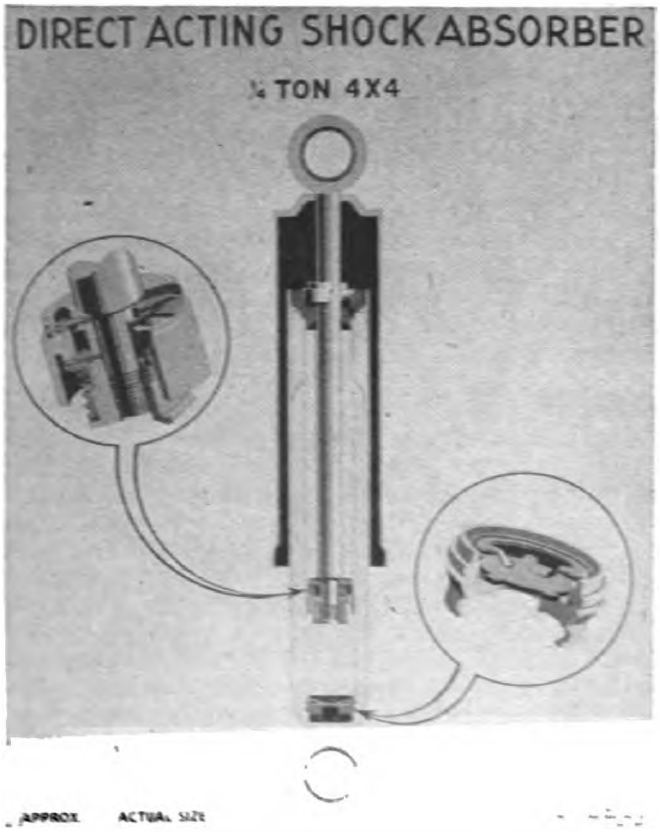

Figure 164. Direct Acting Shock Absorber.

permitting a larger quantity of fluid to flow to the rebound end of the cylinder, at a pressure controlled by the compression valve spring. At the same time, the intake valve in the rebound piston opens and allows fluid to flow from the reservoir into the rebound end of the cylinder. This action prevents formation of a vacuum and compensates for any loss of fluid between piston and cylinder wall. As the shock absorber arm moves downward on rebound, the cam pushes the piston toward the rebound end of the cylinder, and forces fluid out through the other drilled passage and through the rebound relief valve into the compression end of the cylinder. On slow action, the fluid flows only through the small orifice of the rebound relief valve; on rapid action, the valve is lifted from its seat, and the fluid passes through at a pressure controlled by the rebound valve spring. At the same time, the intake valve in the compression piston opens to allow fluid to pass from the reservoir into the compression end of the cylinder. The purpose of the static valve and spring is to limit the initial flow

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of fluid through the compression relief valve orifice during very short piston movements. The static spring holds the static valve against the top of the compression relief valve at the proper pressure to limit fluid flow through the compression relief valve orifice. In addition to maintaining a minimum pressure through the compression relief valve orifice in one direction, the static valve becomes a check

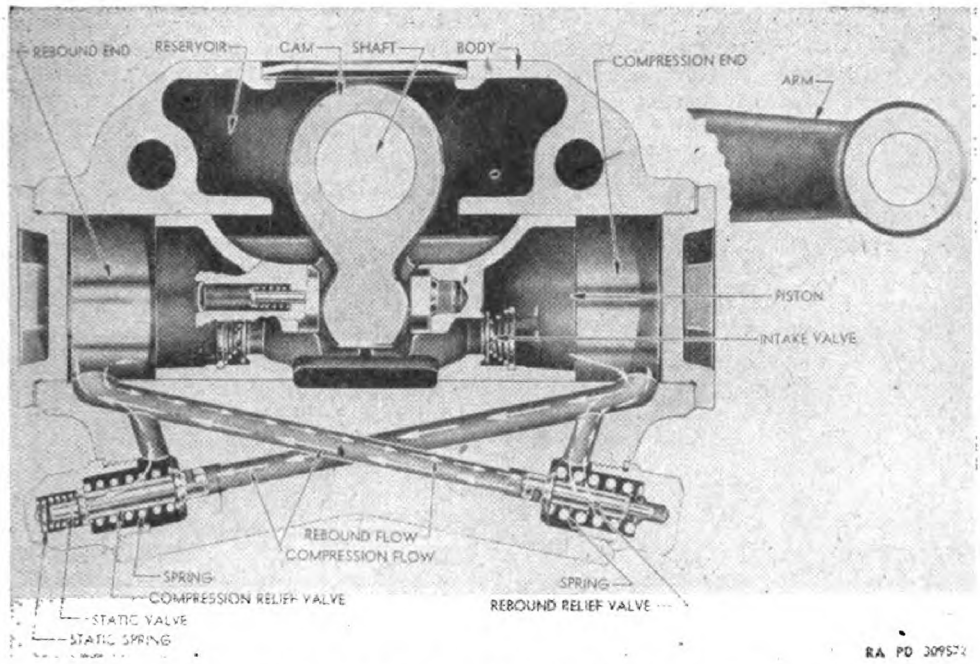

Figure 165. Cross Section of Shock Absorber Showing Fluid Flow.

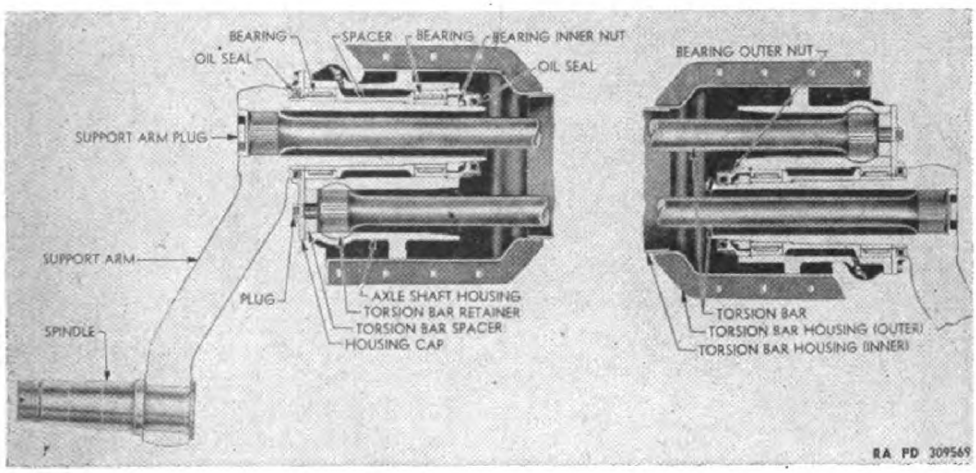

Figure 165A. Support Arms. Axle Shaft Housings and Torsion Bars—Sectional View.

valve on rebound movements. On compression movements, the compression and rebound relief valve orifices are both effective in parallel; on rebound movements, the static valve closes and prevents a reversed flow through the compression relief valve orifice so that only the rebound relief valve orifice is effective. This pressure regulation by the static valve assists in maintaining ride balance and improves roadability. A longitudinal groove cut in the top surface of each piston permits any air in the fluid to escape from the cylinder into the reservoir.

Shock absorbers require little care or attention except a periodic check to see

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that the reservoir is filled to the proper level with the proper fluid and to replace worn or missing rubber grommets.

Broken Springs result from a number of factors. Some of these cannot be avoided but those due to the neglect of the vehicle operator can be. If springs are found broken at the center bolt hole, the cause in most cases will be a broken center bolt or loose spring clamps. A loose spring clamp will allow a spring to flex in the middle and break several leaves at this point. If a spring is suspended under the axle instead of resting on the axle, it is possible for the spring clamps or 'U'-bolts to stretch under load and thereby not return to the original position when the load is removed.

Spring breakage near the eyes or shackles is generally caused by the shackle bolts being pulled up too tight or by lack of lubrication. Spring eyes bound up so that they cannot move are sure invitations to breakage.

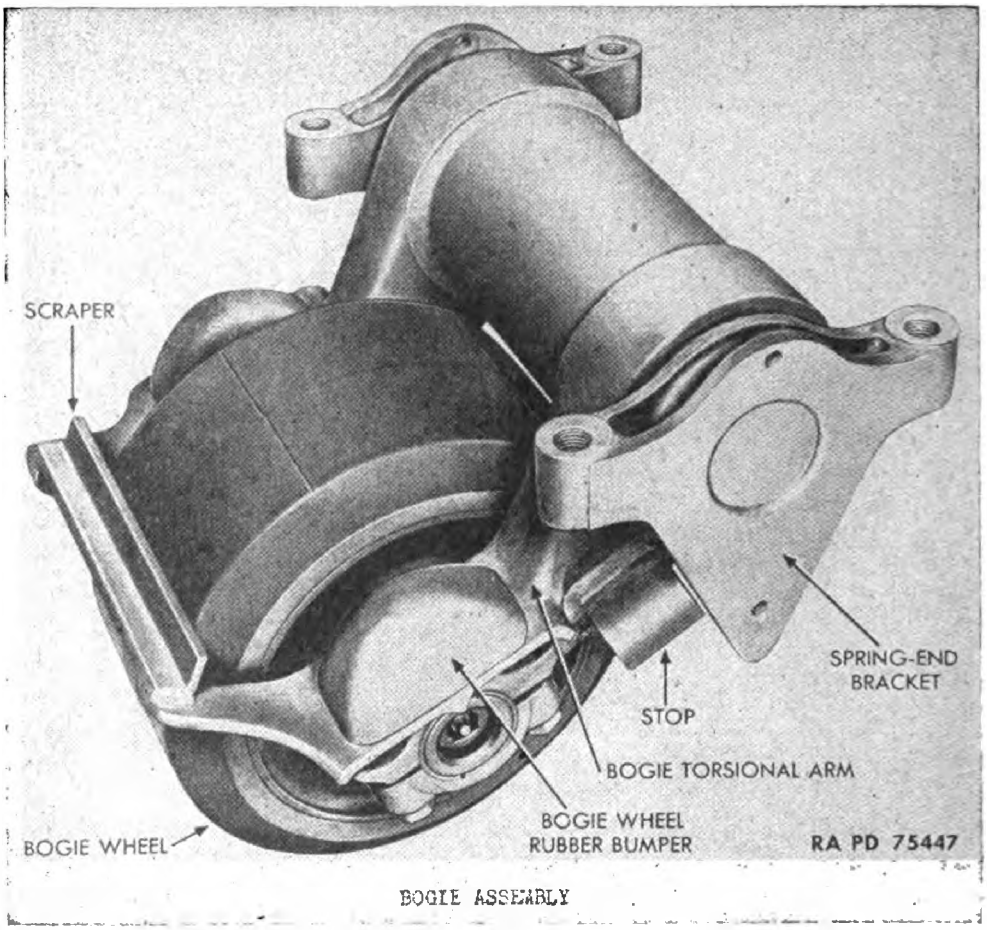

Figure 165B. Bogie Assembly.

Missing rebound clips, or clips which are loose because the threads on the bolts have been stripped by overtightening (or on which the rivets have been broken), cannot prevent extreme rebound; broken springs result.

Loose spring clips also allow the leaves to shift or fan out sideways which in many cases throws all the shock on a few or even one leaf.

When a faulty or broken shock absorber develops, spring trouble results. Bad shock absorbers allow the vehicle to whip up and down so much that the normal fatigue of the spring metal is immensely speeded up.

Lubrication of springs except where specified leads to excess 'bounce' and excess bounce leads to breakage. Even spraying the edges of springs is considered dangerous because of bounce, and also because the oil picks up dirt particles which work their way between the leaves.

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Volute springs require no maintenance and are only replaced when fatigued or broken.

WINTERIZATION

The operation of automotive materiel under arctic conditions entails serious but not insurmountable problems. Cooling systems freeze, cracking radiators and cylinder blocks. Batteries lose their ability to crank the engine. Lubricants thicken. Traction becomes difficult. Personnel are uncomfortable. A large forward step in the solution of these problems was taken by the standardization of winterization kits. Before we consider these kits, let's make a few general rules for cold weather operation.

First, choose your motor park with care. Of course, if a heated building is available, use it. If there are no buildings ,settle for a place where the vehicles will be protected from the wind, behind a windbreak, in the lee of a hill (but not in a hollow where they may be snowed in), and park them so that they will not be facing into the prevailing wind.

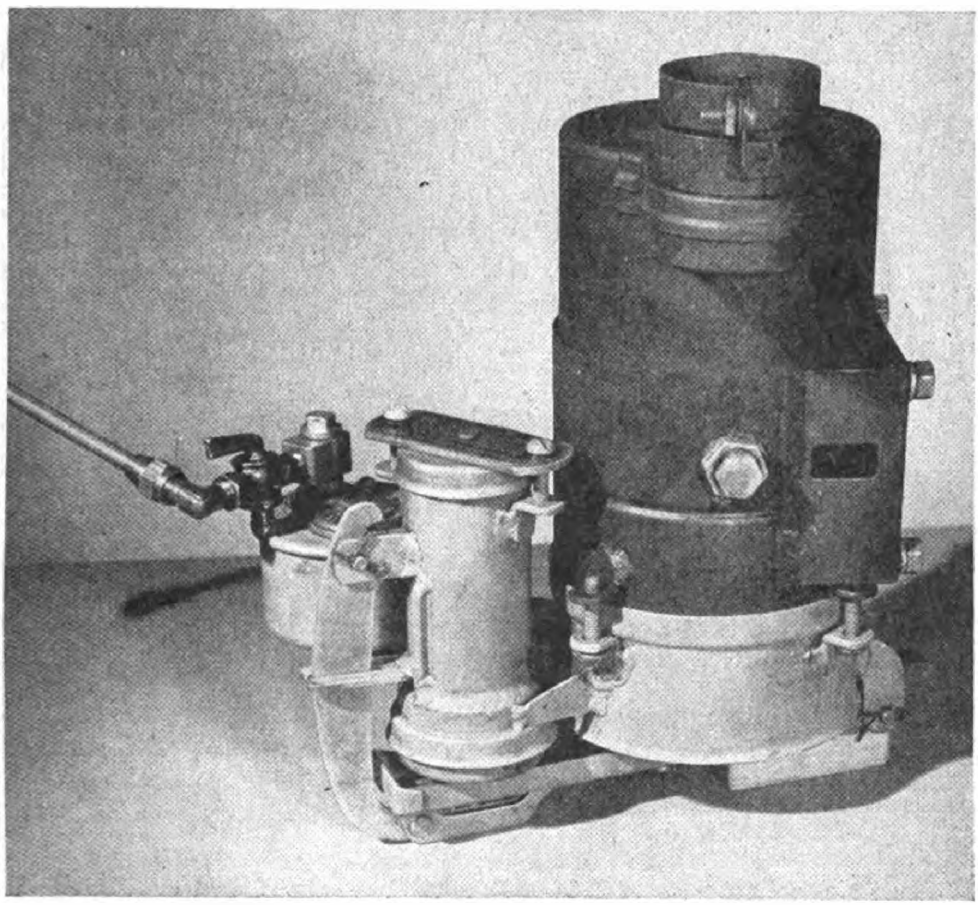

Figure 166. Heater Unit Showing Location of Fuel Valve.

In protecting the cooling system, antifreeze compound (Ethylene Glycol type) is used. Be sure that the cooling system is clean and in good condition. If the temperature will not exceed ten above zero F., add two pints of antifreeze compound for each gallon of the cooling system capacity. For each ten degrees under ten above zero F., increase the amount of antifreeze compound by one-half pint. Be sure that you have an adequate supply of antifreeze hydrometers. Even with care they get broken regularly when in constant use.

Batteries must be kept charged at all times. Demand on them will be great because of the difficulty in cranking cold engines and because the chemical reaction on which they depend will be slowed down by the cold. Also, a fully

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charged battery will not freeze until the temperature reaches ninety degrees below zero, but a battery with a specific gravity of 1.100 will freeze at nineteen degrees *above* zero. Do not add water to the cells unless the vehicle is to be used immediately; otherwise, the water forms a layer on top and will freeze before it is mixed into the electrolyte by the charging of the battery.

Using the winter grade of the prescribed fuel will guarantee quick starting provided you have taken defensive measures against water from condensation. At all times keep vehicle fuel tanks as full as possible. Add a quart of grade 3 denatured alcohol to the tank at the beginning of the season and one half pint at each refueling.

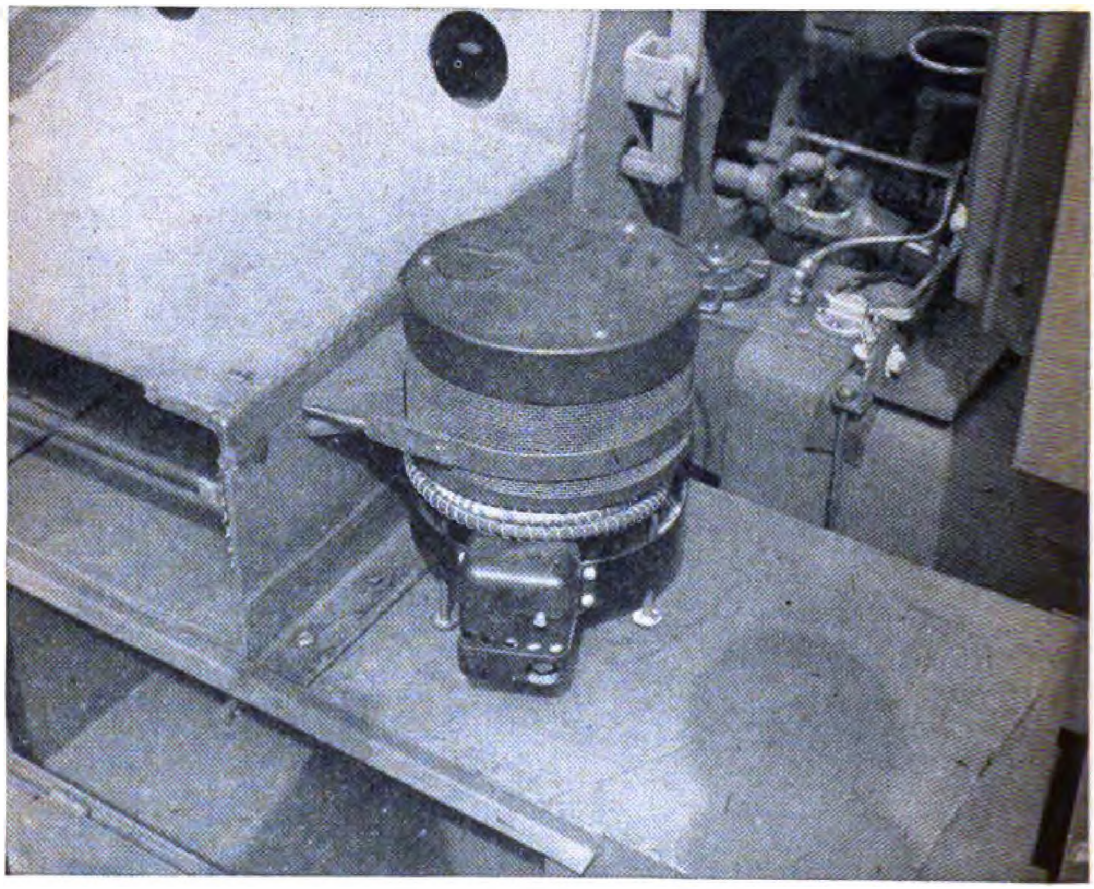

Figure 167. Underchassis Heater.

Winter grade lubricants will work with perfect satisfaction down to twenty degrees below zero. If it get colder than that, it will be necessary to dilute engine oil SAE 10 with fuel: one and one-half parts of fuel to five parts of oil. If gear lubricant SAE 75 is available, dilution will not be necessary at any tem- of one part to six. General purpose grease #0 will function perfectly as a chassis lubricant at all temperatures. General purpose grease #2 will meet the demands of wheel bearing lubrication. Caution th emen to lubricate Bendix drive starters sparingly. In sub-zero temperature, don't put the oil in the oil bath type air filters.

You will need skid chains—lots of them and lots of spare links. Warn the drivers to slow down, particularly on turns. Caution them that speedometers are unreliable in the cold. Direct them to park their vehicles without setting the brakes as the bands may freeze to the drums. You might provide chocks so that they can park on sloping ground without setting the brakes. Sometimes wheel cylinders of hydraulic brake systems may freeze. If so, warming with a blow torch will release them. On vehicles equipped with air brakes it is more important than ever that reservoirs be drained *daily*.

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Save your drivers as much as possible by providing lots of warm clothing. Construct sides on open cab trucks. Don't keep the men out in the cold for protracted periods of time, if you can help it. Institute a 'buddy system' for detecting signs of frostbite. Realize that they will be slower and less capable with heavy clothing and awkward mittens.

Many undesirable conditions that occur in winter operation will be alleviated or eliminated by the use of winterization kits. Each kit is tailored to a specific vehicle and consists of a heater, an engine primer, battery heaters, driver's compartment heater, radiator shutters, louvre covers, and other accessories.

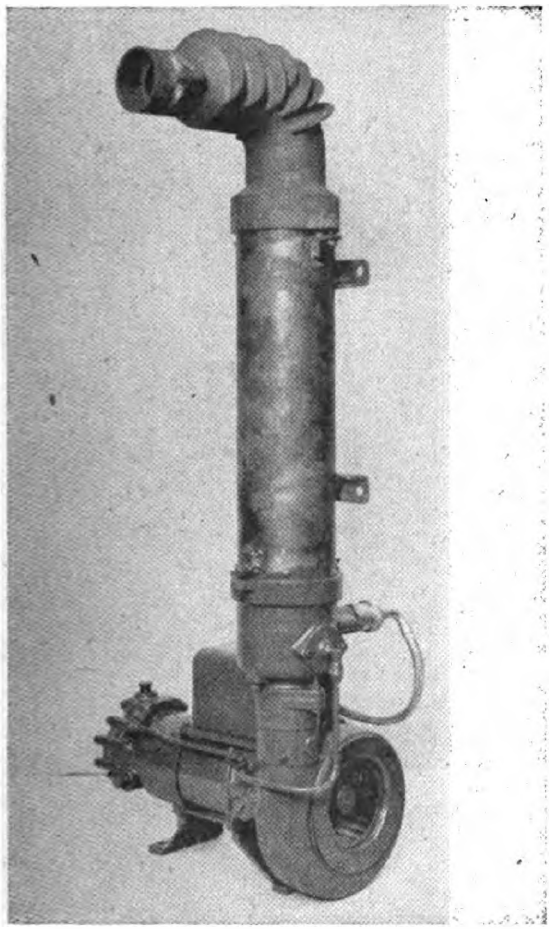

Figure 168. High Output Heater.

The type of heater most commonly used is a coolant heater. It is put into operation whenever the vehicle is not in use. It burns the same fuel as the vehicle and has two connections with the cooling jacket of the engine. The lower connection allows the coolant to flow from the engine to a coil inside the heater and the upper connection allows the return of the coolant to the top of the engine block after heating. Thus coolant circulation is on the thermosiphon principle. Another type of heater in use is the underchassis heater which is simply a space heater. It is hung under the engine or placed on the ground under the engine and a tarpaulin is placed over the hood. The air surrounding the engine is heated and the engine components and accessories are warmed by convection. A third type of heater is in limited use to protect the power plants of tanks and tank-like vehicles which employ a radial, air-cooled engine. It is called a high output heater. It produces approximately 100,000 BTU/hr which is piped to the critical parts of the vehicle. The second named type of heater, the underchassis, with an eighteen foot square tarpaulin, is issued for the vehicles for which a winterization kit is not available. In addition to the individual vehicle winterization kits, an auxiliary cold starting aid kit is issued one to every fifty vehicles. It consists of a heater, eight batteries, generator, etc. Since there are 6, 12, and 24 volt leads, this kit may be used as a slave kit to help in starting any of the vehicles. The proper designation of winterization kits for each type of vehicle is listed in Supply Bulletin 9-16, dated 2 March 1944.

FUELS AND LUBRICANTS

Without gasoline and diesel fuel and lubricating oils and greases, our modern Army would come to a creaking halt. Over half of the supplies required by our fighting forces are petroleum products. And yet, we are inclined to take the quantity and quality of our automotive fuels and lubricants pretty much for granted. At the present time, we are supplied with three automotive fuels: two gasolines and one diesel. The two gasolines are: (1) Motor Fuel, all purpose, U.S.A. specification 2-103b; and (2) Motor Fuel, 72 octane, U.S.A. specification 2-114. The one diesel fuel is: Oil, fuel, diesel, U.S.A., specification 2-102c.

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Motor Fuel, all purpose, is an eighty octane gasoline. It is supplied in two seasonal grades: Grade A for temperatures consistently above zero and Grade C for temperatures consistently below ten degrees above zero. This gasoline in the proper seasonal grade is the only one supplied to overseas areas. Seasonal grades are determined by the boiling range of the gasoline. Since modern gasoline is a hand-tailored mixture of an infinite number of highly complex chemical compounds and since each compound has its own boiling point, the refiner can include or exclude any series of compounds and thereby control the range of boiling points. If a relatively high percentage of the gasoline has low boiling points, it will be very volatile and hence provide easy motor starting in cold weather. But this same volatility would present a problem in warm weather as it would encourage 'vapor lock.'

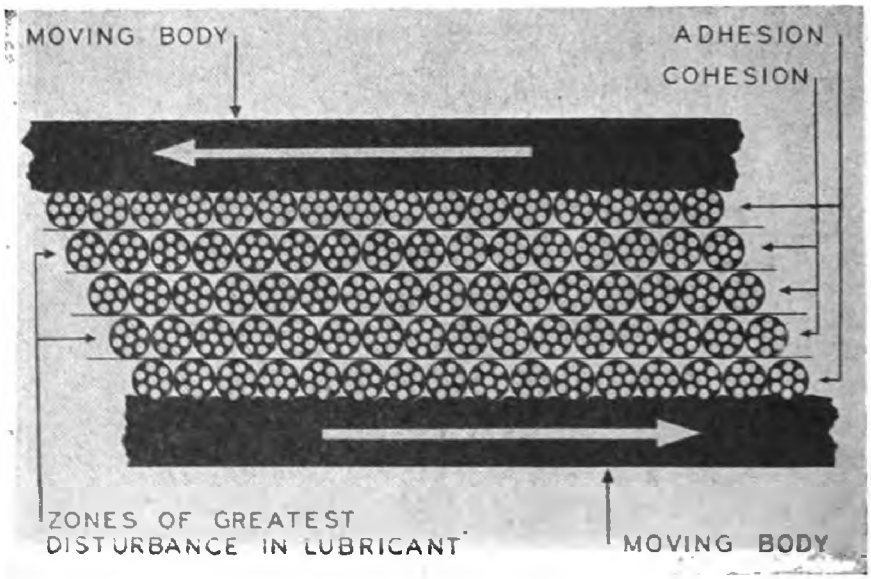

Figure 169. Fluid Friction Within Oil.

Motor Fuel, 72 octane, is supplied in three seasonal grades: Grade A is the summer grade, Grade B is the spring and fall grade, and Grade C is the winter grade. In the proper seasonal grade, this gasoline is designed for domestic use in transport vehicles.

What is the significance of octane rating? Actually, a high octane rating only tells us that we may successfully use that gasoline in a high compression engine with a well-advanced spark timing. The use of a low octane fuel in a high compression engine would cause detonation (spark knock, pinging, etc.). We should realiize that if a specific engine is running without detonation on a fuel of a certain octane rating, we will gain nothing by the use of a fuel with a higher octane rating, unless we advance the spark or make some other mechanical adjustment to take advantage of the higher octane rating. A high octane rating, of itself, is no indication that the fuel has better starting qualities or that we will obtain more miles per gallon of gasoline.

In addition to controlling the boiling range of the gasoline and its octane rating, the aforementioned specifications also specify the permissible gum forming tendency of the fuel, the amount of tetraethyl lead which may be used to improve octane rating, and the ability of the gasoline to withstand protracted storage.

Oil, fuel, diesel is supplied in two seasonal grades: Grade A for temperatures consistently above zero and Grade C for temperatures consistently below ten degrees above zero. There is one all-important quality in any diesel fuel oil. **It must be clean.** Contamination with water, dirt, or rust will cause abnormal wear in pumps and injection nozzles. It may also cause clogging of the nozzles

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and thereby stop the engine. Likewise, the fuel must have the viscosity for which the engine is designed, or the pumps and nozzles will not be able to handle the fuel properly. The ignition quality of a diesel fuel is indicated by the cetane rating of the fuel. Oil, fuel, diesel has a specified octane rating of 40 which is sufficiently high for all practical purposes. An amazing characteristic of our winter grade diesel fuel is that it remains fluid down to fifty degrees below zero.

The three fundamental types of automotive lubricants are: engine oil, gear lubricant, and grease. We are presently supplied with one engine oil in three grades, one gear lubricant in three grades, and four greases. It is not belaboring the obvious to point out that without lubrication our automotive equipment cannot function at all and that without the proper lubricant the serviceable life of our vehicles will be appreciably shortened.

Oil, lubricating, engine (symbol OE) U.S.A. specification 2-104b is supplied in grades SAE 10, SAE 30, and SAE 50. SAE stands for the Society of Automotive Engineers and, in this instance, indicates a system established by that organization to classify engine oils according to viscosity. It means that SAE 10 will flow more easily and readily than SAE 30 and SAE 30 will flow more easily and readily than SAE 50. Hence, we use SAE 30 in an engine with average clearances as in the jeep, and SAE 50 in an engine with relatively large clearances and which operates under heavy loads as does the radial engine in the M4 medium tank. Of course, temperature has it effect on viscosity, so that when it gets cold, we use SAE 10 in the jeep and SAE 30 in the tank engine.

There is one quality of our engine oil which is sometimes misunderstood. Oil, lubricating, engine is said to be a 'detergent' oil. This means simply that there are certain chemicals added to the oil which retard its tendency to form sludge. The manner in which it does this enables us to drain out all dirt, water, etc., (which go to make up sludge) whenever we drain the crankcase, thus leaving the engine as clean as new.

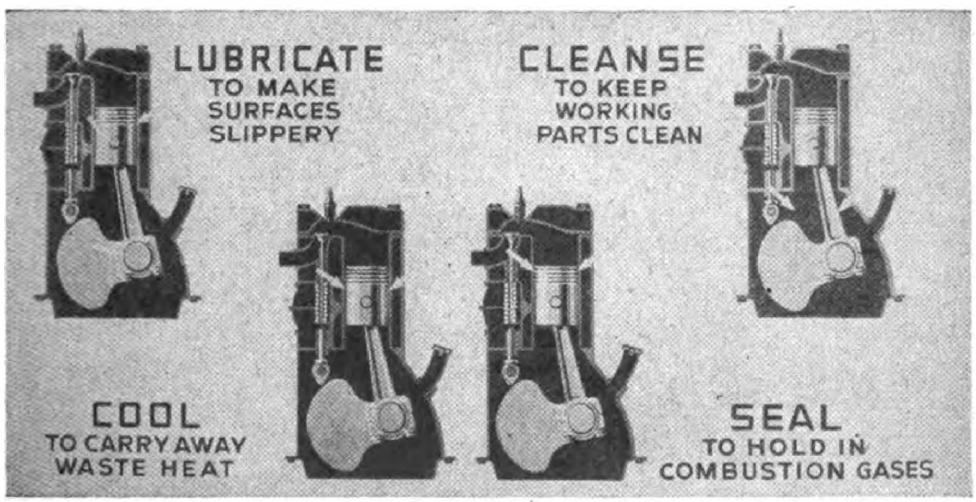

Figure 170. Oil in an Internal-Combustion Engine Must Do Four Jobs at the Same Time.

Gear, lubricant, universal (symbol GO) U.S.A. Specification 2-105 is supplied in three grades: SAE 75, SAE 80, and SAE 90. The word universal is employed since this gear lubricant may be successfully used in the lubrication of any type of gear: spur, helical, spiral bevel, hypoid, etc. Grade SAE 75 is used only in arctic operation and Grade SAE 80 in cold operation consistently between freezing and zero. SAE 90 is used in all other conditions. Th esame differences exist between the three grades of gear lubricant as existed between the three grades of engine oil. SAE 75 pours more readily than SAE 80, and SAE 80 pours more readily than SAE 90. But the three gear lubricants are not more viscous than all engine oils. The SAE system arbitrarily assigns all numbers from 10 to 70 to engine oils and the numbers from 80 to 250 to gear lubricants. The two systems

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overlap. Our gear lubricants have about the same viscosity as SAE 40 engine oil would have. The difference between engine oils and gear lubricants lies in their film strengths. Gear lubricants have chemicals added to the oil which enable them to maintain a film of lubricant despite the scraping action of the gears as they revolve in mesh.

The four greases with which we are supplied are: Grease, general purpose, No. 0, U.S.A. specification 2-106; Grease, general purpose No. 1, U.S.A. specification

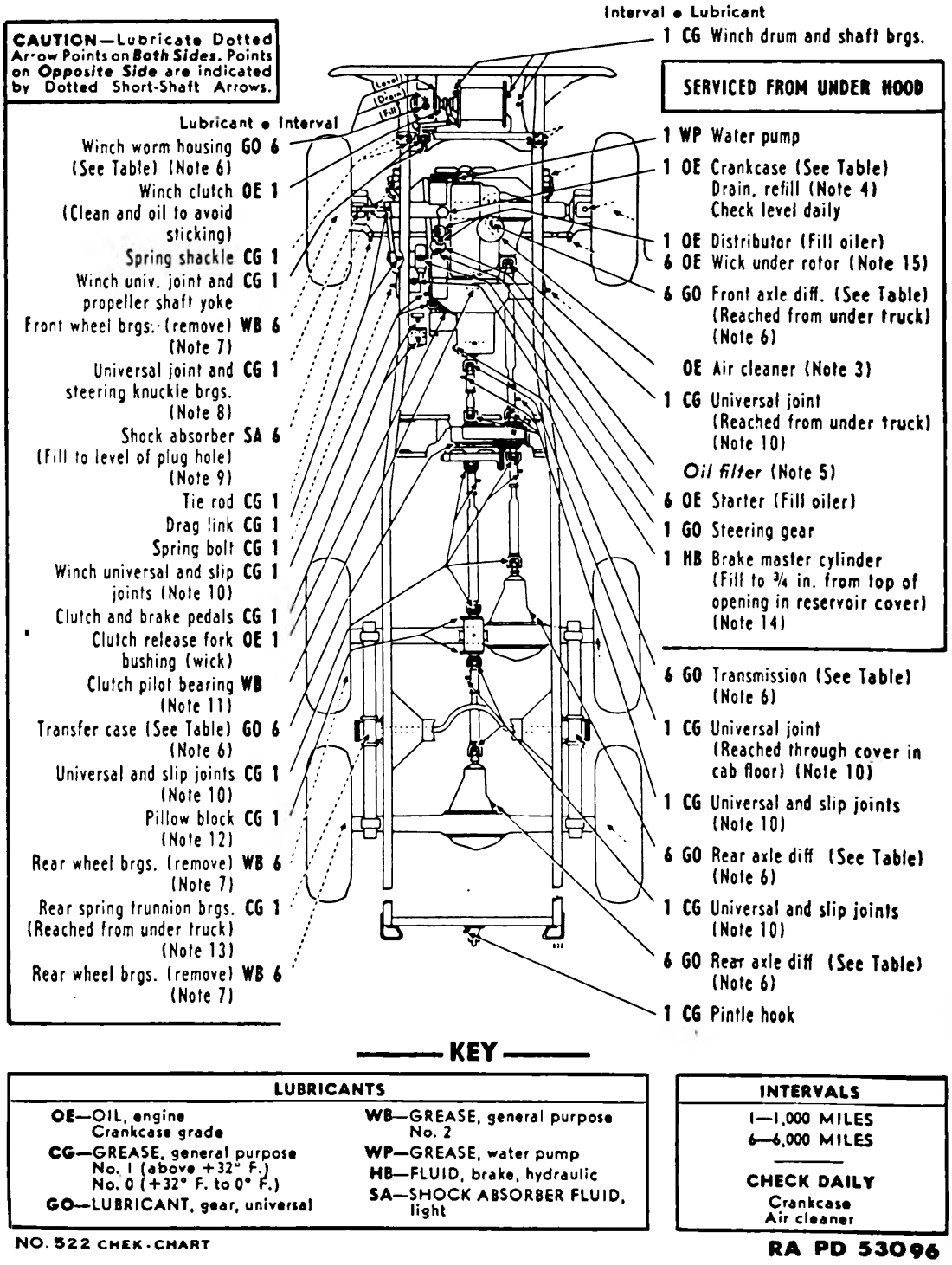

Figure 171. War Department Lubrication Order.

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2-107; Grease, general purpose, No. 2, U.S.A. specification 2-108; and Grease, water pump, U.S.A. specification 2-109. The symbol for both general purpose No. 0 and general purpose No. 1 is CG since they are both chassis greases. No. 0 is used in cold weather and No. 1 in warm weather. The symbol for general purpose No. 2 in WB, since it is the wheel bearing grease; and, of course, the symbol for grease, water pump, is WP. In respect to any lubricant (but particularly greases), it is of the utmost importance that containers be kept closed whenever possible so that the lubricant can be kept free of sand, dirt, and other abrasives.

It is well to note here the development by the Ordnance Department, of a new type of grease fitting. Fitting, lubricating, straight, (Ord. Pc. Mk. CLDX6A, Fed. Stock No. 45-f-448-200) presents several advantages over previous types. The grease channel is larger and there is a spring loaded ball acting as a dirt and water seal at the extreme end.

The what, where, when, and how of actual lubrication is very well presented in War Department Lubrication Orders. There is one issued for each vehicle.

Ordnance personnel should be earnest disciples of intelligent and systematic lubrication. Good lubrication practices will reduce the time spent by our equipment 'on deadline' and in the shop, thereby making the accomplishment of the mission of Ordnance more effective.

PREVENTIVE MAINTENANCE SERVICE AND INSPECTIONS

Definition. Preventive maintenance service is the policy initiated by the War Dept. to provide:

1. A systematic program of inspection to detect and correct minor vehicular malfunctions before they develop into major failures.
2. A system of planned inspections to maintain vehicles on a satisfactory operating status.

This policy has been developed by examination of methods used by field organizations, training establishments, civilian manufacturers and maintenance establishments, and through consultation with experts in this field. Through this means, information governing this policy has been established as the most efficient standard operating procedure for periodic maintenance of government vehicles.

FORMS, RECORDS, REPORTS. (FIRST ECHELON)

In order that all inspections be uniform throughout the armed forces, certain forms have been designated for each responsibility.

W.D. Form No. 48. 'Driver's Trip Ticket and Preventive Maintenance Service Record.' This form is the operator's official authorization for driving a vehicle. When completed, it contains a record of his route, destination, load, speedometer readings, and other information pertinent to the trip. In addition, the reverse side of this form lists the items to which the driver must give attention to daily: namely, before operation, during operation, at-halt operation, after operation, and weekly services.

Drivers in convoy are not required to use this form, but it is suggested that it be used by all drivers, at all times, as a handy check list for the above mentioned inspections. Detailed instructions concerning these checks will be covered in paragraphs to follow.

FORMS, RECORDS, REPORTS (SECOND ECHELON)

W.D., A.G.O. Form No. 461 and 462. 'Preventive Maintenance Service and Technical Inspection Work Sheet for Wheeled and Half-Track Vehicles.'

W.D., A.G.O. Form No. 463. 'Preventive Maintenance Service and Technical Inspection Work Sheet for Motorcycles.' These three forms are the basis for regular second echelon (using arm) inspections, clearly defining the points to be checked and lubricated throughout the vehicle. When completed, the exact status of the unit is indicated with other pertinent information dealing with such subjects as vehicle nomenclature, date of inspection, inspector, responsible officer, and a clear statement under 'Remarks' of all malfunctions to be corrected by higher echelons. If a vehicle is to be turned over to Ordnance personnel for servicing, this category should, as closely as possible, state the symptoms and necessary repairs required.

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W.D. Form No. 48

U.S.A. No. _____

Driver's Name _____ Date _____

DRIVER'S TRIP TICKET AND P.M. SERVICE RECORD.

Report to _____ Time out _____

Organization _____ Time in _____

Department or address _____

Kind of work (or route) _____

Requested by _____
(Organization or Individual)

_____
(Dispatcher's Signature)

		Speedometer	Hour Meter
Fuel added (Gals.) _____	In		
Oil added (Qts.) _____	Out		
Total: Miles - Hours			

I have performed the "Preventive Maintenance Services" of this form and recorded all deficiencies and any accident.

Driver's Signature _____

I have noted all entries on this form and taken the necessary action

Dispatcher's, etc. Signature _____

TRIP OR LOAD RECORD	Passengers or Weight	Speedometer or Hour Meter
From		
To		
To		
To		
To		
To		
To		
To		

Vehicle released at _____ _____ _____
(Speedometer - Hour Meter) (Date) (Hour)

Official User _____
(Signature) (Rank)
(See reverse side)

RA PD 317189

Figure 172. Obverse, W.D. Form No. 48, Driver's Trip Ticket and Preventive Maintenance Service Record.

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War Dept. Form No. 6. 'Duty Roster.' This is an Ordnance adaptation of the standard organizational 'Duty Roster.' With slight modifications it serves as a guide to all types of inspections, their due dates and the location of each unit at all times.

The right hand page of form No. 6 contains 31 columns for the days of the month. The adjacent columns on the left hand page will be used to list the make, nomenclature, and U. S. A. registration number for each vehicle of the unit. One line for each vehicle will be used to indicate the periodic maintenance

DRIVER'S DAILY PREVENTIVE MAINTENANCE SERVICES

Perform these services according to the instructions in TM 9-2610, or manual

BEFORE OPERATION SERVICE

1 TAMPERING & DAMAGE	10 HORN & W/S WIPERS	19 BODY, LOAD & TARPS
2 FIRE EXTINGUISHERS	11 GLASS & RV MIRRORS	20 DECONTAMINATOR
3 FUEL, OIL & WATER	12 LAMPS & REFLECTORS	21 TOOLS & EQUIPMENT
4 ACCESSORIES & DRIVES	13 WHEEL & FLANGE NUTS	22 ENGINE OPERATION
5 AIR BRAKE TANKS	14 TIRES &/OR TRACKS	23 DR. PERMIT & FORM 26
6 LEAKS; GENERAL	15 SPRINGS & SUSPENSIONS	24 AMPHIBIAN SERVICES
7 ENGINE WARM-UP	16 STEERING LINKAGE	25 DURING OPERATION CHECK
8 CHOKE OR PRIMER	17 FENDERS & BUMPERS	
9 INSTRUMENTS	18 TOWING CONNECTIONS	

DURING OPERATION SERVICE

26 STEERING BRAKES	31 ENGINE & CONTROLS	36 GUNS; MOUNTINGS, & ELEVATING, TRAVERSING, GYRO & FIRING CONTROLS
27 FOOT & HAND BRAKES	32 INSTRUMENTS	37 AMPHIBIAN SERVICES
28 CLUTCH	33 STEERING GEAR	
29 TRANSMISSION	34 RUNNING GEAR	
30 TRANSFER	35 BODY & TRAILER	

AT HALT SERVICE

38 FUEL, OIL & WATER	43 STEERING LINKAGE	50 TOWING CONNECTIONS
39 TEMPERATURES; HUBS, BRAKE DRUMS, TRANSFER, TRANSMISSION & AXLES	44 WHEEL & FLANGE NUTS	51 BODY, LOAD & TARPS
40 AXLE & TRANSFER VENTS	45 TIRES &/OR TRACKS	52 APPEARANCE & GLASS
41 PROPELLER SHAFTS	46 LEAKS; GENERAL	53 AMPHIBIAN SERVICES
42 SPRINGS & SUSPENSIONS	47 ACCESSORIES & BELTS	
	48 AIR CLEANERS	
	49 FENDERS & BUMPERS	

AFTER OPERATION SERVICE

54 FUEL, OIL & WATER	67 ENGINE CONTROLS	80 VISION DEVICES
55 ENGINE OPERATION	68*TIRES &/OR TRACKS	81 TURRET, & GUN; MOUNTINGS, & ELEVATING, GYRO, TRAVERSING & FIRING CONTROLS
56 INSTRUMENTS	69*SPRINGS & SUSPENSIONS	82*TIGHTEN; WHEEL, RIM, AXLE DRIVE FLANGE & SPRING U-BOLT NUTS
57 HORN & W/S WIPERS	70 STEERING LINKAGE	83*LUBRICATE AS NEEDED
58 GLASS & RV MIRRORS	71 PROPELLER SHAFTS, CENTER BEARING & VENT	84*CLEAN ENGINE & VEHICLE
59 LAMPS & REFLECTORS	72*AXLE & TRANSFER VENTS	85*TOOLS & EQUIPMENT
60 FIRE EXTINGUISHERS	73 LEAKS; GENERAL	86*AMPHIBIAN SERVICES
61 DECONTAMINATOR	74 GEAR OIL LEVELS	
62*BATTERY & VOLTMETER	75*AIR BRAKE TANKS	
63*ACCESSORIES & BELTS	76 FENDERS & BUMPERS	
64*ELECTRICAL WIRING	77*TOWING CONNECTIONS	
65*AIR CLEANERS & BREATHER CAPS	78 BODY, LOAD & TARPS	
66*FUEL FILTERS	79 ARMOR & FRONT ROLLER	

* Those items marked by an asterisk (*) require additional weekly services.

Record any accident and all deficiencies, indicating if corrected

RA PD 317190

Figure 173. Reverse. W.D. Form No. 48, Driver's Trip Ticket and Preventive Maintenance Service Record.

services performed on it during the month. If desired, a second line may be left for each vehicle in which lubrication records will be entered. At the top of the form, the heading 'Guard Roster' will be lined out and 'Motor Vehicle Preventive Maintenance Roster' entered instead. The month and year should be written at the right.

On the line with each vehicle, blank spaces will be left for the number of days remaining until the vehicle is due for its next weekly, monthly, or semi-annual preventive maintenance service. In the column representing the appropriate date, the letter W (weekly), M (monthly or 1000 mile), or S (semi-annual or 6000 mile) is inserted. For tank-like vehicles F will indicate 50 hour check and H the one hundred hour check to cover these corresponding periods. In addition to the letter, a small numeral will be added in the last square to indicate the number of similar periods between each more comprehensive check.

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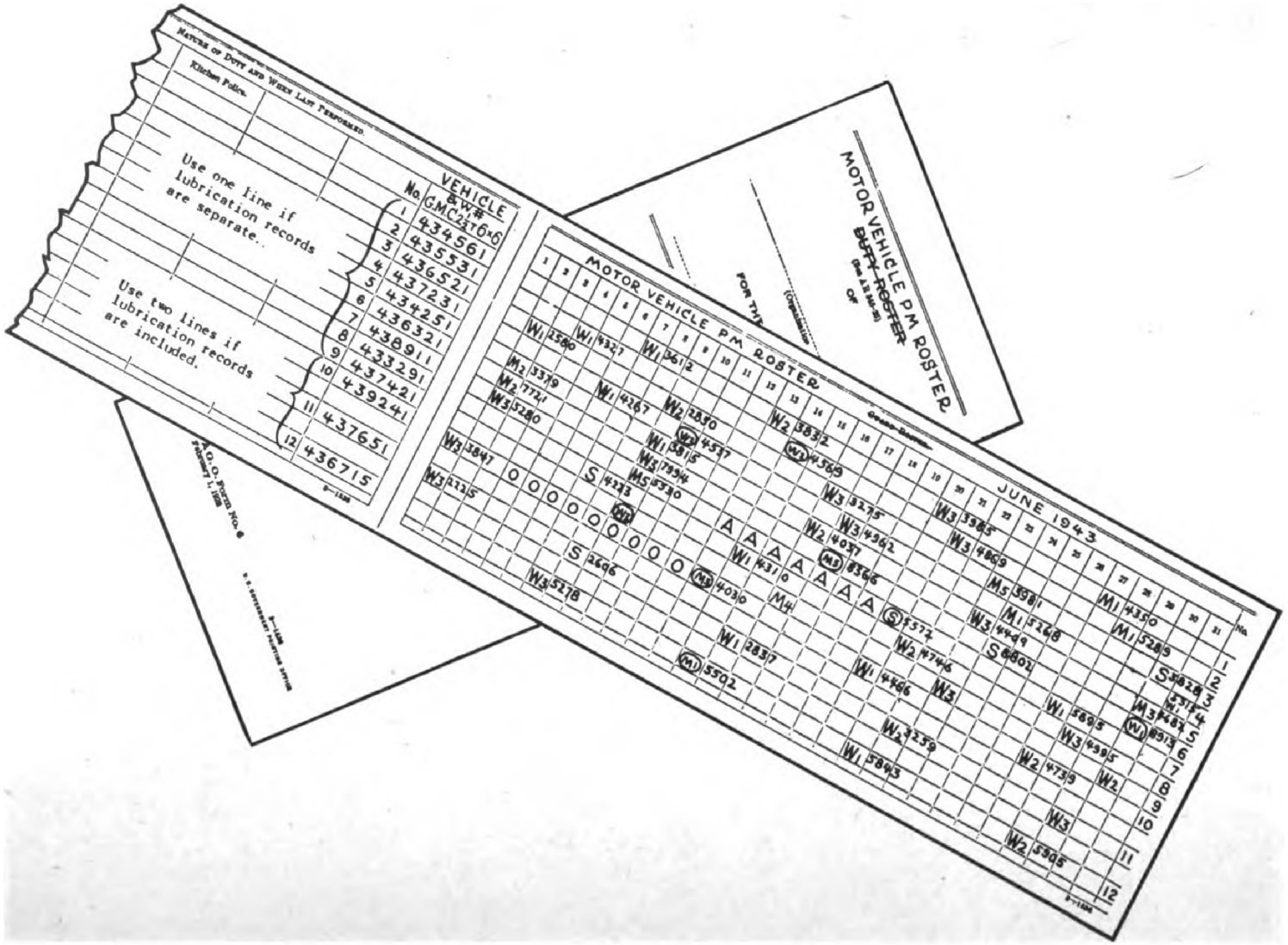

Figure 174. W.D., A.G.O. Form No. 6, Duty Roster Adapted for Use as a Motor Vehicle Maintenance Roster.

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In the case of weekly checks the first check after the monthly service will be indicated as W-1, the second as W-2, etc., until the next monthly check is performed when the numbering starts again. After each service, the date and nature of the next scheduled inspection will be noted following this system: W1, W2, W3, M1, W1, W2, W3, M2, W1, W2, W3, M3, W1, W2, W3, M4, W1, W2, W3, M5, W1, W2, W3, S1. For greater efficiency the mileage should be added after each symbol.

Three additional symbols are used where they apply.

P—Deadlined for parts.
A—Deadlined due to accident
O—Deadlined in Ordnance shop

Spot-Check Form W.D., O.O. Form 7353. 'Spot Check Inspection for All Motor Vehicles.' This form is provided as a record for use of officers other than the using arm and is used for conducting this type of command inspection.

TYPES OF INSPECTIONS (FIRST ECHELON)

Vehicle inspections can roughly be broken down into two categories known as First and Second Echelons of Maintenance. The former deals exclusively with driver responsibilities and the latter with more thorough organizational checks. In addition to these two classifications, occasional command and technical inspections are performed. These, however, are irregular and are not within the scope of responsibility of using units.

Daily Inspection. As mentioned previously, Form 48, 'Driver's Trip Ticket and P.M. Service Record' lists the driver's responsibilities. Daily checks include the following general headings:

Before Operation Service. This service should never be entirely omitted no matter how urgently the vehicle's use is required. After a short period of time the driver can perform this service almost automatically. Strict adherence to these checks will bring to light. to a large degree, any major defects present.

During Operation Service. While the vehicle is in motion a good operator should listen for any signs of trouble, usually indicated by unusual noises or erratic behavior of his vehicle. He should be constantly on the alert for odors, squeals, and overheating; any of these can mean serious trouble. A conscientious driver should check his instruments constantly and notice promptly if any instrument indicates that some unit may be operating improperly. Should any irregularities develop he should stop and investigate.

At-Halt Service. This servicing is performed while the vehicle is at rest enroute. It consists of investigating and correcting defects that may have developed during operation, and a general check-up to see if the vehicle is still in a satisfactory condition. During this period such things as air, water, fuel, and visual inspection of major units for overheating and leakage are included.

After Operation Service. The purpose of the after operation service is to prepare the vehicle for its next operation. This group is particularly important, for it allows time to correct any minor defects. If this service is performed thoroughly. the vehicle will be ready to roll again at a moment's notice.

Weekly Service (First Echelon). This service is primarily to subsidize daily checks. It includes all the points listed under after operations service plus additional attention to certain items, including a general tightening and cleaning and lubrication if required. The weekly service can serve as a check on the caliber of day by day maintenance of the driver.

TYPES OF INSPECTIONS (SECOND ECHELON)

In addition to the elementary inspections performed by the driver, more comprehensive checks are also the duty of the using organization. These fall under second echelon requirements and include:

(1) Wheeled and half-track vehicles at monthly or 1000 mile (whichever occurs first) and six month or 6000 mile (whichever occurs first) intervals.

(2) Full track and tank-like vehicles at monthly (50 hr.) and 6 month (100 hr.) intervals.

While the personnel performing this type of work are normally more highly trained than the vehicle drivers, it is desirable that the operator assist the

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mechanics with their work as much as possible. They are most familiar with the units they drive daily, and can give considerable assistance to inspection crews because of this fact. In addition to this, by working with more experienced men they broaden their own relatively limited knowledge, giving them improved qualifications for maintaining their vehicles on a sound basis. It is imperative that organizational mechanics be thoroughly trained. They must be completely familiar with forms used and their intent, as well as being capable technicians. Supplying correct information and understanding symbols are mandatory if their work is to be accurate and reliable. Special symbols indicate that certain parts are to receive mandatory services in addition to inspection and lubrication. These symbols are:

A—Adjust. Make all adjustments in accordance with publications.

C—Clean. Clean parts in question according to prescribed methods and keep them clean until re-installed.

L—Special Lubrication. This includes lubrication of parts not shown on normal lubrication charts.

S—Serve. Usually consists of performing special operations such as replenishing battery water, brake fluid, and shock absorber fluid, draining and refilling units with oil, and changing or cleaning the fuel or oil filter cartridge.

T-Tighten. All tightening operations should be performed with sufficient torque to tighten the nut according to good mechanical practice.

SAMPLE

Tech. Insp.	6000 Mile	1000 Mile		
		20	**Spark Plugs.** Examine the installed spark plugs to see that their insulators are in good condition and clean; note any evidence of leakage around the insulators or gaskets.	Applies to 1000-mile maintenance only.
20	20		Remove the spark plugs and examine for poor condition, paying particular attention to broken insulators, excessive carbon deposits, and to electrodes which are burned thin. Replace unserviceable plugs. Report excessive deposits or damaged insulators, as these conditions may indicate incorrect heat range.	Applies both to technical inspection and 6000-mile maintenance
	20		CLEAN. Clean the deposits from the insulators and electrodes, and check the insulators to see whether they are cracked. If a plug cleaner is not available, install new or reconditioned plugs.	Applies to 6000-mile maintenance only.
	20		ADJUST. Adjust gaps to specifications by bending the grounded electrodes. After completing item number 21, reinstall the plugs, using new gaskets and taking care not to overtighten them as this may cause distortion and damage.	

Figure 175. Sample of Inspection Sheet.

Procedures for Wheeled and Half Track Vehicles. W.D., A.G.O. Form 461 is used in this category. The items on this form should be performed in the numerical sequence in which they are listed wherever possible, since they have been so arranged for maximum efficiency and economy of motion. The general order of the listed items is:

1. A road test and items closely related to it.

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2. Maintenance operation.
   a. Operations in the engine compartment.
   b. Chassis, body and attachment items.
   c. Items pertaining to half-track vehicles.
   d. Items pertaining to amphibious vehicles.
   e. Items pertaining to trailers.
   f. Final road test.
3. Tools and equipment
4. Final road test.

Any items on half-tracks, trailers, and amphibians which are common to other vehicles are serviced in the same manner as the wheeled vehicles. Trailer items are indicated with an asterisk. If at any time a unit is disassembled, 6000 mile maintenance should be performed.

All inspection forms are retained by the using organization. 1000 mile sheets are filed until the following 6000 mile check, then destroyed. 6000 mile sheets are filed until the next 6000 mile check is performed and then are also destroyed.

The detailed procedure for each maintenance service is to be followed as per instructions outlined: TM 9-2810 Motor Vehicle Inspections and Preventive Maintenance Service. The illustration below shows a typical item of inspection and how it applies to the work sheet as directed in that publication.

The number '20' represents item 20 on Form 461. Suppose work done is on the 1000 mile maintenance service. Item 20, in this sample, appears in the 1000 mile maintenance column opposite the first paragraph only, giving this as the only required procedure. Similarly, the figure 20 appears in technical inspection and the 6000 mile maintenace columns opposite the second paragraph, indicating that this procedure is to be performed on both these operations. In the 6000 mile maintenance column item 20 again appears in paragraph three (clean) and four (adjust). These correspond with the letters C and A on W.D. A.G.O. Form 461 and are mandatory only on the 6000 mile inspection. If the principles outlined in TM 9-2810 are adhered to rigidly, no item can possibly be overlooked or be improperly serviced.

Procedure for Full Track and Tank-Like Vehicles. W.D., A.G.O Form 462 applies to this group and is similar to W.D. A.G.O. Form 461, except that maintenance periods are determined by engine hours of operation (50 and 100) rather than mileage. As suggested above, items should be followed numericaly as much as possible. Sub-divisions on the form are broken down into:

1. Road Test.
2. Maintenance Operations.
   a. Items on exterior of vehicle.
   b. Items on the engine compartment.
   c. Items on the fighting compartment.
   d. Items pertaining especially to tank-like vehicles.
   e. Items of armament.
3. Tools and Equipment.
4. Final Road Test.

Procedures and directions concerning specific operations are outlined in TM 9-2810 and follow the same general pattern as wheeled vehicle services.

All 50 hour work sheets are retained until the following 100 hour service; all 100 hour sheets are filed until the following 100 hour check.

Procedure for Motorcycles. W.D., A.G.O. Form 463 is used for motorcycles exclusively. Some slight difference exists between the two forms previously mentioned and this type. The column for 6000 mile inspections is eliminated and an asterisk is added after certain items: This indicates that special servicing is performed every sixth 1000 mile check. Aside from this single difference the inspection is conducted along the same lines as tank and wheeled vehicle services.

All 1000 mile maintenance service forms are to be held until six are accumulated, when the oldest is destroyed. Technical inspection forms are retained until completion of the following inspection. In the event that a vehicle is transferred to another organization, the latest inspection sheet should accompany the unit to its destination.

Technical Inspections. This type of check is not the responsibility of the using

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PREVENTIVE MAINTENANCE SERVICE AND TECHNICAL INSPECTION

WORK SHEET

FOR

WHEELED AND HALF-TRACK VEHICLES

(See AR 850-15)

W.D. No. _____

Mileage _____ Date _____

Organization _____

Vehicle nomenclature ← (Make) (Model) (Size) (Drive) (Body Type) →

Special instructions: See TM 9-2810 for detailed instructions and procedures. See vehicle maintenance manual for technical information.

Legend for marking. ✓—Satisfactory X—Adjustment required XX—Repair or replacement required O—Defect corrected

SYMBOLS: □ —INSPECT AND CORRECT C—CLEAN T—TIGHTEN A—ADJUST L—SPECIAL LUBRICATION S—SERVE

6000-MILE MAINTENANCE OR TECHNICAL INSPECTION | 1000-MILE MAINTENANCE | Line out words and columns that do not apply

ROAD TEST

1 **Before Operation Inspection**
2 **Air Pressure** (build-up) (governor cut-off) (low-pressure indicator)
3 **Dash Instruments and Gages;** (oil pressure) (viscometer) (ammeter) (voltmeter) (speedometer and odometer) (tachometer) (temperature) (fuel) (air pressure)
4 **Horns, Mirrors, and Windshield Wipers**
5 **Brakes;** foot, hand and trailer (braking effect) (feel) (side pull) (noise) (chatter) (pedal travel) (hand control-air or electric)
6 **Clutch** (free travel) (drag) (noise) (chatter) (grab) (slip)
7 **Transmission and Transfer;** (lever action) (declutching) (vibration) (noise)
8 **Steering** (free play) (bind) (wander) (shimmy) (side pull) (column and wheel)
9 **Engine** (idle) (acceleration) (power) (noise) (governed speed)
10 **Unusual Noises** (attachments) (cab) (body) (wheels or tracks)
11 **Brake Booster Operation**
12 **Air-Brake System Leaks**
13 **Temperatures** (brake drums) (hubs) (axles) (transmission) (transfer)
14 **Leaks** (engine oil) (water) (fuel)
15 **Track Tension** (final road test)
16 **Gear Oil Level and Leaks** (axles) (transmission) (transfer)

RAISE VEHICLE-BLOCK SAFELY

17 **Unusual Noises** (engine) (belts) (accessories) (transmission) (transfer) (shafts and joints) (axles) (wheel bearings)

ENGINE AND ACCESSORIES

18 **Cylinder Head and Gasket**
19 **Valve Mechanism** (clearances) (lubrication) (cover gaskets)
20 **Spark Plugs** (gaps) (deposits)
21 **Compression Test** (record)
22 **Battery** (cables) (hold-downs) (carrier) (record gravity and voltage)
23 **Crankcase** (leaks) (oil level)
24 **Oil Filters, Coolers, and Lines**
25 **Radiator** (core) (shell) (shutters) (mountings) (hose) (cap and gasket) (antifreeze, record) (overflow tank) (steam relief tube and valve)
26 **Water Pump, Fan, and Shroud**
27 **Generator, Starter, and Switch**
28 **Air Compressor** (unloader valve) (governor) (hose)
29 **Drive Belts and Pulleys**
30 **Tachometer Drive and Adapter**
31 **Distributor** (cap) (rotor) (points) (shaft) (advance [illegible])
32 **Coil and Wiring** (secondary and low voltage) (supports)
33 **Manifolds and Heat Control** (gaskets) (seasonal setting)
34 **Air Cleaners** (carburetor) (Diesel) (air compressor)
35 **Breather Caps and Ventilators**
36 **Carburetor** (choke) (throttle) (linkage) (governor)
37 **Fuel Filters, Screen, and Lines**
38 **Fuel Pump** (vacuum and pressure)
39 **Starter** (action) (noise) (speed)
40 **Leaks** (engine oil) (fuel) (water)
41 **Ignition Timing** (advance)
42 **Engine Idle and Vacuum Test**
43 **Regulator Unit** (connections) (voltage) (current) (cut-out)
44 **Power Tire Pump** (drive) (lines)
45 **Diesel Fuel Injector Pump**
46 **Diesel Fuel Nozzles and Lines**

CHASSIS, BODY, & ATTACHMENTS

47 ***Tires and Rims** (valve stems and caps) (condition) (direction) (matching) (spare carriers)

ON HALF-TRACKS DO 106 TO 115 NOW

48 ***Rear Brakes** (drums) (supports) (cylinders) (cams and shafts) (magnets and armatures)
49 ***Rear Brake Shoes** (linings) (links) (guides) (anchors)
50 ***Torque Rods** (bushings) (brackets)
51 ***Rear Spring Seats and Bearings**
52 ***Rear Wheels** (bearings) (seals) (drive flanges) (nuts)
53 ***Front Brakes** (drums) (supports) (cylinders) (cams and shafts) (hose) (air chambers) (push rods and seals) (adjusters)
54 ***Front Brake Shoes** (linings) (links) (guides) (anchors)
55 ***Steering Knuckles** (joints) (bearings) (seals) (boots)
56 ***Front Springs** (clips) (leaves) (U-bolts) (hangers) (shackles)
57 **Steering** (arms) (tie rods) (drag link) (seals and boots) (Pitman arm) (gear) (column) (wheel)
58 **Front Shock Absorbers and Links**
59 **Knee Action Suspension**
60 ***Front Wheels** (bearings) (seals) (flange) (axle end play) (nuts)
61 **Front Axle** (pinion end play) (seal) (vent) (alinement)
62 **Front Propeller Shaft** (joints and alinement) (seals) (flanges)
63 **Engine** (mountings and braces) (ground strap) (side pans)
64 **Hand brake** (ratchet and pawl) (linkage) (drum or disk) (lining)
65 **Clutch Pedal** (free travel) (linkage) (return spring)
66 **Brake Pedal** (free travel) (linkage) (return spring)
67 **Brake Master Cylinder** (vent) (fluid level) (leaks) (switch)
68 **Brake Vacuum Booster** (linkage) (air cleaner and hose) (cylinder)
69 **Air-Brake Application Valve**
70 ***Air-Brake Reservoirs**
71 **Transmission** (mountings) (seals) (power take-off) (linkage)
72 **Transfer** (mountings) (linkage) (seals) (vent) (power take-off)
73 **Rear Propeller Shafts** (see 62)
74 **Center Bearing** (seals) (vent) (oil level) (mountings)
75 **Rear Axles** (pinion end play) (seals) (vents) (alinement)
76 ***Rear Air Brake** (chambers) (rods and seals) (slack adjusters)
77 ***Rear Springs** (clips) (leaves) (U-bolts) (hangers) (shackles)
78 **Rear Shock Absorbers and Links**
79 ***Cab and Body Mountings**
80 ***Frame** (rails and cross members)
81 ***Wiring, Conduits, and Grommets**
82 **Fuel Tanks, Fittings, and Lines**
83 ***Brake Lines** (fittings) (hose)
84 **Exhaust Pipes and Muffler**
85 ***Vehicle Lubrication**

LOWER VEHICLE TO GROUND

86 **Toe-In and Turning Stops**
87 **Winch** (clutch) (brake) (drive) (shear pin) (cable) (guides)
88 **Fifth Wheel** (bed plate and bolts)
89 **Tractor-to-Trailer Brake Hose, Wiring and Connections**
90 **Hoist** (mounting) (drive) (controls) (pump) (lines) (cylinder)
91 ***Lamps** (head, tail, body, running, directional, stop, and blackout)
92 ***Safety reflectors**
93 **Front** (bumpers) (roller) (tow hooks) (brush guards) (grills)
94 **Hood** (hinges) (fasteners)
95 **Front Fenders and Running Boards**
96 **Cab or Pass. Body** (doors) (hardware) (glass) (top and frame) (curtains and fasteners) (seats and upholstery and trim) (safety straps and grab rails) (floor boards and mats) (ventilators) (map compartment and tables)
97 **Heater, Fan, and Defroster**
98 **Circuit Breaker and Fuse Block**
99 ***Rear Fenders and Splash Guards**
100 ***Body** (panels) (rear doors) (tailgate and chains) (floor) (skid strips) (stakes) (sockets) (bows) (tops) (tarpaulins) (rear curtains) (troop seats) (stowage compartments)
101 ***Rear Bumper and Pintle Hook** (latch and lock pin) (Crash-bar)
102 **Armor Plate** (body) (cowl) (doors) (windshield) (port covers)
103 ***Paint and markings**
104 **Radio Bonding** (suppressors) (filters) (condensers) (shielding)
105 **Armament** (guns) (mounts) (rails) (spare parts) (covers)

*TRAILER ITEMS ALSO COMMON TO OTHER WHEELED VEHICLES

FOLD TO ← VEHICLE NOMENCLATURE LINE → AND FILE

RA PD 317193

W.D., A.G.O. Form No. 461
April 15, 1948

Figure 176. Obverse, W.D., A.G.O. Form No. 461.

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RECORD: Compression pressure: Cylinder No. 1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ 7 ____ 8 ____ 9 ____ 10 ____ 11 ____ 12 ____

BATTERY: SPECIFIC GRAVITY—Cell No. 1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____ Antifreeze protection to ____ °F

VOLTAGE— Cell No. 1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____

Man hours required for this 1,000 mile maintenance ____ 6,000 mile maintenance ____ or tech. inspection ____

Driver ____ (Grade or title) Mechanic or inspector ____ (Grade or title)

Repairs by higher echelon entered on Job Order Request No. ____ Supervising officer ____ (Grade or title)

Repairs requested ____ (Date) (Initials) Vehicle forwarded ____ (Date) (Initials) Vehicle returned ____ (Date) (Initials)

Disposition of work sheets: 1000 Mile—May be retained until completion of next 6000 mile, then destroy
6000 Mile—May be retained until completion of next 6000 mile, then destroy
Technical inspection—May be retained until completion of next 6000 mile, then destroy
} EARLIER DESTRUCTION MAY BE ORDERED BY LOCAL COMMAND

REMARKS OR RECOMMENDATIONS ____

6000-MILE MAINTENANCE OR TECHNICAL INSPECTION	1000-MILE MAINTENANCE		
			ITEMS SPECIAL TO HALF-TRACKS
T		106	**Tracks** (guides) (tread wear)
CLAT		107	**Sprockets** (flanges) (bearings) (seals)
T		108	**Brake** (drums) (supports) (exhibiters)
CA	A	109	**Brakes Shoes** (hinges) (links) (guides) (anchors)
CLAT		110	**Idlers** (flanges) (bearings)
		111	**Idler** (posts) (shackles) (shafts) (adjusting rods) (brackets)
T		112	**Frame Brackets and Cross Tube**
		113	**Bogie** (crab assemblies) (springs and blocks) (guides and slides) (arms and bolts)
CL		114	**Bogie Rollers: Upper and Lower** (tires) (bearings) (seals) (bolts)
A	A	115	**Track Tension** (on ground)
			ITEMS SPECIAL TO AMPHIBIANS

NOTE: The following items 114 to 123 are the required minimum maintenance for amphibian vehicles in land operations. For maintenance requirements for water operations, consult the vehicle maintenance manual.

6000-MILE MAINTENANCE OR TECHNICAL INSPECTION	1000-MILE MAINTENANCE		
T	T	116	**Rudder and Shearpins, Propeller Strut and Bearing**
		117	**Propeller Shaft Housings** (seals) (boots) (plugs)
		118	**Hull** (plugs) (rub strakes) (decks) (hatches) (ventilators) (compartments) (bulkheads) (plates) (frame)
TA	TA	119	**Bilge Pumps** (drives) (valves) (controls) (lines) (strainers)
T	T	120	**Water Propeller** (shafts) (joints) (bearings) (stuffing box)
		121	**Hand Crank Ratchet and Cover**
T		122	**Rudder** (shafts) (arms) (cables) (rod) (brackets) (stuffing box)
		123	**Anchor, Hand Bilge Pump and Boat Hook**
			ITEMS SPECIAL TO TRAILERS
T		124	**Tow Hitch** (king pin) (5th wheel plates) (lunette) (tongue)
		125	**Air and Electric Connections**
		126	**Safety Devices** (chains) (switch and battery)

6000-MILE MAINTENANCE OR TECHNICAL INSPECTION	1000-MILE MAINTENANCE		
LT	T	127	**Landing gear** (shafts) (wheels) (supports) (lock pin) (gears) (crank)
		128	**Front and Rear Axles**
		129	**Electric Brake** (application) (controller) (dual control) (resistors)
		130	**Parking Brakes** (ratchet) (pawl)
			TOOLS AND EQUIPMENT
		131	**Tools** (vehicle) (operator)
		132	**Fire Extinguishers**
		133	**Decontaminator**
		134	**First-Aid Kit** (of spec. field)
		135	**Publications and Form No. 26**
		136	**Traction Devices** (chains) (plates and connectors) (grousers)
		137	**Tow** (chain) (cable) (rope) (block)
		138	**Spare** (shearpins) (fuses) (bulbs)
		139	**Fuel and Water Cans and Bracket**
		140	**Fuel Can Nozzle and Bucket**
		141	**Modifications** (FSSMWO's completed)
		142	**Final Road Test** (repeat items 2 to 16)

NOTE: Correct or report all deficiencies found during final road test.

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RA PD 317192

Figure 177. Reverse, W.D., A.G.O. Form No. 461.

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PREVENTIVE MAINTENANCE SERVICE AND TECHNICAL INSPECTION

WD No. _____

Mileage _____ Date _____

Hour meter _____

Organization _____

WORK SHEET
FOR
FULL-TRACK AND TANK-LIKE WHEELED VEHICLES
(See AR 850-15)

Vehicle nomenclature _____ (Make) (Model) (Engine No.) (Bits) (Tank, medium armored car, etc.)

Special instructions: See TM 9-2810 for detailed instructions and procedures. See vehicle maintenance manual for technical information.

Legend for marking: ✓-Satisfactory X-Adjustment required XX-Repair or replacement required O-Defect corrected

SYMBOLS: -INSPECT AND CORRECT, C-CLEAN, T-TIGHTEN, A-ADJUST, L-SPECIAL LUBRICATION, S-SERVE

Line out words and subjects that do not apply

100-HOUR MAINTENANCE OR TECHNICAL INSPECTION	50-HOUR MAINTENANCE		
			ROAD TEST
		1	**Before-operation Inspection**
		2	**Instruments and Gages** (oil pressure and hour meter) (Ammeter and voltmeter) (speedometer and odometer) (tachometer and revolution counter) (engine temperature) (transmission oil temperature) (transmission oil pressure) (fuel) (clock)
		3	**Windshield, Windshield Wipers, and Siren**
		4	**Wheel Brakes** (braking effect) (feel) (side pull) (noise) (chatter) (pedal travel) (vacuum booster action)
		5	**Brakes** (steering and parking) (levers) (braking effect) (steering action) (hycon vacuum booster)
		6	**Clutch** (free travel) (drag) (noise) (grab) (chatter) (slip)
		7	**Transmission and Transfer** (lever action) (vibration) (noise) (control synchronization)
		8	**Steering** (free play) (bind) (wander) (shimmy) (side pull) (booster)
		9	**Engine** (idle) (acceleration) (power) (noise) (smoke) (governed speed) (oil consumption)
		10	**Unusual Noise** (propeller shafts and joints) (differential and final drives) (sprockets) (idlers) (wheels) (support rollers) (tracks)
		11	**Temperatures** (transmissions) (transfer) (differential and final drives) (hubs, sprockets, idlers, wheels, and rollers) (brake drums)
		12	**Gun Elevating and Traversing Mechanism** (operation)
		13	**Leaks** (engine oil) (water) (fuel)
		14	**Noise and Vibrations** (engine) (mountings) (accessories and drives) (clutch) (exhaust)
		15	**Track Tension** (final road test)
			MAINTENANCE OPERATIONS
		16	**Engine Vacuum and Fuel Pump Test**
			Stop engine—Open Battery Switch
S	S	17	**Crankcase** (leaks) (level)
		18	**Side Armor** (fenders) (guards) (paint and markings) (shackles) (eyes)
TL	TL	19	**Bottom** (armor) (escape hatch) (inspection plates) (drain plugs)
T		20	**Differential and Final Drives**
T	T	21	***Track** (blocks) (connectors) (wedges)
T	T	22	***Idler** (wheels) (arms) (eccentrics) (serration plates) (adjustment nuts) (springs)
T		23	**Bogie** (levers) (arms) (lines) (gudgeons, collars and guides) (springs and seats) (frames) (wearing plates)
T		24	**Wheels** (tires) (rollers and skids)
T	T	25	***Sprockets** (hubs) (teeth) (nuts)
A	A	26	**Track Tension**
		27	**Top Armor**; (turret) (deck) (paint and markings) (grills) (doors) (hatches) (covers and latches) (antenna mast)
		28	**Caps and Gaskets** (fuel) (radiator)
S	S	29	**Radiator Removal** (overhead)
RC		30	**Engine Removal** (when required)
A		31	**Valve Mechanism** (clearances) (lubrication) (rover gaskets) (rocker boxes) (push rod housings)
CAB		32	**Spark Plugs** (gaps) (deposits)
		33	**Compression test** (record)
CT		34	**Generators and Starting Motors**
ST	CT	35	**Cartridge Starter**
LA	L	36	**Distributors** (cap) (rotor) (points) (shaft) (advance unit)
A		37	**Magnetos** (points)
C	C	38	**Ignition Wiring and Conduits**
		39	**Coils** (standard) (booster)
TCS	C	40	**Radial Engine** (oil pumps) (sump) (oil screens and lines) (accessory case) (crankcase) (fuel screens and lines) (control linkage)
AT		41	**Diesel** (fuel pumps) (injectors) (lines) (governor)
CB	CB	42	**Breather Caps and Ventilators**
CB	CB	43	**Air Cleaners** (carburetor) (Diesel)
C	C	44	**Carburetor** (choke) (throttle) (linkage) (governor) (primer)
T		45	**Manifolds** (intake) (exhaust)
C		46	**Cylinder** (heads) (gaskets) (radial cylinders)
T		47	**Radial Engine** (cowling) (air deflectors) (flywheel, fan and guard) (steady bar) (support beam)
		48	**Clutch Assembly**
		49	**Water Pumps, Fans, and Shrouds**
A	A	50	**Accessory Drives** (belts) (pulleys) (shafts and couplings)
C		51	**Engine Compartment** (bulkhead) (control linkage)
TS		52	**Engine Oil** (tanks) (coolers) (lines and fittings)
TS		53	**Fuel** (tanks) (vents) (lines) (pumps)
CS		54	**Engine Oil Filters**
CS	C	55	**Fuel Filters and Screens**
C	C	56	**Oil Coolers** (transfer unit transmission) (cores) (lines)
T		57	**Exhaust Pipes and Mufflers**
T		58	**Engine Mountings**
T		59	**Clutch Release** (radial) (yoke) (rollers) (linkage) (mountings)
TL	L	60	**Fire Extinguisher System** (tanks) (valves) (lines and nozzles) (mountings)
S		61	**Engine** (install mountings) (lines and fittings) (wiring) (control linkage) (oil supply)
S	S	62	**Radiators** (install) (core) (mountings) (hose) (antifreeze, record)
CS	CS	63	**Batteries** (cables) (hold downs) (carrier) (record gravity and voltage) (switch and fuel valves)
A		64	**Accelerator** (linkage) (dual-throttle synchronization)
		65	**Starter** (primer) (instruments)
		66	**Leaks** (engine oil) (fuel) (water)
		67	**Ignition Timing**
		68	**Regulator Unit** (connections) (voltage) (current) (cut-out)
A		69	**Engine Idle and Vacuum Test**
		70	**Throttle Synchronization**
		71	**Fighting Compartment** (paint) (seats) (safety straps) (crash pads) (stowage boxes) (ammunition boxes, clips and racks)
		72	**Turret** (basket) (cupola) (locks)
		73	**Protectoscopes and Periscopes**
A	A	74	**Clutch Pedal** (free travel) (linkage) (return spring)
TA		75	**Brakes** (steering) (parking) (levers) (latches) (linkage) (shafts)
TS		76	**Steering Brake Booster** (hycon)
TC		77	**Differential and Breathers**
TC		78	**Transmissions** (breathers) (seals)
T		79	**Transfer-Unit** (seals) (vent)
		80	**Transmission and Transfer-Unit** (controls) (linkage)
T		81	**Propeller Shafts** (joints and alinements) (seals) (flanges)
		82	**Hand-Crank Ratchet and Lever**
		83	**Oil Dilution Valve and Lines**
		84	**Compass** (fluid) (lamp)
A		85	**Lamps and Switches** (head) (tail) (stop) (blackout) (internal)
		86	**Wiring** (junction and terminal blocks and boxes) (fuses and spares)
		87	**Collector Ring** (brushes) (heads) (cylinder) (cover)
		88	**Radio Bonding** (suppressors) (filters) (condensers) (shielding)
			AUXILIARY GENERATOR
		89	**Engine** (crankcase) (fan and housing) (cylinder shield) (mountings) (exhaust pipe and heater ducts)
S	CS	90	**Spark Plug** (gap) (deposits) (shaft)
A	A	91	**Magneto** (points) (wiring) (shaft)
CS	CS	92	**Carburetor and Air Cleaner**
C	C	93	**Fuel** (filters) (lines) (tank) (cap)
C		94	***Generator** (commutator) (brushes) (control box) (wiring)
		95	**Operation** (engine) (generator) (ammeter) (water) (leaks)

*Note.—Those items marked * require special additional services at a Ordnance maintenance service.

W. D., A. G. O. Form No. 462
April 1, 1942

FOLD TO ← VEHICLE NOMENCLATURE LINE → AND FILE

RA PD 317194

Figure 178. Obverse, W.D., A.G.O. Form No. 462.

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RECORD: Compression pressures: Right engine, Cylinder No. 1____ 2____ 3____ 4____ 5____ 6____ 7____ 8____ 9____

Antifreeze protection to_____°F Left engine, Cylinder No. 1____ 2____ 3____ 4____ 5____ 6____ 7____ 8____ 9____

BATTERY — No. 1 Battery — No. 2 Battery

SPECIFIC GRAVITY — Cell No. 1____ 2____ 3____ 4____ 5____ 6____ 1____ 2____ 3____ 4____ 5____ 6____

VOLTAGE — Cell No. 1____ 2____ 3____ 4____ 5____ 6____ 1____ 2____ 3____ 4____ 5____ 6____

Man hours required for this 50-hour maintenance_____ 100-hour maintenance_____ or technical inspection_____

Driver_____ (Grade or title) Mechanic or inspector_____ (Grade or title)

Repairs by higher echelon entered on job order request No._____ Supervising officer_____ (Grade or title)

Repairs requested_____ (Date) (Initials) Vehicle forwarded_____ (Date) (Initials) Vehicle returned_____ (Date) (Initials)

Disposition of worksheets: 50-hour—May be retained until completion of the third 100-hour, then destroy. 100-hour—May be retained until completion of the third 100-hour, then destroy. Technical inspection—May be retained until completion of the third 100-hour, then destroy.

EARLIER DESTRUCTION MAY BE ORDERED BY LOCAL COMMAND

REMARKS OR RECOMMENDATIONS_____

100-HOUR MAINTENANCE OR TECHNICAL INSPECTION
50-HOUR MAINTENANCE

ITEMS SPECIAL TO TANK-LIKE WHEELED VEHICLES

100-hour	50-hour		
AT	S	96	**Steering Gear** (case) (power cylinder, valve and link) (reservoir) (lines) (pumps) (electric motor) (column) (wheel)
BA	A	97	**Clutch** (pedal) (main cylinder) (reservoir) (lines) (slave cylinders) (arms and free travel)
S		98	**Throttle** (treadle) (main cylinder) (reservoir) (lines) (slave cylinder) (arm)
S	S	99	**Brake** (pedal) (master cylinder, boot, and switch) (reservoir and vent) (lines)
CSL	CA	100	***Brake Vacuum Boosters** (air cleaners) (lines and hose) (reserve tanks) (cylinders) (control valves) (leaks)
I		101	***Transmission Controls-Vacuum** (lever and button) (valve) (lines) (cylinder) (shaft and linkage)
B		102	**Hand Brake** (lever) (ratchet and pawl) (linkage) (drums) (linings)
BA	A	103	***Vacuum Pump** (oil) (drive) (lines)
CB		104	***Power Tire Pump** (mountings) (shaft) (lines and dust covers) (air cleaners and filter)

ON THIRD 100-HOUR SERVICE, RAISE VEHICLE AND BLOCK SAFELY

100-hour	50-hour		
R	T	105	***Tires and Rims** (valve stems and caps) (condition) (direction) (matching) (spare carriers)
CLAT	T	106	***Rear Wheels** (bearings) (seals) (drive flanges) (nuts)
CT		107	***Rear Brakes** (drums) (supports) (cylinders and end covers)

100-HOUR MAINTENANCE OR TECHNICAL INSPECTION
50-HOUR MAINTENANCE

100-hour	50-hour		
CA	A	108	***Rear Brake Shoes** (linings) (links) (guides) (anchors)
		109	**Torque Rods** (bushings) (brackets)
		110	**Rear Spring Seats and Bearings**
T	T	111	**Rear Springs** (clips) (leaves) (U-bolts) (hangers) (shackles)
S		112	***Rear Shock Absorbers and Links**
S	C	113	**Rear Axles** (pinion end play) (seals) (vents) (alinement) (radius rods) (brake lines and hose)
CT	CI	114	**Propeller-Shaft Center Bearing** (seals) (vent) (end play) (mounting)
CLAT	T	115	***Front Wheels** (bearings) (seals) (flanges) (axle end play) (nuts)
CT		116	***Front Brakes** (drums) (supports) (cylinders and end covers)
CA	A	117	***Front Brake Shoes** (linings) (links) (guides) (anchors)
CLA		118	***Steering Knuckles** (joints) (bearings) (seals) (boots)
T	T	119	**Front Springs** (clips) (leaves) (U-bolts) (hangers) (shackles)
S		120	***Front Shock Absorbers and Links**
C	C	121	**Front Axles** (pinion end play) (seals) (vent) (alinement) (radius rods) (brake lines and hose)
T		122	**Steering** (arms) (tie-rods) (drag link) (seals and boots) (pitman arm)
		123	**Toe-in and Turning Stops**
		124	**Caster, Camber, Turning Angle**

100-HOUR MAINTENANCE OR TECHNICAL INSPECTION
50-HOUR MAINTENANCE

ARMAMENT

100-hour	50-hour		
T	T	125	**Bow and Sponson Guns (37-mm and Smaller)** (mounts) traversing and elevating mechanism) (firing controls)
T	T	126	**Guns (37-mm and Larger)** (mounts) ((traversing and elevating mechanism) (firing controls)
		127	**Gyro Stabilizer and Recoil Control**
T		128	**Antiaircraft and Cupola Guns** (mounts) (traversing and elevating mechanism)
		129	**Spare Gun Barrels and Parts**

TOOLS AND EQUIPMENT

100-hour	50-hour		
		130	**Tools** (vehicle kit) (pioneer)
		131	**Equipment** (check these items against vehicle stowage list)
		132	**Grousers and spare track blocks**
		133	**Spare Oil Supply** (recoil) (hydraulic) (engine) (transmission)
		134	**Decontaminator**
		135	**Fire Extinguisher** (portable)
		136	**Publications and Form No. 26**
L	L	137	**Vehicle Lubrication**
		138	**Modifications** (fsmwo's completed)
		139	**Final Road Test** (repeat items 2 to 15 inclusive)

NOTE.—Correct any deficiencies found during the road test.

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RA PD 317195

Figure 179. Reverse, W.D., A.G.O. Form No. 462.

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PREVENTIVE MAINTENANCE SERVICE AND TECHNICAL INSPECTION

WORK SHEET
FOR
MOTORCYCLES
See AR 850-15

WD No. _____

Mileage _____ Date _____

Organization _____

Vehicle Nomenclature _____ (Make) _____ (Model) _____ (Bike) _____ (Drive) _____ (Body type)

Special Instructions: See TM 9-2810 for detailed instructions and procedures. See vehicle maintenance manual for technical information.

Legend for marking: √-Satisfactory X-Adjustment required XX-Repair or replacemet required O-Defect corrected

SYMBOLS ☐ -INSPECT AND CORRECT C-CLEAN T-TIGHTEN A-ADJUST L-SPECIAL LUBRICATION S-SERVE

1000-MILE MAINTENANCE OR TECHNICAL INSPECTION } Line out words that don't apply.

ROAD TEST

	1	Before-operation inspection
	2	Ease of starting
	3	Oil circulation
	4	Instruments
	5	Brake operation
	6	Clutch operation
	7	Gear shifting
	8	Unusual noises
	9	Steering
	10	Balance
	11	Speedometer and odometer
	12	Throttle and spark controls
	13	Power and operation
	14	Carburetor adjustment
	15	Brake drum and hub temperature
	16	Power train temperatures

MAINTENANCE OPERATIONS

	17	Compression test (kickstarter)
KT	18	Transmission
S	19	*Rear drive housing
S	20	Engine oil
CST	21	Battery and carrier
T	22	Battery cables and terminals
	23	Electric wiring
A	24	Generator, drive and mounting
LA	25	Timer (circuit breaker)
CA	26	Spark plugs
	27	Ignition and lamp switch
	28	Lamps: Service and blackout

1000-MILE MAINTENANCE OR TECHNICAL INSPECTION

	29	Horn
	30	Cylinder-head nuts
	31	Cylinder-hold-down nuts
T	32	Engine mountings
	33	Engine crankcase
	34	Intake manifold
	35	Muffler and exhaust pipes
A	36	Valve mechanism
	37	Kick starter
C	38	Engine cooling fins
	39	Filler caps and vents
	40	Fuel tanks, valves and lines
	41	Oil system leaks
TC	42	Carburetor and fuel filter
CS	43	Air cleaner
L	44	Gearshift lever and linkage
A	45	Primary drive
LA	46	Clutch pedal and linkage
CLA	47	Rear chain and guard
	48	Final-drive sprockets
	49	Propeller shaft
	50	Paint and markings
	51	Frame
	52	Steering head and fork stem
	53	Handlebars
	54	Throttle control
	55	Spark control
LA	56	Clutch hand lever and linkage
	57	Rear view mirror
	58	Front fender

1000-MILE MAINTENANCE OR TECHNICAL INSPECTION

	59	Weapon carrier
	60	Ammunition box
	61	Front springs
	62	Front forks
T	63	Front fork shackles or rocker arms
	64	Front fork dampers
LA	65	Front brake and control linkage
	66	Front wheel: Alinement and spokes
CLA	67	*Front-wheel bearings and seals
T	68	Front-wheel-axle nuts
	69	Tires: Front and rear
	70	Rear wheel: Alinement and spokes
CLA	71	*Rear-wheel bearings and seals
T	72	Rear-wheel-axle nuts
T	73	Rear springs
	74	Rear fender
LA	75	Rear brake and control linkage
	76	Stands: Jiffy, rear and center
	77	Foot boards and rests
	78	Saddle: Springs and hinge
	79	Luggage carrier
	80	Saddle bags
	81	Tools and tire pump
	82	Safety guards
	83	Leg shields
	84	Skid plate
L	85	Vehicle lubrication
	86	Final road test (items 2 to 16)

Note: Correct any defects found during final road test.

Note: [illegible] maintenance service

REMARKS OR RECOMMENDATIONS: _____

RECORD: Compression test (kickstarter): Good _____ Fair _____ Poor _____ Battery: Specific gravity: Cell No. 1 _____ 2 _____ 3 _____

Man hours required this service _____ Voltage: Cell No. 1 _____ 2 _____ 3 _____

Driver _____ (Grade or title) Mechanic or Inspector _____ (Grade or title)

Repair by higher echelon entered on job order request No. _____ Supervising officer _____ (Grade or title)

Repairs requested _____ (Date) _____ (Initials) Vehicle forwarded _____ (Date) _____ (Initials) Vehicle returned _____ (Date) _____ (Initials)

Disposition of work sheets: 1000-mile—May be retained until six have been accumulated, then destroy oldest.) Earlier destruction may be ordered Technical inspection—may be retained until completion of the next technical inspection, then destroy.) by local command.

FOLD TO VEHICLE NOMENCLATURE LINE AND FILE

W. D., AGO Form No. 463
April 15, 1941

RA PD 317196

Figure 180. W.D., A.G.O. Form No. 463.

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unit but is the mission of higher echelons, usually Ordnance. They are performed by technically qualified personnel under the direction of specially trained officers. Technical inspections are made for the following reasons:

1. To determine whether a vehicle should be continued in service, withdrawn for overhaul, or reclaimed for its component parts.
2. To determine extent of damage and estimated cost of repair in Report of Survey and similar proceedings.
3. To discover causes of difficulties encountered by combat troops with materiel so that all around efficiency may be improved.
4. Whenever a vehicle goes to third or higher echelon maintenance shop for repair it will receive a technical inspection to insure that all defects have been corrected before it is returned to the using organizations.
5. To determine exact status of a vehicle when accountability is transferred.

W.D. AGO Forms 461, 462, 463 are used for these services.

Command Inspections. The command inspection is a function of all commanding officers. It should be performed often enough so that a unit commander may become thoroughly familiar with the condition and care of all vehicles under his jurisdiction. In order that these inspections be thorough and revealing, definite procedures are outlined in AR 850-15 and W.D. AGO Form 7353 is used to check items. In the event that this form is not available, W.D. AGO Forms 461 and 463 may be used with certain items checked for inspection. Correctly organized and performed, this type of inspection will not only reveal the status of vehicles but the general efficiency of operating personnel. While these inspections need not be based on comprehensive technical familiarity with the motor vehicle, they should still be thorough enough to reveal major faults and cases of neglect and carelessness as well as outstanding performances deserving awards of merit. One fact must be kept in mind however: command inspections do not take the place of regularly scheduled services. They are merely checks on the operating efficiency of an organization as a whole and are not specific enough in the intent. These inspections may bring to light such things as a need for change of policy or instruction, or possibly training methods. In order to accomplish this, various types of inspections may be used, may be either of the formal or informal type, or may take the form of a spot check.

Formal Command Inspections. These inspections are performed on all vehicles of the unit at intervals as specified by the commander. An order should be issued far enough in advance to allow for preparation of the vehicles and equipment. All tools and accessories are to be laid out in a uniform manner, vehicle compartments are left open to facilitate inspection, and vehicle crews are stationed in an orderly fashion adjacent to the vehicle. The inspector should follow a logical sequence around each vehicle, similar to the order in inspecting a soldier's individual equipment. Procedure may parallel the following suggested outline:

1. Equipment, accessories, tools.
2. Question vehicle crew.
3. Tires, tracks, chassis.
4. Engine and accessories.
5. Steering, cab interior, engine starting.
6. Body.

The following standards are applied during these inspections. See that the unit is:

1. Adequately serviced,
2. In good condition,
3. Secure,
4. Not excessively worn,
5. Clean,
6. Adequately lubricated,
7. Correctly assembled,
8. Correctly adjusted,
9. Not leaking.

Usually the inspecting party is the commanding officer or his authorized representative and representative noncommissioned officers who have automotive responsibilities. To expedite inspections each member of the party can be assigned

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W. D., O. O. Form No. 7353
Approved Dec. 31, 1942

U. S. A. Reg. No. .....
Mileage .....
Date .....
Time .....

SPOT CHECK INSPECTION REPORT FOR ALL MOTOR VEHICLES

To: ..... Location ..... Date .....

1. A spot check by staff representatives disclosed the following conditions in a vehicle of .....

Place of inspection ..... Make and model ..... Type .....

Commander ..... Driver .....

Last maintenance operation: Type ..... Date ..... Mileage, hours .....

Are vehicle records up to date? ..... If not, why? .....

Select at least three (3) additional items for each of the sections listed below, from the Technical Inspection column of W. D., A. G. O. Form No. 461 for Wheeled and Half-track Vehicles, W. D., A. G. O. Form No. 462 for Full-track and Tank-like Vehicles, W. D., A. G. O. Form No. 463 for Motorcycles, and insert in the proper space. If satisfactory, mark "✓", needs adjustment "X", needs repair or replacement "XX". Any condition indicating abuse or neglect, and all items marked "X" or "XX" will be noted under "Remarks". Instructions for accomplishing all operations are explained in Technical Manual 9-2810.

LUBRICATION (Engine, transmissions, transfer unit, differential, final drives, steering gear, etc.)		ENGINE (Fuel, and cooling systems. Valve mechanism, etc.)	
1. Engine oil level and condition		1. Air cleaners, carburetor and controls	
2. Gear cases, vents, oil level and condition		2. Oil filters and lines	
3. Seals, wheels, axles, and gear cases		3. Spark plugs and ignition wiring	
4. Chassis lubrication		4. Magnetos, distributors and coils	
5.		5.	
6.		6.	
7.		7.	
8.		8.	
ELECTRICAL SYSTEM (Regulators, horn or siren, wiring and conduits, radio suppression, etc.)		**IN CAB, BODY OR FIGHTING COMPARTMENT (Controls, vision devices, windshield wipers, heaters, defrosters, etc.)**	
1. Generator and starting motor		1. Parking and service brakes	
2. Battery		2. Clutch	
3. Lamps and switches		3. Instruments	
4.		4. Steering brakes	
5.		5.	
6.		6.	
7.		7.	
8.		8.	
RUNNING GEAR (Frame, shock absorbers, wheels, bogie assemblies, track-support rollers, steering gear assembly, etc.)		**POWER TRAIN (Clutch, sprockets, idler wheels, etc.)**	
1. Steering arms and linkage		1. Axles, differentials, final drives	
2. Wheel, rim, and axle flange nuts		2. Transmissions, transfer case	
3. Tires and tracks		3. Propeller shafts, U-joints and center bearing	
4. Springs, U-bolts and shackles		4.	
5. General tightening		5.	
6.		6.	
7.		7.	
8.		8.	
EXTERNAL (Body or hull, sheet metal and paint, windows, windshield, doors and hardware, etc.)		**ARMAMENT (Guns, firing mechanism, turret, cupola, ammunition, etc.)**	
1. Engine oil, fuel, gear oil and water leaks		1. Gun mounts	
2. Cab or body mountings		2. Elevating and traversing mechanism	
3. Brakes, hose and lines		3. Gyro stabilizer	
4. Tarpaulins or collapsible tops		4.	
5.		5.	
6.		6.	
7.		7.	
8.		8.	

RA PD 317188

Figure 181. Obverse, W.D., O.O. Form No. 7353.

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MISCELLANEOUS (Safety, traction and towing devices, special equipment peculiar to the vehicle being inspected).		ROAD TEST (General performance, controls, unusual noises, instruments, etc.)	
1. Propeller and rudder (amphibian)		1. Engine power, operation and noise	
2. Bilge pumps (amphibian)		2. Clutch and brake action	
3. Fire extinguishers and decontaminators		3. Steering	
4. Pioneer and vehicle tools		4. Power train operation and noise	
5.		5.	
6		6.	
7.		7.	
8.		8.	

Remarks.....

Inspected by ..... Rank or title .....

* To be directed to the C. G., Reg't Commanders, and Automotive Officer's file for follow-up.

U. S. GOVERNMENT PRINTING OFFICE : 1943 O—513404

RA PD 317191

Figure 182. Reverse, W.D., O.O. Form No. 7353.

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specific points to check. Findings are to be reported to the recorder (usually the first sergeant).

Upon completion of the inspection, all findings should be compiled and studied. The inspection is worthless if no action is taken. This information may serve as a basis for future policies governing vehicle use.

Informal Command Inspection. These inspections are made at any opportune time and usually without prior notice. They may be made whenever the need arises. Very often they are more revealing than formal checks since personnel have not had an opportunity to 'set the stage.' The commander may question the driver; inspect the engine compartments; and check for leaks, unfamiliar noises, steering, wobbly wheels, tire inflation, and loading. In fact, check on any item that will indicate the status of the vehicles, or the efficiency of the personnel. By making inspections of this type at regular unscheduled periods, not only will the commander have a working knowledge of his vehicles, but his subordinates will be aware of his constant interest in this phase of his responsibility and will act accordingly.

Spot Check Inspections. Spot checks are made by a staff officer or his representative, at any time, on vehicles selected at random, as a means of increasing the general efficiency of automotive training and maintenance. The object may be attained by calling attention to deficiencies or irregularities noted, or by advising the interested personnel on the performance of their duty in a more efficient manner. W.D., O.O. Form No. 7353 is furnished as a record of such checks, and is submitted to the organizational commander for action. The form lists groups of items under the following headings.

1. Lubrication.
2. External (body, hull, etc.).
3. Electrical System.
4. Running Gear (wheels, tracks, etc.).
5. Engine.
6. Cab, Body, Fighting Compartment.
7. Power Train.
8. Armament.
9. Miscellaneous (special equipment).
10. Road Test.

If an item is found satisfactory a check is placed in the corresponding square; (x) and (xx) if a unit requires repair or replacement. After completion, the inspector forwards a copy of his findings to the officer in charge of the unit and retains a copy for a follow-up inspection at a later date.

PREPARATION FOR DEEP WATER FORDING

The current conflict, with its numerous amphibious operations, has created a need for some method of operating automotive equipment in water deeper than that for which it was designed.

The officer in charge of the waterproofing operations after ascertaining the amount and the different types of vehicles to be waterproofed, must obtain from S4 the necessary number of kits of waterproofing material. In small scale operations he should plan on being without any or all of such material, and should devise substitute and improvised methods.

The waterproofing location must next be chosen. It should, if possible, be indoors and must be within a reasonable distance of the port of embarkation. For security reasons this location should be kept secret.

Close cooperation must exist between the officer in charge of the waterproofing and the commanding officers (or officer) of the unit where vehicles are being waterproofed. As only the best automotive equipment can be taken on amphibious operations all vehicles must be inspected and when necessary thoroughly overhauled. During the inspection the vehicle must be completely cleaned with steam (if available), solvent, or soap and water. This is to insure that the waterproofing materials will have a good foundation.

Within the park, the handling of the vehicles and the distribution of the waterproofing equipment must be carefully planned. One method which is used successfully is to have the vehicles line up facing each other with a supply point in the center.

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The following steps on waterproofing procedures are taken from TM 9-2853. The general instructions are applicable for tank and tank-like vehicles, wheeled and half-track vehicles, artillery and small arms. By means of these preparations vehicles may be operated satisfactorily for a period of 8 minutes in water of the following depth.

Transport vehicles	3 ft.
Combat vehicles (wheeled and half-tracks)	4½ ft.
Tanks	6 ft.
Tractors	5 ft.

Classification of Vehicles. Ordnance vehicles to be prepared for deep water fording fall into the following two classes:

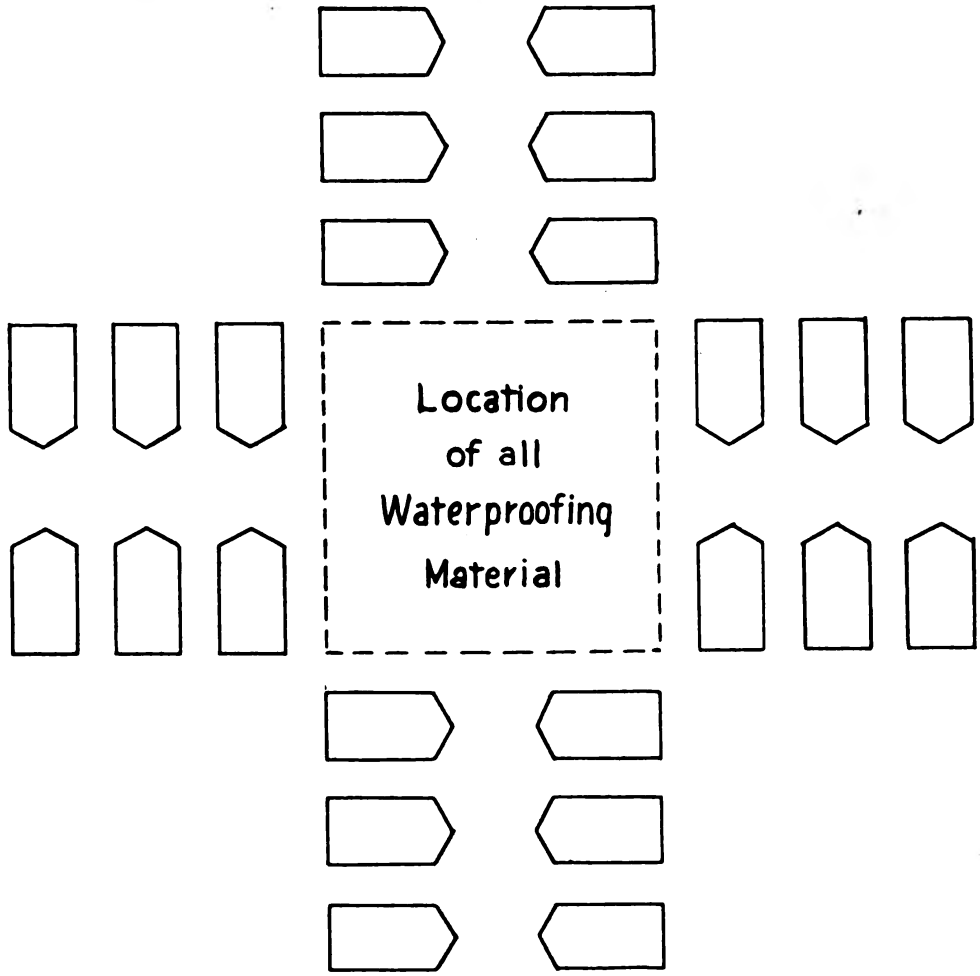

Figure 183. Waterproofing Park Diagram.

Those in which the hull must be waterproofed, and necessitates no waterproofing of the individual components. This class includes tanks and tank-like vehicles.

Those in which the water surrounds the individual components of the vehicle and in which the separate units must be individually waterproofed. This class includes cars, trucks, half-tracks, and tractors.

Types of Openings. Openings to be sealed for deep water fording fall into the following divisions:

Normal openings for components which must be vented to operate successfully when the unit is submerged. For these openings, venting is provided by the use of auxiliary exhaust and intake pipes, stacks and adapters, and material contained in the fording kits.

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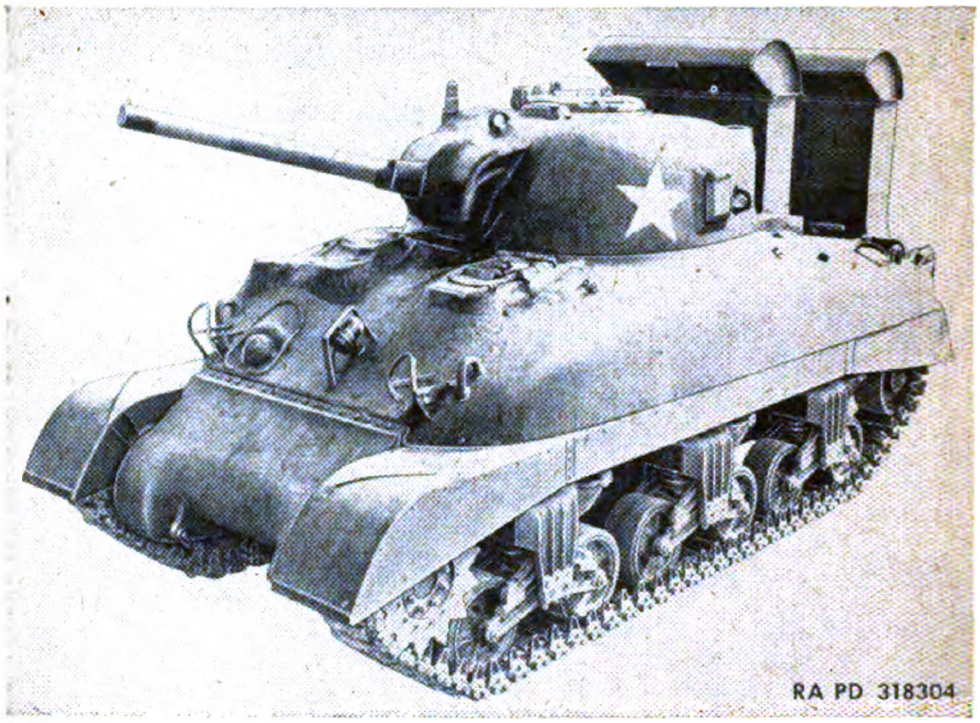

Figure 184. Waterproofing Medium Tank.

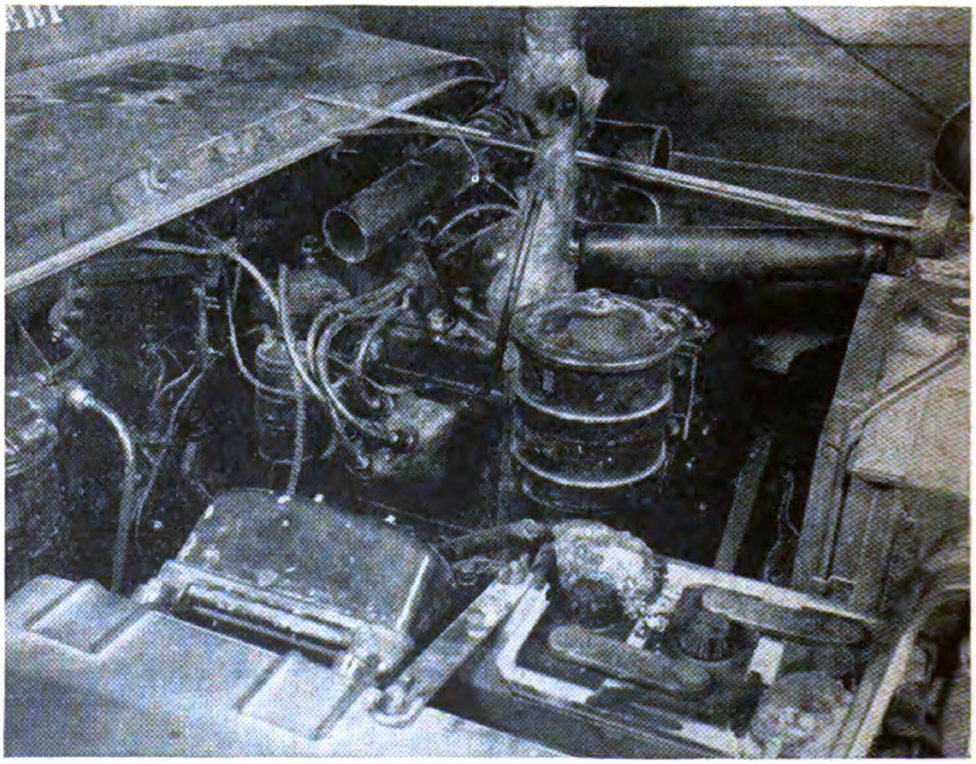

Figure 185. Waterproofing General Purpose Vehicle.

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Normal openings which may be sealed watertight for the short time they will be immersed. Vents on gear cases, oil filler caps, and radiator filler caps are examples of this class of opening. These are generally sealed by use of tape and sealing compound.

Abnormal openings that are not necessarily a serious matter under normal vehicle operation, but might adversely affect the operation of the unit during deep water fording. Missing bolts, cracks, or leaking seams in tank hulls are the most common type of this class of opening. These are the ones most commonly overlooked, and careful inspection will insure their disclosure. Large cracks and holes must be caulked with pieces of felt or rags to produce a backing for the sealing compound. Other openings and cracks are sealed with tape and sealing compound.

All work must be thoroughly performed. One faulty seal on a vehicle component or tank hull might very easily stall the vehicle and immobilize the succeeding vehicles with disastrous results.

TANK AND TANK-LIKE VEHICLES

Tanks and tank-like vehicles are waterproofed by the method in which sealing of the hull is the primary object. Treatment of the components is of secondary importance.

The waterproofing is divided into two phases:

Sealing all unvented openings with tape and sealer to render the hull watertight.

Extension of vented openings by use of stacks and adapters.

Identity of Kits. The materials for the preparation of tanks and tank-like vehicles for deep water fording are contained in several kits. The kits are listed below.

Kit Number	Nomenclature	Contents
T-0	Kit, fording, tank	All common materials, such as tape, paint, sealing compound, brushes, welding rod, etc., for sealing holes and cracks. Used with all tanks and tank-like vehicles.
LT-3	Kit, fording, adapter and stack, light tanks, M3A1.	Metal adapter and stack for sealing of the exhaust system and engine compartment. Canvas for sealing the air intake.
LT-5	Kit, fording, adapter and stack, light tanks, M5A1 and 75mm howitzer motor carriage, M8	Metal adapter and stack for sealing of the exhaust system and engine compartment. Canvas for sealing the air intake.
MT-S	Kit, fording, stack	Standard stacks and stack covers.
MT-1	Kit, fording, adapter M4A1	Special metal adapters for attaching stacks to engine compartment to particular tanks. Intake and exhaust systems constructed to fit the particular model of vehicle.
MT-2	Kit, fording, adapter M4A2	
MT-3	Kit, fording, adapter M4A3	
MT-4	Kit, fording adapter M4A4	
SBA		
SPA-7	Kit, fording, adapter and stack, M7	
SPA-10	Kit, fording, adapter and stack, M-10	
SPA-70	Kit, fording, adapter and stack, T70	

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Vehicle Kit Requirements. Complete waterproofing of a particular vehicle necessitates the use of two or more kits. The kits required for each vehicle are listed below.

Vehicle	Kits
Light tank, M3A1	T-0 and LT-3
Light tank, M5 or M5A1	T-0 and LT-5
75mm howitzer motor carriage, M8	T-0 and LT-5
Medium tank, M4A1	T-0, MT-S and MT-1
Medium tank, M4A2	T-0, MT-S and MT-2
Medium tank, M4A3	T-0, MT-S and MT-3
Medium tank, M4A4	T-0, MT-S and MT-4
105mm howitzer motor carriage, M7	T-0 and SPA-7
3-in. gun motor carriage, M10	T-0 and SPA-10
76mm gun motor carriage, T70	T-0 and SPA-10

Rubber turret seal is used to seal around turret base on all medium tanks.

Cloth is used to seal around gun shield on all medium tanks and 3-inch gun motor carriage, M10. It is also used to seal around turret base on all light tanks and 3-inch gun motor carriage, M10.

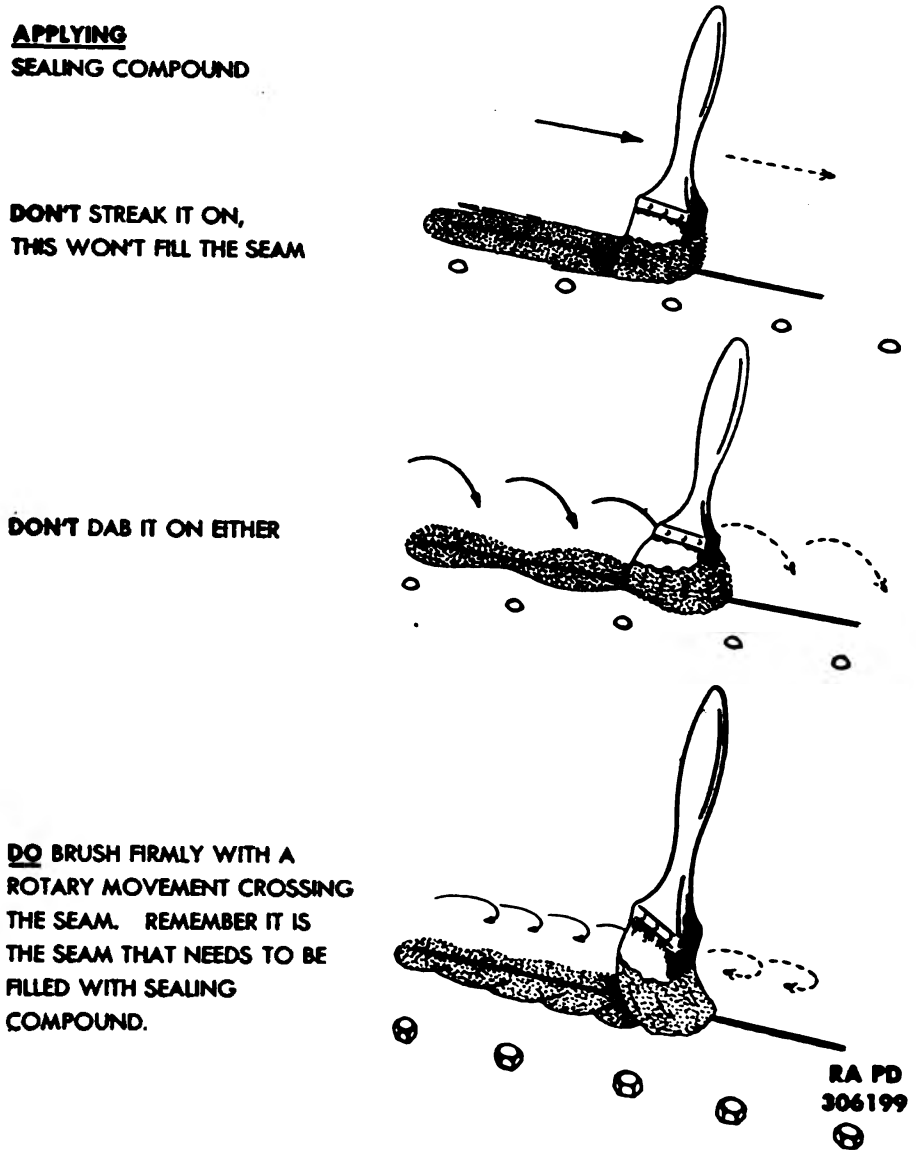

Figure 186. Applying Sealing Compound.

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Sealing compound is used to fill all cracks and joints, and to coat over all rivets and bolts. It is used as a seal over all taped surfaces.

Moistureproof tape is applied wherever possible over all surfaces that have joints and cracks that have been filled with sealing compound. When applying the tape, it should overlap one-half the width of the tape.

Rope is attached to the stacks and the canvas pieces covering air intake vents to permit jettisoning of stacks and canvas after landing.

Welding electrode is used to weld angle irons in position.

Canvas is used to cover the air intake vents. Canvas is held in place by tape.

Engine sealing compound is used to spray electrical systems and engines to waterproof them against any light spray or moisture.

Stacks are used to conduct air into and out of the engine compartment. They can be conveniently jettisoned upon completion of the landing.

Adapters are specially built attachments to connect the inlet and outlet stacks to the vehicle, and form watertight air conductors to a level above the anticipated fording depth.

PREPARATION OF VEHICLES

The preparation of all tanks and tank-like vehicles embodies certain common operations. These operations are performed before and during the installation of the T-0 kit on tanks and tank-like vehicles.

Inspections. A thorough inspection will be made of each vehicle and its component parts to determine correctness of operation, defects, or deficiencies. Particular attention must be given the ignition coil, spark plugs, carburetor, and ignition points. Replace weak coils and questionable spark plugs. The batteries must be fully charged and properly filled with water. Engine will be test-operated. Any defects or deficiencies found will be reported to proper authority for necessary repairs or replacement. No equipment will be released for preparation for fording operations until it is completely equipped and in serviceable condition.

Cleanings. The vehicle must be thoroughly cleaned and dried. Engine and engine compartment must be steam-cleaned if possible, or washed with dry-cleaning solvent if steam is not available. Surfaces to which tape and sealer are to be applied must be thoroughly clean and dry, otherwise the materials will not stick or seal properly.

Lubrications. All vehicles must be completely lubricated in accordance with War Department Lubrication Guides.

Vehicle Components and Hull. T-0 kit, fording, tank, 'common' will be applied to the vehicles as indicated. NOTE: *If vehicle is to be shipped on a voyage exceeding 3 days prior to combat landing, it must be prepared for overseas shipment in accordance with IOSSC-J.*

Engine. Spray the entire engine compartment, including the electrical components, spark plugs, and entire engine with engine sealing compound. CAUTION: *Do not spray the cooling fins of radial engines.* The engine sealing compound waterproofs the engine and components against light spray or any water which might slap over or leak into the air stacks and be thrown over the engine.

Sealing the Hull. Remove all inspection plates on bottom of the hull. If gasket has been removed, clean all edges and coat with sealing compound. Bolt back in place. Thoroughly coat the edges of all inspection plates and the escape hatch with sealing compound. Covers of all other openings in bottom of hull must be securely in place, and all bolts and drain plugs must be tight. Paint over all bolt heads and drain plugs with sealing compound. Be certain that the compound is worked down around the base of the head. Flat head screws will be covered with tape and sealing compound. Figure 187, showing bottom of typical medium tank hull, will help locate points to be maintained but, as the tank bottoms vary in construction, intense vigilance must be maintained not to overlook any possible place for water to enter the hull. **When in doubt, seal it.** Large openings should be caulked with pieces of felt or rags before sealing, to produce a backing for the sealing compound.

Seal all seams and bolts fastening final drive housing to hull. It is not necessary to seal the seams where three-piece final drive housings bolt together or where the

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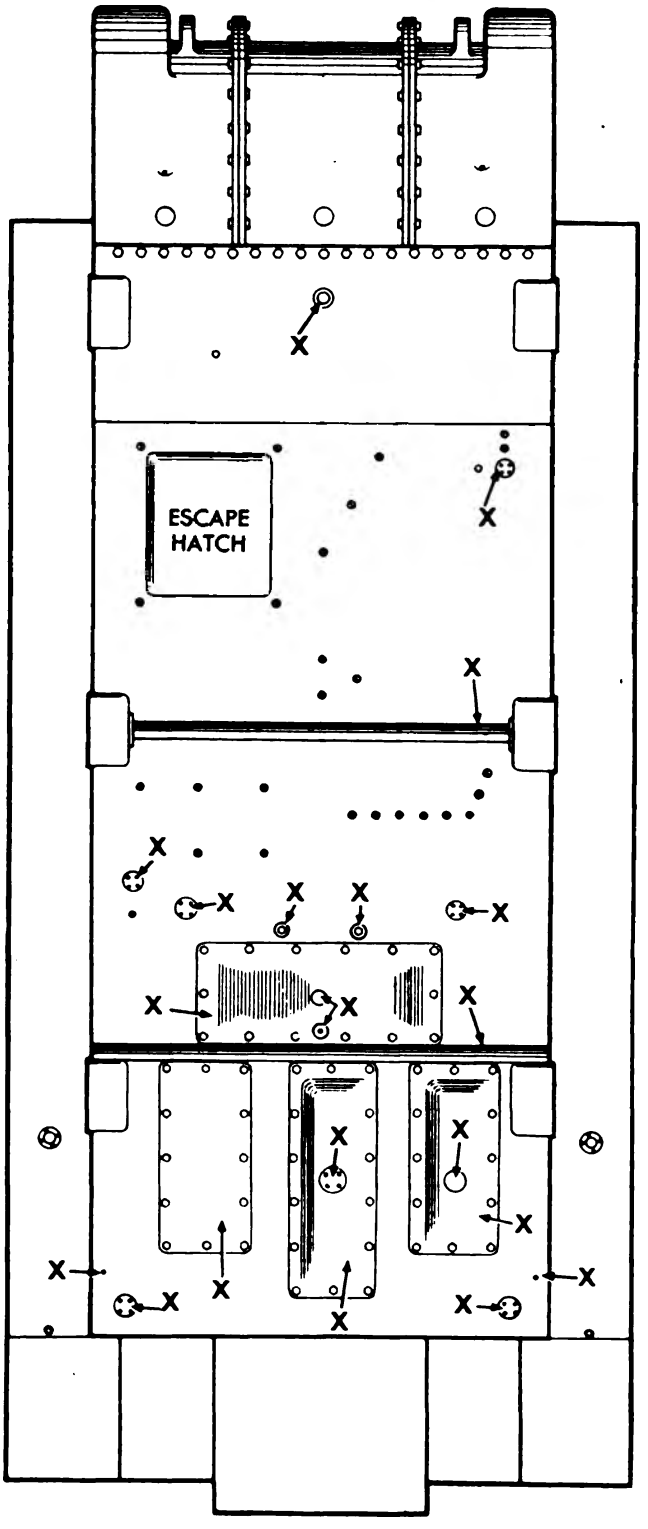

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Figure 187. Typical Medium Tank Hull.

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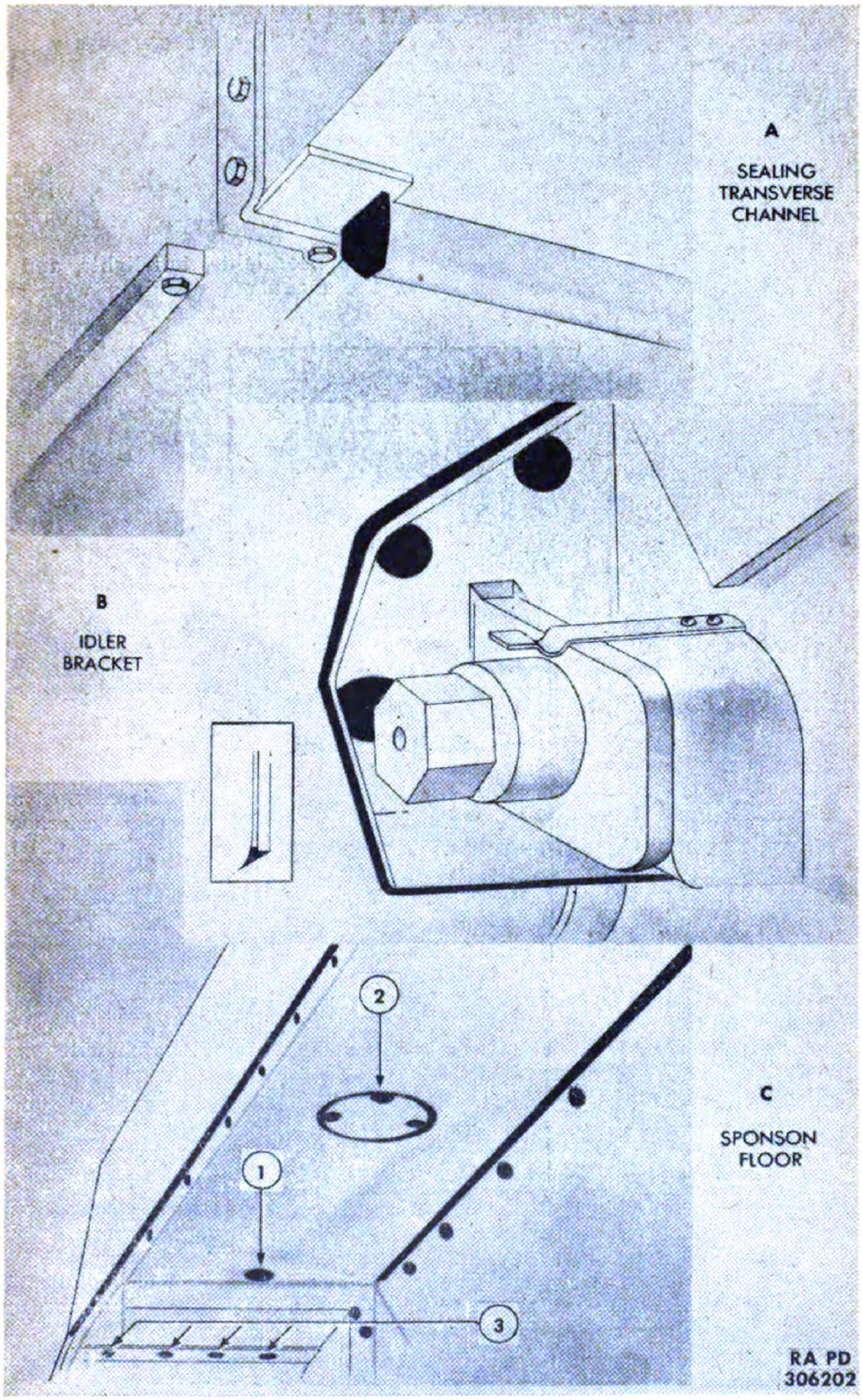

Figure 188. Points To Be Sealed on Medium Tank.

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final drive bolts to the housing. (Fig. 190) Great care must be exercised in sealing the transmission and the front sloping plate around the fenders.

Figures 191, top view, medium tank, M4A1 and 192, top view, light tank, M5A1, indicates the hatches, ventilators, filler cap covers, and other openings which are to be sealed with tape and sealing compound.

All small cracks and crevices will be sealed with tape and covered over with sealing compound. The surfaces to be sealed will be thoroughly cleaned before application of tape. To seal large cracks and openings, clean the surfaces thoroughly; caulk with pieces of felt or rags to produce a backing for the sealing compound; apply sealing compound over the caulking. Where possible, wipe away excess sealing compound from along the edges of the cracks or openings and apply tape. Cover tape with sealing compound.

Tape will be applied around the rims of the headlights, tail-lights, and siren. Cover tape with sealing compound. Seal the mounting openings with sealing compound.

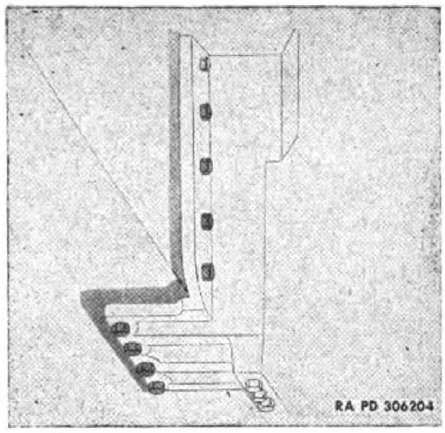

Figure 189. Bogie Bracket.

Remove driver's periscope wiper before sealing periscope in place. Seal around the driver's periscope with asbestos grease. Cover all seams in the periscope head with grease. Be careful not to cover center of glass with grease as it will impair the vision. Cover periscope turntable edges with asbestos grease. The periscope for the assistant driver need not be in position. Seal the assistant driver's periscope cover and turntable with grease.

The pistol ports and pistol port vision devices will be sealed with tape and sealing compound.

The external fire-extinguisher pull handles will be taped and covered with sealing compound.

The driver's hatch, assistant driver's hatch, and the turret hatch will be sealed with tape and sealing compound.

All machine guns will be placed inside the hull. The opening for the gun in the ball mount will be sealed with two crossed pieces of tape and covered with sealing compound. The ball mount will be sealed with water pump grease.

Sealing Turret Race on Light Tanks and 3-inch Gun Motor Carriage M10. Do not seal between turret and hull until after air intake system is sealed on light tanks and air intake adapter is in place on 3-inch gun motor carriage, M10; then waterproof as follows:

On 3-inch gun motor carriage, M10, the intake adapter must be installed before sealing the turret. Fasten a sash cord at the back of the turret. Run cord around the base of the turret on each side to the front.

Place 12-inch strips of cloth around the base of the turret over the rope, extending around the turret and out on the hull. Attach the edges of the cloth to the turret and hull with tape. Do not tear all of the cloth into 12-inch strips, as wider pieces are needed around the back of the turret to extend over ventilators or fuel caps.

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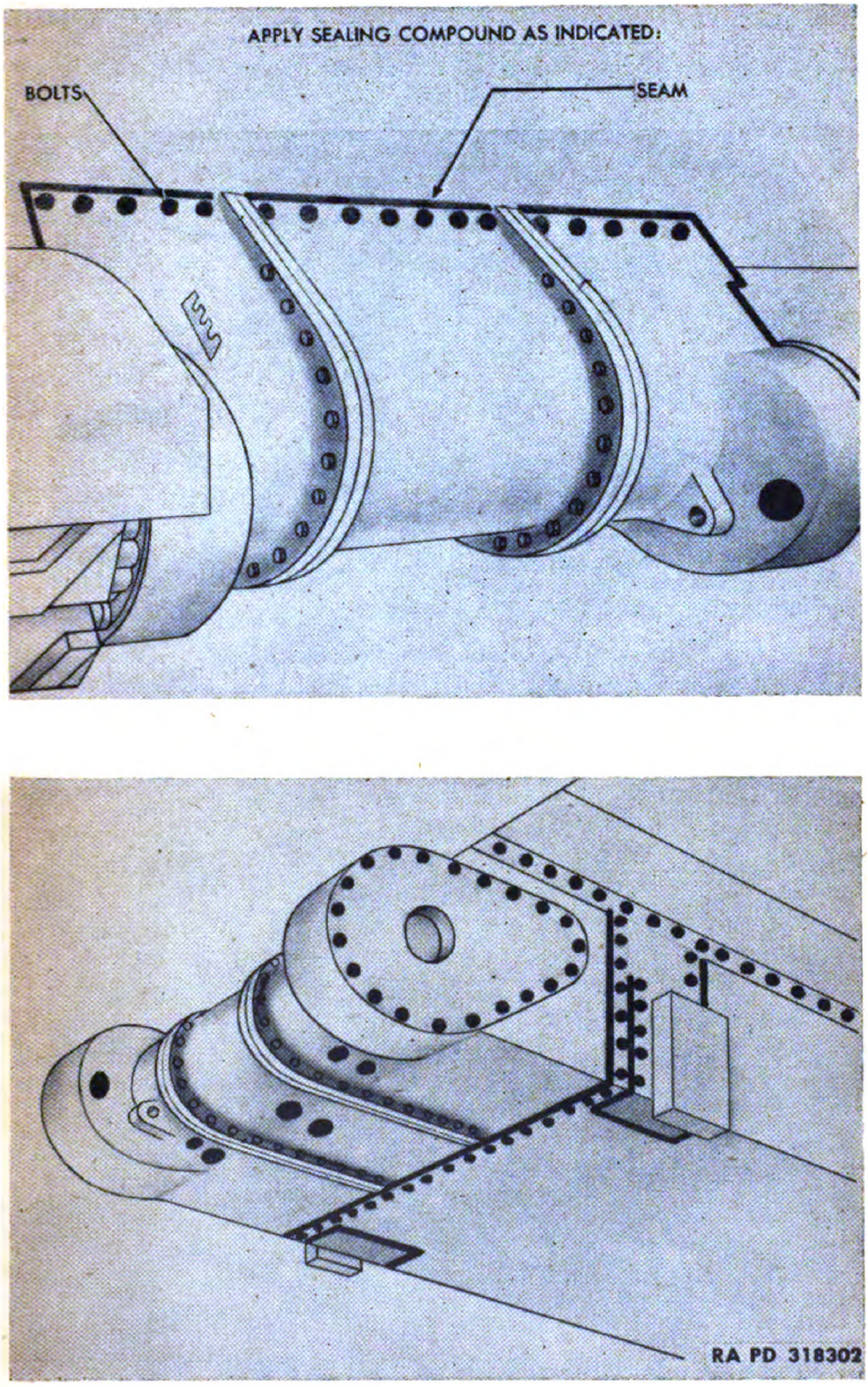

Figure 190. Sealing Front of Medium Tank Hull.

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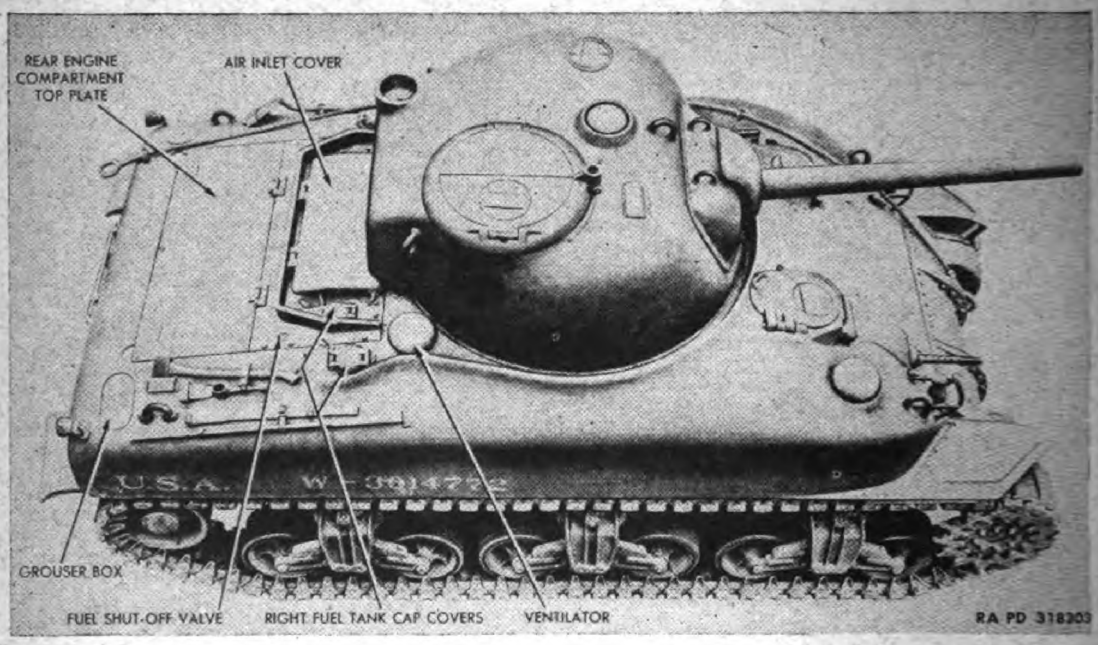

Figure 191. Top View of Medium Tank, M4A1.

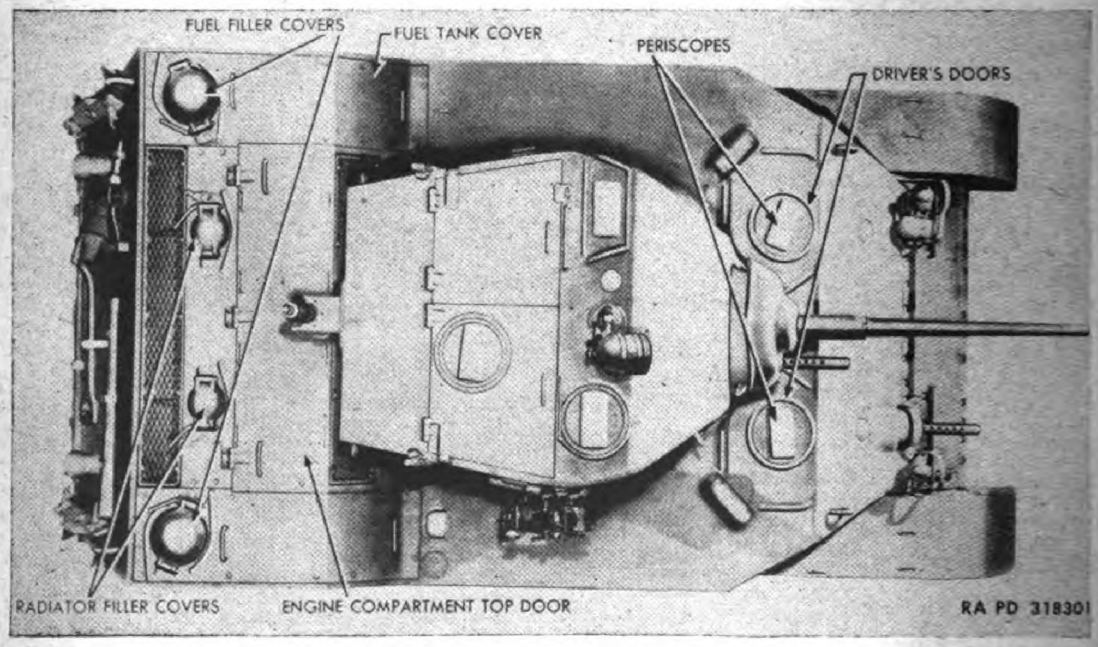

Figure 192. Top View of Light Tank M5A1.

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Bring rope ends out from edge of cloth and into turret top hatch, being careful not to cross rope, so that either rope end may be pulled to release seal.

Seal securely where rope emerges from the cloth, and cover all cloth and tape with sealing compound.

Sealing Turret Race on Medium Tanks. Thoroughly clean the turret ring of dirt and rough spots all the way around, and put a light coat of grease, graphite grease if available, around turret ring.

Slip turret seal over the gun barrel, and pull it around the gun shield and over the commander's hatch.

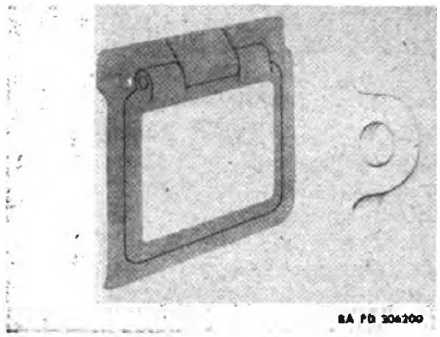

Figure 193. Sealing Pistol Port and Front Adapter.

Stretch seal over radio bulge of turret by pulling on each side to get equal stretch throughout the seal. Pull seal from top of turret down around the left side.

Place turret seal in place. This may be simplified by revolving turret and placing seal in position at left rear of turret as it is moved around.

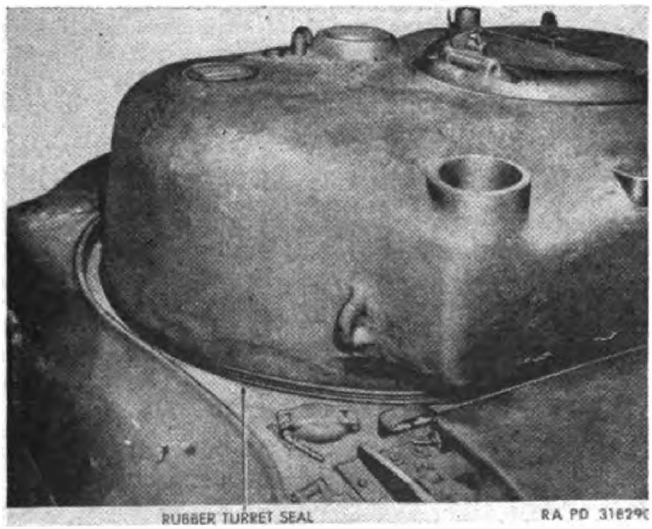

Figure 194. Rubber Turret Seal For Medium Tanks, Installed.

The notch cut in turret under gun shield for removing turret ring bolts may be closed by cutting a piece of light sheet metal and bending it so that the opening will be covered by placing one edge of the sheet metal under the edge of the turret seal. Tape sheet metal in place over opening and to the top edge of turret seal. The top edge of the turret seal should be taped to the turret wherever the rough casting does not permit a tight seal.

Gun Shield. Set gun elevation to position where gun traveling lock is engaged. Clean gun shield thoroughly and seal opening between the gun shield and turret with cloth and tape. (See Figure 184). Apply sealing compound over the tape. Clean exterior of gun tube, and seal between the gun shield and a point on the gun tube farther away from the shield than the maximum length of recoil of the gun,

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so that the sealing compound cannot contact the sleeve in the cradle and foul the gun.

Armament. For fording operations, clean all armament and treat bore and breech mechanism with Oil, lubrication, preservative, medium AXS674.

The muzzle of the gun will be covered with two crossed pieces of tape. A third piece of tape will be wrapped around the gun barrel, securing the ends of the two crossed pieces of tape. The tape may be removed under combat conditions by firing the gun. Use an A.P. or smoke shell for this purpose. CAUTION: *Do not use H.E. shells until tape has been removed.*

SEALING EXHAUST AND INTAKE SYSTEMS—MEDIUM TANKS

Kits MT-1, MT-2, MT-3, MT-4, and SPA-10 will be applied to M4 series medium tanks and the 3-inch gun motor carriage, M10, as indicated below.

All medium tanks and 3-inch gun motor carriages have a rear adapter and stack which is installed in a similar manner as the adapter for light tanks. Block adapter in place. Position attaching angles and plates, and tackweld them in place. Mark adapter where holes must be drilled. Remove adapter, and weld angles and plates solidly. Fill all joints with sealing compound. Put the adapter in position and bolt in place. Seal all corners and openings. In addition, these vehicles have a front adapter which fits over the air inlet grille. A stack of the same type as used at the rear fits over the front adapter. Ropes are fastened to the latches on both stacks for jettisoning them.

OPERATING INSTRUCTIONS

If lights are to be used, clean lenses of all lights.

Warm up engine to proper operating temperature, 160° to 180°F.

Set hand throttle to maintain a speed of approximately 1800 revolutions per minute.

Place foot in position so that a steady, even pressure on accelerator pedal may be maintained at all times.

Place vehicle in second speed, and retain in that gear until ashore.

Descend ramp and enter water slowly to avoid surge of water. Drive through surf at moderate speed.

Avoid stalling the engine on entering water as failure of your vehicle may prevent succeeding vehicles from disembarking.

SERVICING VEHICLES AFTER LANDING

After landing, jettison the stacks by pulling the ropes.

As soon as practicable after landing, do the following:

Lubricate vehicle completely.
Remove front and rear adapters.
Remove all sealing tape.
Wash vehicle thoroughly with fresh water to remove brine.

WHEELED AND HALF-TRACK VEHICLES

Each component of wheeled and half-track vehicles must operate in direct contact with water and must be individually waterproofed.

The following components must be vented for successful operation under water:

(1) Engine: Carburetor, exhaust, and crankcase.
(2) Brake system: Hydrovac or air compressor.
(3) Fuel tank: Filler cap.

All other components must be able to operate under water successfully without special treatment, or may be sealed airtight.

Identity of Kits. The materials for the preparation of wheeled and half-track vehicles for deep water fording are contained in three kits.

Kit Number	*Nomenclature*	*Contents*
WV-6 Kit, fording	Universal ¼-2½-ton	All materials such as: tape, paint, flexible tubing, sealing compound, air intake hose, and so forth.
WV-7 Kit, fording	Universal 4-10-ton	
HT-1 Kit, fording	Half-track, scout car, light armored car, M8	

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The WV-6 kit contains all necessary materials to waterproof any vehicle of ¼-ton to and including 2½-ton capacity. The WV-7 kit has all materials to waterproof those vehicles from 4-ton to 10-ton capacity. The HT-1 kit contains all material to waterproof half-track vehicles manufactured by White, Autocar, and Diamond T, scout car, M3A1, and light armored car, M8.

PREPARATION OF VEHICLES

The preparation of all wheeled and half-track vehicles embodies certain common operations. These operations are performed before the installation of the kits. NOTE: *If vehicle is to be shipped on a voyage exceeding 3 days prior to combat landing, it must be prepared for overseas shipment in accordance with IOSSC-J.*

Inspection. A thorough inspection will be made of each vehicle and its component parts to determine correctness of operation, defects, or deficiencies. Particular attention will be given the ignition coil, spark plugs, carburetor, and ignition points. Weak coils and questionable spark plugs will be replaced. The batteries must be fully charged and properly filled with water. Engine will be test-operated, and any defects or deficiencies found will be reported to proper authority for necessary repairs or replacement. No equipment will be released for preparation for surf landing operations until it is complete and in serviceable condition.

Cleaning. All material will be thoroughly cleaned and dried. Engine and engine compartment will be steam-cleaned if possible, or washed with dry-cleaning solvent if steam is not available. Surfaces to which tape and sealing are to be applied must be thoroughly clean and dry, otherwise the materials will not stick or seal properly. (If engine is steam-cleaned, operate engine for at least ½ hour, or until all condensation has disappeared.)

Lubricant. All vehicles must be completely lubricated in accordance with War Department Lubrication Guides.

APPLICATION OF WV-6 KIT ON VEHICLES OF ¼-TON TO 2-½ TON CAPACITY

Sealing Engines. All openings in the engine will be sealed or vented. Later model vehicles have forced crankcase ventilation and require special preparation. Check vehicle for this modification, and follow proper instructions for venting crankcase. NOTE: *In applying asbestos grease, care must be taken that there are no air pockets within the grease or surrounding the surface of the unit being prepared. Work the absestos grease with the fingers carefully against all points of the surface being covered in order to fill all cracks and crevices. The asbestos grease must adhere securely to all surfaces. Special care must be taken when sealing spark plugs, distributors, and ignition coils.*

Breather Pipe (½-ton truck, 4 x 4 and ¾-ton truck, 4 x 4, Dodge). Remove filler cap and let it hang by its chain. Wrap opening with tape, and paint with gray insulating enamel. Apply asbestos grease at base of breather pipe where it enters the crankcase.

Crankcase Ventilator (¼-ton truck, 4 x 4, Ford and Willys, and ½-ton truck, 4 x 4, Dodge). Wrap ventilator with tape, and paint with gray insulating enamel.

Crankcase Ventilator Pipe (¾-ton truck, 4 x 4 Dodge). Apply asbestos grease around the air cleaner body where it enters the block; also apply asbestos grease around the cover and bolt. If vehicle (½, ¾, and 1½-ton trucks, Dodge) has positive crankcase ventilation, remove entire air cleaner assembly at top of oil filler tube. Insert crankcase vent adapter (Fig. 195) firmly in top of filler tube. Seal around plug with tape, and paint with gray insulating enamel. Connection from vent to air intake hose attachment is described below.

Oil Filler Cap (½-ton truck, 4 x 4, Ford and Willys, and 2½-ton truck, 6 x 6, GMC). Wrap oil filler cap and top of oil filler neck with tape, and paint with gray insulating enamel. On the ¼-ton, 4 x 4, Ford and Willys, trucks having positive crankcase ventilation, disconnect the rubber tube running from the oil filler pipe to the connection between the air cleaner and carburetor. Connect a piece of ⅝-in. I.D. hose, as furnished in kit, to crankcase vent on oil filler pipe and to air intake vent clamp on air intake hose as described below. NOTE: *Oil*

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filler pipe connection is ½-in. O.D. Build up to ⅝-in. O.D. by wrapping with tape. On the 2½-ton truck, 6 x 6, GMC, with positive crankcase ventilation, remove entire air cleaner assembly at top of oil filler tube. Insert crankcase vent adapter, as furnished in kit, firmly in top of oil filler tube. Seal around plug with tape, and paint with gray insulating enamel. Connection from vent to air intake vent clamp is described below.

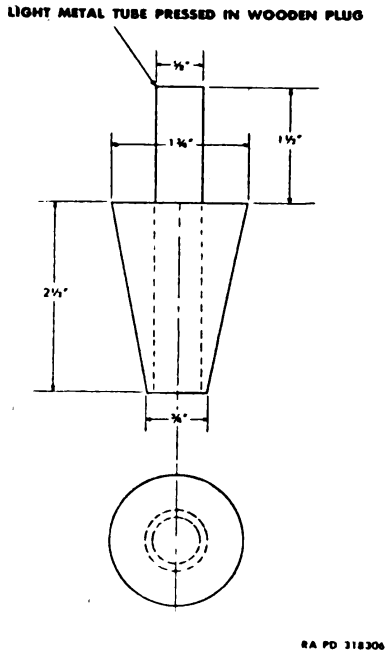

Figure 195. Crank Case Vent Adapter.

Oil Filler and Vent (1½-ton truck, 4 x 4, Chevrolet). Wrap oil filled cap and top of oil filler neck with tape, and paint with gray insulating enamel. Wrap the bottom of the crankcase ventilator vent with tape, and paint with gray insulating enamel. On the 1½-ton truck, 4 x 4, Chevrolet, with positive crankcase ventilation, remove air cleaner from the top of the rocker arm cover. Insert crankcase vent adapter firmly in the place of the air cleaner. Seal around plug, especially the two slots on side of hole, with tape. Tape over entire plug, and paint with gray insulating enamel. Connection from vent to air intake vent clamp is described below.

Oil Level Indicator (½-ton and ¾-ton truck, 4 x 4 Dodge, and 2½-ton truck, 6 x 6, GMC). Remove the indicator on the Dodge trucks, and stow in safe place in vehicle for future use. (Indicator can be attached to radiator brace rod.) Plug hole with wooden plug, and paint over plug with gray insulating enamel. On the 2½-ton truck, 6 x 6, GMC, wrap tape around the dip stick and tube. Paint over tape with gray insulating enamel.

Rocker Arm Cover Vents (1½-ton truck, 4 x 4, Chevrolet, and 2½-ton truck, 6 x 6, GMC). Where rocker arm covers are vented by louvres, seal with tape, and paint with gray insulating enamel.

ELECTRICAL SYSTEM

Spark Plugs. Starting around hex of spark plug, apply asbestos grease over porcelain, terminal, and suppressor and out along ignition wire 1 inch beyond suppressor. Work the asbestos grease with the fingers carefully around all surfaces of the spark plug and suppressor. Cover with a thickness of asbestos grease approximately ½ inch. Do not fill the wells in the cylinder head. Smooth the outer surface of the asbestos grease after completion.

Distributors. Remove distributor cap and rotor. Paint inside of distributor cap and rotor with a thin coat of engine sealing compound, being careful to

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keep compound off contact points. Wipe compound off center contact button and brass segments in distributor cap and off metal surface of rotor. Allow compound to dry at least 5 minutes before replacing rotor and cap. If there are no rubber nipples covering the openings where spark plug and coil leads enter the distributor cap towers a small piece of tape should be wrapped around leads and cover openings in towers, thus keeping the asbestos grease from entering the openings when it is applied. Before distributor is covered with asbestos grease, a short piece of tape should be placed over the distributor vent (to prevent grease from filling hole) in such a manner that it can be used as a 'rip cord' to open vent immediately after vehicle leaves the water. Use an ample supply of asbestos grease and cover the distributor, working the grease well down between towers and along the lead wires for a distance of about 3 inches. Asbestos grease must also be applied around base of distributor to completely seal cracks and openings. If distributor is not perfectly sealed, it is very probable that engine will fail immediately when vehicle enters the water. The thickness of asbestos grease should be approximately ½ inch. Cover portion of tape next to distributor with asbestos grease, leaving one end free and the vent open. (The vent must be left open until just before landing operations start in order to prevent condensation within distributor.) NOTE: *The following operation is performed aboard the landing craft within a maximum of 12 hours from the time the vehicle is to be landed. This should preferably be completed during the last hour before landing. The engine must be cool when this operation is performed.* Seal distributor vent by covering with tape and a layer of asbestos grease at least ½ inch thick. The end of the tape 'rip cord' should be left protruding from the asbestos grease. Do not bring tape out of asbestos grease directly over distributor vent hole. As soon as practical after the landing has been accomplished, the 'rip cord' should be pulled, thus unsealing the distributor vent.

Ignition Coil. Make sure that the high tension cable has a good contact in the coil terminal. Check primary wires for good contact. Paint entire coil with gray insulating enamel. After enamel has dried, cover high tension end of coil with asbestos grease to a thickness of approximately ½ inch, being careful that high tension terminal or tower is well sealed. Work asbestos grease beyond the high tension terminal, or tower, and along the high tension wire a distance of approximately 3 inches. Cover the primary connections of the coil with asbestos grease approximately ½ inch thick.

High Tension Cables. Paint all high tension cables from distributor cap to spark plugs, and from ignition coil to distributor cap with gray insulating enamel.

Generator. Paint the generator terminals with gray insulating enamel. NOTE: *As soon as possible after landing, wash out generator with fresh water.*

Voltage Regulator. Paint the terminals of the voltage regulator with gray insulating enamel. Seal around junction of cover and regulator base with asbestos grease approximately ½ inch thick. Cover terminals and seal entrance of terminals into regulator with asbestos grease. Seal cover retaining nuts and cover small bolt holes in regulator base with asbestos grease. Cover name plate with asbestos grease.

Starter. On the ½- and ¾-ton trucks, 4 x 4, Dodge; 1½-ton, 4 x 4, Chevrolet, and 2½-ton, 6 x 6, GMC trucks, paint starter terminal with gray insulating enamel. Cover starter switch loosely with tape. Press the tape firmly around the switch. Paint the tape with gray insulating enamel. On the ¼-ton, 4 x 4, Ford and Willys trucks, seal the starter button on the toe board by bridging it with tape. Apply tape crosswise so that starter button and section around starter button is covered and protected from water, which may run into switch from toe board. The tape should be applied loosely over starter button so that button may be depressed readily. Paint over tape with gray insulating enamel.

Horn. Cover the bell of horn with tape, and paint with gray insulating enamel. Disconnect wires from horn, and cover terminals with tape. Paint the tape with gray insulating enamel.

Junction Block. Paint all junction blocks and electrical terminals with gray insulating enamel.

Filters, Condensers, and Suppressors. Filters, condensers, and suppressors will be painted with gray insulating enamel. Cover openings in filters, if any, with tape before painting.

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Head, Tail, Stop, and Blackout Lights. The junction of the door, lens, and body of lights will be sealed with tape and painted with gray insulating enamel. Exterior wiring to light plugs will be sealed at plugs and connections with tape and painted with gray insulating enamel.

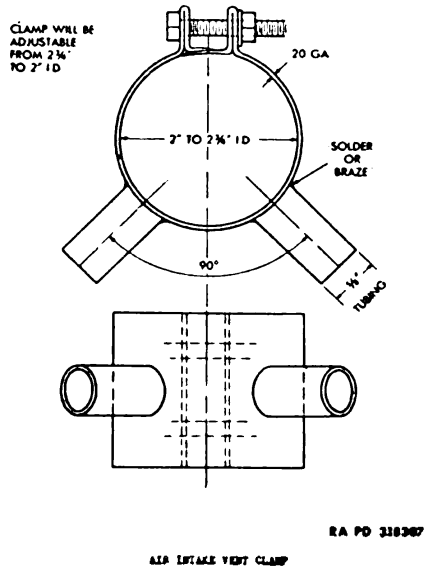
Trailer Lighting Socket. Seal edges and back of socket with tape, and paint with gray insulating enamel.

Battery. Thoroughly clean battery and paint terminals and all connecting straps with gray insulating enamel.

CARBURETOR AIR INTAKE

¼-ton, 4 x 4, Ford and Willys Trucks. Place a center punch mark on side of air intake hose adapter, ¾ inch from top of large end, directly in line and above one of the four slots at small end of adapter. Using the punch mark as center, drill a ⅜-inch hole through side of adapter. Cut through side of adapter from bottom to top with a hack saw, selecting the slot opposite the ⅜-inch hole as starting point. This will allow adapter to spread, permitting its application to various sizes of carburetor air horns. Remove air cleaner and elbow connection to air horn of carburetor. Place adapter over carburetor air horn, with the ⅜-inch hole facing toward crankcase vent on top of oil filler tube. Fasten adapter in place securely, using clamp removed from elbow. Take 3-foot length of 2½-inch I.D. 3-ply radiator hose, and drill a ⅜-inch hole, its center ½-inch from end of hose. Slip

ATTACHMENT CLAMP TO AIR INTAKE RADIATOR HOSE
FOR VENTING ENGINE COMPARTMENT COMPONENTS



AIR INTAKE VENT CLAMP

Figure 196. Air Intake Vent Clamp.

radiator hose over adapter on carburetor air horn, alining ⅜-inch holes in adapter and hose. Place air intake vent clamp over radiator hose, alining one vent tube with ⅜ inch holes in hose and adapter. Tighten air intake vent clamp securely. There must be no movement between adapter, hose, and clamp. A punch may be inserted in the ⅜-inch holes to prevent shifting of various units while clamp is tightened. Seal all openings, crevices, and slots around hose clamp, adapter, hose, and vent clamp with tape. Care must be taken that opening where adapter has been slotted is sealed thoroughly, especially around, below, and above clamp, securing the adapter to the carburetor. Connect the alined vent tube of air intake vent clamp to crankcase vent adapter tube on oil filler pipe with a length of ⅝-inch I.D. hose, using hose clamps as furnished. Seal end of unused vent tube with tape. Apply asbestos grease over the tape. Seal around adapter, hose, and

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vent clamp with asbestos grease. Any openings left unsealed will permit entrance of water into carburetor, stalling engine and preventing restarting. Place sheet metal air intake hose top on upper end of the air intake hose. Do not force air intake hose top past stops. Tape hose top support springs to hose, being careful not to obstruct air passage.

½- ¾-ton, 4 x 4, Dodge Trucks, 1½-ton, 6 x 6, Dodge Trucks; 1½-ton Truck, 4 x 4, Chevrolet Trucks; and 2½-ton 6 x 6, GMC Trucks. To attach carburetor air intake extension, remove the upper section of the air cleaner, consisting of the cover and filter, and leave lower section of the air cleaner attached to carburetor. Connect the carburetor air intake extension hose to the tube inside the lower section of the air cleaner. Cut a 3-inch hole in the hood to permit passage of hose upwards and place sheet metal top on upper end of hose. To vent the crankcase, the following steps must also be performed. Fasten air intake vent clamp to lower end of hose above hose clamp, making sure it is above pipe of air cleaner inside the hose. Position air intake vent clamp vent tube so that it is in line for connecting ⅝-inch I.D. hose to vent for crankcase. Remove air intake extension with vent clamp fastened to it, and drill through hose for one vent, using vent tube as guide. Clean inside of all cuttings and other dirt before replacing and fastening hose on carburetor air horn. Seal round air intake vent clamp with asbestos grease. Connect one end of ⅝-inch I.D. hose to air intake vent clamp vent tube, and connect other end to vent tube on crankcase vent adapter. NOTE: *Save metal disk cut out of hood. Reinstall by welding when time permits after landing.* CAUTION: *When reconnecting air cleaner, lower section must first be removed, cleaned, and refilled with clean oil.*

CARBURETOR

Cover all carburetor controls and shafts, i.e., accelerator, throttle, and choke, with a light coating of asbestos grease. Be sure to seal around shafts at body of carburetor. Cover idle adjusting screw with asbestos grease.

On the ¼-ton, 4 x 4, Ford and Willys trucks, cover the accelerator pump with cloth cut in the shape of a 'T'. The top of the 'T' is to measure approximately 16 inches across and 2 inches wide. The stem of the 'T' is to measure approximately 5 inches long by 3 inches wide. Cover the opening at the bottom of the accelerator pump with the top of the T-shaped cloth, and bring the stem up along the outside of the accelerator pump. After cloth is tied in place, carefully apply asbestos grease over the cloth to a thickness of approximately ½ inch. There is a small vent hole at the base of the carburetor pump jet. This hole is at the rear of the carburetor and can be found near the head of the rear screw which secures the center section to the flange section of the carburetor. Seal this vent with tape and cover over with asbestos grease. Carburetor controls, shafts, and gaskets should be sealed in accordance with instructions given above.

Fuel Pumps. Seal base of fuel pump to the engine and the vent in underside of fuel pump, using asbestos grease.

Grease Fittings, Propeller Shaft Splines, and Front Wheel Universal Joint Housings. Slush these parts with heavy grease. Cover brake controls with a coating of heavy grease (not asbestos grease).

Control Housing on Transmission. Lift dust cover on transmission gearshift lever. Work asbestos grease around base of gearshift lever and replace dust cover.

Vents. Cover transfer case vent nipple with asbestos grease. Cover front and real axle housing vents with asbestos grease. Seal the vent in the brake master cylinder filler cap with asbestos grease.

Winch (If so equipped). Plug vent hole in filler plug with asbestos grease.

Hydrovac Brake Cylinder. 1½-ton, 4 x 4, Chevrolet trucks and 2½-ton, 6 x 6, GMC truck, are so equipped. Remove the air filter and connect a length of ⅝-inch I.D. hose in its place. Extend hose upwards alongside of body to a height of approximately 6 feet from ground. Fasten hose to body with soft iron wire as furnished in kit.

GASOLINE TANK

½- and ¾-ton, 4 x 4, Dodge Trucks; 1½-ton, 4 x 4, Chevrolet Trucks; and 2½-ton, 6 x 6, GMC Trucks. The gasoline tank is to be waterproofed and vented. Drill ⅛-inch hole in cap. (If cap is pressure type, do not drill through valve chamber

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but only through first section.) Insert ⅛-inch x 4-inch bundy tubing; solder in place. Attach windshield wiper hose, and extend to a height of approximately 7 feet from ground. Seal cap to the filler neck of gasoline tank with asbestos grease.

¼-ton, 4 x 4, Ford and Willys Trucks. When inserting bundy tubing on the ¼-ton, 4 x 4, Ford and Willys truck, drill through the top of the pressure cap completely. Insert bundy tubing into hole in cap so that it protrudes approximately ¼ inch beyond the inner surface of the cap. Solder around bundy tubing both on the inside and the outside of the cap securely. The soldered joints must be waterproofed. Bend tubing on outer surface of cap horizontally so as to lie over gasoline cap; seal cap to filler neck of tank with asbestos grease. Attach windshield wiper hose to bundy tubing and run hose alongside the driver's seat, floor board, and up windshield post. Fasten hose to post with tape. Seal around electrical connections of fuel gage connector on top of gasoline tank by painting with gray insulating enamel.

TAIL PIPE

Disconnect exhaust pipe at manifold. Lay it away from the manifold and wire it to frame or other suitable place in order to permit installation of waterproof exhaust pipe. Connect universal flange with attached flexible metal hose after selecting the proper adapter and gaskets. There are four adapters to be used with the universal flange for the particular vehicle that they fit. They are identified as follows:

Adapter for ¼-ton, 4 x 4, Ford and Willys, has smallest inside opening (1½ inches).

Adapter for 1½-ton, 4 x 4, Chevrolet truck, has the next larger inside opening (1 11/16 inches).

Adapter for ½-, ¾-, or 1½-ton Dodge truck, has the next larger inside opening (1⅞ inches).

Adapter for 2½-ton, 6 x 6, GMC truck, has the largest inside opening of the four adapters (2⅜ inches).

Use thick triangular gasket between flange, adapter, and gasket for the particular vehicle between adapter and manifold. On the ¼-ton, 4 x 4, Willys and Ford trucks and the ½-, ¾-, and 1½-ton Dodge trucks lead the flexible metal hose underneath the frame and up alongside the windshield frame to a height of approximately 7 feet. Use iron wire to fasten hose to windshield frame bolts or body bolts. Bend the top of the metal hose downwards at the top, facing forward. After metal hose is fastened, apply a coat of high temperature cement to the exterior of the metal hose. Cement must be applied carefully and thoroughly to all crevices and surface of the hose, particularly at bends. After cement has dried, metal hose will no longer be flexible. Care must be taken that hose is not forced out of position as any movement or twisting of hose will break the seal and permit entry of water. To install flexible exhaust pipe on 2½-ton GMC and 1½-ton Chevrolet, remove hood left side panel. Thread the outlet end of the flexible exhaust pipe from under vehicle up through opening in front of engine left rear support back of steering column and out through the side panel opening. Connect flange end of pipe to manifold, using proper adapter. Extend metal hose up and facing forward, and fasten to windshield post with soft wire. NOTE: *Before applying high temperature cement, make sure flexible pipe is forced down toward steering column to allow sufficient clearance for clutch pedal when depressed.* Replace side panel, securing it at front end only. Rear of panel will remain unfastened.

INSTRUMENT PANEL

Cover the face of each instrument with tape. Apply a few drops of penetrating oil (or a mixture of light lubricating oil and kerosene) to all dash controls and cables, such as throttle, choke, spark, etc. Follow the flexible control cables from instrument panel to carburetor, distributor, etc., applying a few drops of penetrating oil along the entire length of flexible cables. Work the controls back and forth until they operate freely. On vehicles equipped with ignition keys, place key in lock and seal around the key and lock, and the rims of all instruments with asbestos grease. Do not remove key after sealing. Apply a few

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drops of penetrating oil to shafts of lighting switches. Spray the entire front and rear of instrument panel, being sure to cover all wiring and connections at rear of panel, with engine sealing compound. Remove tape from instruments after engine sealing compound has dried.

ENGINE COMPARTMENT

After completion of all deep water fording preparations, spray interior of engine compartment of vehicle, including exterior of engine air compressor (if so equipped), carburetor, fuel pump, air cleaner, distributor, coil wiring, spark plugs, voltage regulator generator, starter, engine manifold, and all components within the engine compartment with engine sealing compound.

ARTILLERY

The materials for the preparation of artillery for deep water fording are listed below.

Item	*Substitute*	*Specification*	*Source*
Grease, asbestos			Ord.
	1. Grease, water pump	USA 2-109	Q.M.C.
Cement (Bostik 692)			British
Cement (Bostik 292)			Ord.
Cover, protective, individual (gas cape)			Q.M.C.
	1. Cotton, oiled		British
	2. Vinylite		Ord.
Tape, adhesive, non-hygroscopic (Utilitape) 6-in. wide, 4 in. wide		AXS-871	Ord.
Solvent, dry-cleaning		Fed.P-S-661a	Ord.
Oakum	1. Burlap		Ord.
	2. Rope		
Oil, lubricating, preservative, medium		AXS-674	Ord.
Grease, O.D., No. 0		AXS-781	Ord.

Grease, asbestos, is used to fill all cracks and joints, and to cover over rivets, bolts, and taped surfaces. It is used on breech blocks, elevating and traversing mechanisms, axles, and trails. NOTE: *Grease should never be applied to fire-control instruments.*

Cover, protective, individual (gas cape), is cut to proper size for covering on-carriage sighting equipment as specified in detailed instruction.

Cement (Bostik) is used to seal waterproof sheets and cement them to metal surfaces.

Oil, lubricating, preservative, medium, is used for lubricating breech mechanisms and gun bores.

SERVICING PRIOR TO WATERPROOFING

Clean gun (or howitzer) and carriage thoroughly.

Lubricate all points ordinarily lubricated *daily, weekly,* and *monthly* in accordance with pertinent War Department Lubrication Guide. Lubricate points ordinarily lubricated every *6 months* if they have not been done recently.

Apply medium preservative lubricating oil to the bore of the tube and breech mechanism. In the case of the 40mm gun, apply the oil to the casing and automatic loader assemblies.

Tighten bolts and nuts in all covers or openings such as oil gear transmission cases, electrical fixture boxes, etc.

Remove all oil and grease from points to which waterproofing compound or materials are to be applied.

Put materiel in traveling position.

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WATERPROOFING PROCEDURES

Be sure that all parts to which asbestos grease, Bostik cement, or tape is to be applied are thoroughly clean and dry. This is necessary to secure adhesion and to prevent water from working around or under the waterproofing materials.

When applying asbestos grease, work it well up against all points of the surface being covered so as to fill in all cracks, seams, holes, and crevices. Be sure that it is smoothed down well and adheres at the edges.

When applying waterproof sheets, put cement on both the metal and the edge of the cloth to be sealed down, and press firmly in place. Seal all edges carefully, giving particular attention to the folds of cloth, as water can easily enter through hidden openings in a fold.

Make doubly sure that *all electrical equipment is* perfectly sealed as instructed.

Unless otherwise noted, all instructions using the term:

'Seal' refer to asbestos grease
'Cement,' refer to Bostik.
'Waterproof sheet,' refer to gas cape or alternate waterproof covering.

105MM HOWITZER MATERIEL M2 (EXAMPLE)

Seal all openings in the battery box located on the trail.

Seal the forward end of the recuperator cylinder (top). Seal the rear end of the recoil cylinder (lower) by reaching under the breech.

Seal both the front and rear edges of the howitzer locking ring so that no water can enter the threads. If water enters these threads, damage may result to both the ring and the tube when the ring is removed.

Seal the muzzle, using a piece of waterproof sheet and cement or waterproof tape and asbestos grease.

The recoil slides must be sealed so that no water can enter. Seal both the top and bottom joints through the entire length and around the ends. Particular attention must be given to obtaining a good seal under the yokes as these parts are hard to reach.

Seal the telescope mount on the left side of the carriage with asbestos grease so that all seams and moving parts are covered. Give the range quadrant on the right side of the carriage the same treatment. Be sure that no water can enter the gear trains.

Place the panoramic telescope and the elbow telescope in the telescope case and seal. In sealing the case, seal all rivet and bolt heads from the inside; then close the door and seal around the edges.

Seal the pintle pin around the top. Seal the cover over the lower end of the pin. This cover is located under the support. Seal the joint between the rotating parts of the top carriage and the lower carriage.

Seal the support pin and support locks.

Seal the cradle lock strut and pins and the strut support latch.

Seal all openings and seams in the elevating cross shaft housing. Seal the elevating gear case and elevating worm gear case.

Seal the trunnion bearings all around on both inner and outer sides.

Seal all openings around the cradle traveling lock shaft so that no water can reach the needle bearings in the top of the equilibrator rod where the equilibrator fastens to the cradle.

Seal the traversing worm shaft around each end so no water can enter the bearings located in the traversing bracket.

Seal the axle lock mechanisms, both right and left, and the cradle traveling lock mechanisms, right and left.

Seal the breech mechanism so that no water can reach the chamber or interior parts. Starting at the forward edge on the right side of the breech, seal a piece of waterproof sheet with cement in such a position that it may then be wrapped around the rear of the breech and on around the left side. Seal with cement as it is wrapped around. Cover the portion of the operating handle not covered with the sheet with asbestos grease.

Cover all grease fittings with asbestos grease.

Coat the elevating and traversing gear segments with medium preservative

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lubricating oil only. Grease will not be used since sand will adhere and cause excessive wear.

Quantities of materials required per unit are listed below.

Asbestos grease	10 lb.
Bostik cement	¼ lb.
Waterproof sheet (or ½ gas cape)	1 sq yd

PREPARATION FOR OPERATION

To place weapons into immediate action.

Remove breech covers and seals.

Remove muzzle covers or plugs.

Remove waterproof sheet seals when necessary.

Remove respirator seals when applicable. NOTE: *It is advisable to remove as much of the waterproofing materials as possible before use.*

Complete dewaterproofing as soon as time and facilities permit.

Remove all waterproofing materials.

Wash with fresh water.

Clean and lubricate, in accordance with pertinent War Department Lubrication Guide, all points to be covered *daily, weekly, monthly,* and *semiannually.*

Remove wheels; clean and relubricate wheel bearings.

Clean all exposed unpainted surfaces with dry-cleaning solvent and lubricate with medium preservative lubricating engine oil.

SMALL ARMS

The materials for the preparation of small arms for deep water fording are listed below.

Cover, waterproof, small arms (film type) (Specification No. P.Q.D. No. 377):

Type 1. Cover, waterproof, pistol

Type 2. Cover, waterproof, rifle

Type 3. Cover, waterproof, submachine gun

Type 4. Cover, waterproof, machine gun.

Tape, abhesive, non-hygroscopic, 2-inch (same type as used on tanks for overseas shipment).

Oil, lubricating, preservative, medium (landing operations).

Grease, asbestos.

Grease, water pump, U. S. Army 2-109, may be used as a substitute for grease, asbestos.

The waterproof covers for all types of pistols, rifles, submachine and machine guns used in wading and landing operations can be obtained at Quartermaster overseas supply points. In all cases, these covers are of sufficient size to envelop the largest item of each group.

WATERPROOFING INSTRUCTIONS

Before operations are started, the weapon should be properly lubricated, placed in the waterproof cover, and securely tied.

The muzzle of each mortar should be sealed with non-hygroscopic adhesive tape, and further protected by an application of asbestos grease along the seams of the tape. Gears and working parts of elevating and traversing mechanisms should be lubricated with medium preservative lubricating oil (landing operations). Exposed surfaces of ring joints, sleeve joints, and other possible points of entry of water should be protected by applying asbestos grease. Work the grease well up against all points of the surfaces being covered so as to fill in all cracks, seams, holes and crevices. Be sure that it is smoothed down well and adheres at the edges.

Machine gun mounts should be handled in the same manner as mortar mounts—the objective being to prevent the entry of water by using the asbestos grease.

For any other type of small arms materiel not covered by these specific instructions, medium preservative lubricating oil (landing operations) should be used.

As soon as possible after landing operations are completed, the waterproofing material should be removed. Parts subjected to salt water should be washed with fresh water, thoroughly dried, cleaned, and properly lubricated as described in the pertinent technical manuals.

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TRACK VEHICLES

	Road Speed	Ignition	Track Width	Gross Weight	Electrical System (Voltage)		Page
							191
							100
							102
							103
							105
							31
							31
							36
							39
	24 mph	Magneto	16" Side-guide	47,000	12 Volts	Sl	7
						S	12
	20 mph, Water 7.5 mph	Battery	14¼	32,800	12 Volts	Sl	17
						S	24
							26
	35 mph	Battery	16" Center Guide	38,500	24 Volts	H	27
							27
							28
							30
	35 mph	Battery	11⅝"	34,580	12 Volts	H	31
							44
							44
							44
	53 mph	Magneto	14⅜"	37,500	24 Volts	T	48
							50
	29 mph	Compression	16-9/16" Side Guide	66,000	24 Volts	Se	48
						S	48
	28 mph	Magneto	16-9/16" Side Guide	63,000	24 Volts	Se	49
						S	49
							51
	30 mph	Magneto	16-9/16" Side Guide	62,000	12 Volts	Se	196
						S	196
	25 mph	Magneto	16-9/16" Side Guide	52,000	24 Volts	Se	68
						S	69
	24 mph	Magneto	16-9/16" Side Guide	58,000	24 Volts	Se	70
						S	71
							72
	40 mph	Battery	11⅝"	32,340	12 Volts	H	74
							76
	35 mph	Battery	16" Center Guide	38,000	24 Volts	H	168
							54
							55
							60
	24 mph	Magneto	16-9/16" Side Guide	67,300	24 Volts	Se	62
						S	63
	29 mph	Battery	16-9/16" Side Guide	70,100	24 Volts	Se	66
						S	197
	28 mph	Magneto	16" Side Guide	68,400	24 Volts	Se	
						S	
	24 mph	Magneto	16-9/16" Side Guide	61,700	24 Volts	Se	264
						S	232
	35 mph	Battery	11⅝"	28,000	12 Volts	Se	255
						C	
te	35 mph	Battery	16-9/16"	31,400	12 Volts	C	239
						S	256
						C	259
te	20.5 mph	Battery	21-9/16"	75,000	12 Volts	C	253
						S	246
						C	229

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Transmission	Technical Manuals	Parts List
iding ;yncromesh	TM 9-751	SNL G-158
lding 'yncromesh	----------	SNL G-168
ydromatic	----------	----------
ydromatic	TM 9-732B, 1727B, 1727C, 1727D, 1727E, 1727F, 1727G, TM 9-1732A	SNL G-127
orquematic	TM 9-755	SNL G-163
:lective ;yncromesh	TM 9-752A, 1750, 1750B, 17509	SNL G-130
·lective ;yncromesh	TM 9-731G, 1731B, 1731C, 1750, 1750B	SNL G-170
·lective yncromesh	TM 9-758	----------
·lective ;yncromesh	TM 9-731E, 1750, 1750B, 1750D, 1751	SNL G-128
.lective ;yncromesh	TM 9-751, 1750, 1750B, 1750D, 1751	SNL G-158
ydromatic	TM 9-372, 1727B, 1727C, 1727D, 1727E, 1727F, 1727G, 1727K	SNL B-105
ydromatic	----------	----------
lective ;yncromesh	TM 9-730C, 1731A, 1731E, 1731G, 1731K, 1750, 1750D, 1750K	SNL G-104 Vol. VI & XIV
·lective ;yncromesh	TM 9-731B, 1731F, 1731G, 1731K, 1750, 1750B, 1750G, 1750K	SNL G-104 Vol. VII
·lective ;yncromesh	TM 9-759, 1731B, 1731G, 1731C, 1731K, 1750, 1750B	SNL G-104 Vol. XIII & XV
:lective ;yncromesh	TM 9-738	SNL G-185, 186, 187, 188
·lective 'onstant Mesh.	TM 9-786	SNL G-162
ombination ;elective Slid. & 'onstant Mesh.	TM 9-785	SNL G-150
ombination ;elective Slid. & 'onstant Mesh.	----------	SNL B-184

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