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RESEARCH AND DEVELOPMENT OF MATERIEL

ENGINEERING DESIGN HANDBOOK

GUNS SERIES

GUNS—GENERAL

U.S. ARMY MATERIEL COMMAND

HEADQUARTERS, U. S. ARMY MATERIEL COMMAND AUGUST 1964

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(AMCRD)

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PREFACE

This handbook has been prepared as one of a series on Guns and forms part of the Engineering Design Handbook Series of the Army Materiel Command. This handbook is intended to serve as an introduction to the series on Guns. It presents the elements of which guns are constituted and the usual variations in form of these elements; surveys the current and recently used types designed to serve various military purposes; defines a number of terms used in reference to guns and their operation; and introduces physical, mechanical and logistical problems encountered in design, for which specific procedures for solution will be presented in the other handbooks of the series.

The first draft of this handbook was prepared at Watervliet Arsenal of the Weapons Command. Assistance by review services and the supplying of additional material was obtained from Springfield Armory of the Weapons Command and Frankford Arsenal of the Munitions Command. Final editing and arranging was by the Engineering Handbook Office of Duke University, prime contractor to the Army Research Office—Durham.

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Comments and suggestions on this handbook are welcome and should be addressed to Army Research Office—Durham, Box CM, Duke Station, Durham, North Carolina 27706.

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CHAPTER 1

INTRODUCTION

1-1 Scope of This Handbook

This handbook deals with the general subject of guns. It highlights early developments, classifies and describes guns according to military characteristics and usage, and again, according to design characteristics. It deals with the major components and assemblies in sufficient detail only to make clear their functions, their operation and their relationships to other assemblies and to the gun as a whole. It introduces problems encountered in design for which specific procedures for solution will be presented in other handbooks. It is intended that other handbooks of the Guns Series cover in more detail problems relating to gun tubes (barrels), gun forgings, breech closures, breech rings, firing mechanisms, extracting and ejecting mechanisms, breech operating mechanisms, loading mechanisms and muzzle devices. Automatic weapons is intended as the subject of still another handbook. Carriages and Mounts is the subject of a series already prepared. That series covers cradles, recoil systems, top carriages, bottom carriages, equilibrators, elevating mechanisms, traversing mechanisms, and carriages and mounts—general.

Ammunition and ballistics are covered in other handbooks and this volume treats these subjects only as necessary to provide an understanding of the interrelationship between these subjects and guns.

1-2 Early Development

In the pre-gunpowder period, man tried to increase the range of his weapons by using various types of catapults and ballistae. These methods of projectile propulsion were nothing more than great slings used to hurl stones and other large, heavy objects for a considerable distance.

The development of the gun came about as a logical sequence to the development of gunpowder (black powder), first described by the English friar, Roger Bacon, in the year 1242. This mixture of saltpeter, sulfur and charcoal was not thought of as a propellant at that time, but rather as an explosive which would cause terror among the enemy with its bright flash and thundering noise. To Berthold Schwartz, a German monk, is given the credit for having invented, about 1313, a firearm using black powder as the propellant. The first organized use of guns in open battle was by the English at the Battle of Crecy in 1346. Explosive mixtures and pyrotechnics are said to have been employed in China, India and Greece in very ancient times. There are early recorded uses of "Greek fire" and Chinese rocket-propelled "fire arrows."

1-3 Smooth-bore Era

By the time of Columbus' voyages of discovery, guns had become the principal weapons of the Old World powers and were destined to play a large part in shaping the history of the New World. Earlier firearms were crude, inefficient and heavy, existing only as cannon, but by now hand guns had been developed from the crude cannon. All guns were smooth-bore and muzzle-loaded, utilizing solid spherical projectiles and black powder propellant. It was to be several centuries before these gave way to the use of rifled bores, stabilized projectiles, breech loading and smokeless powder. Rifling had been tried but was not very practical before breech loaders were developed.

From the earliest use of firearms until about 1500, little was understood about the curved path taken by the projectile. Beyond pointblank range,

the gunner was never sure of hitting his target. Early cannon were made by casting the tube around a core. As cannon evolved, they were later cast solid and the bore drilled, a practice which improved the uniformity of the piece.

During the Hundred Years' War (1399-1453) cannon came into general use. Those early pieces were very small, made of iron or cast bronze, and fired lead, iron, or stone balls. They were laid directly on the ground, with muzzles elevated by mounding up the earth. Cumbersome and inefficient, they played little part in battle, but were quite useful in a siege.

Mohammed II of Turkey used gunpowder in his famous military conquest of Constantinople in 1453. The single weapon possessed by the Turks weighed 19 tons and hurled a 600-pound stone 7 times a day. It took 60 oxen and 200 men to move the piece, and the difficulty of transporting such heavy ordnance reduced its usefulness. It was responsible, however, for destroying the city walls which had successfully resisted many attacks by other weapons for more than 1,000 years.

Called *bombards,* weapons of this period were very large, but the powder used was very weak and the pressures in the barrels were low. Even so, barrels frequently burst. The early barrels were often made of staves and hooped like a barrel and derived their name from this construction.

An increased knowledge of gunpowder and an improvement in the art of casting caused the replacement of bombards with lighter cannon in the 16th century. From the time of their invention until about 100 years ago, cannon were of extremely simple construction—they had a cast barrel, wedge elevating mechanism, and crude wheels and carriages. Such weapons were fired by igniting the gunpowder by a live fire or match applied to the touch hole at the breech. The improved weapons were of decreased size and were soon cast in one piece of cast iron or bronze. At the beginning of the 15th century, cast-iron balls had made an appearance. The greater efficiency of the iron ball, together with an improvement in gunpowder, further encouraged the building of smaller and stronger guns. Before 1500, the siege gun had been the predominant piece. Now, forged-iron cannon for field, garrison, and naval service—and later, cast-iron pieces—were steadily developed along with cast-bronze guns. Throughout the 1500's, improvement was mainly toward lightening the enormous weights of guns and projectiles as well as finding better ways to move the artillery. The casting of trunnions on the gun made elevation and transportation easier, and the cumbersome beds of the early days gave way to crude artillery carriages with trails and wheels. About 1500, the French invented the limber and standardized the calibers of their artillery.

The earliest small arm was nothing more than a short metal tube of large caliber mounted on a rod or stick. The stick gradually became a stock which permitted firing from the shoulder. Ignition of the gunpowder charge was by fire or match applied by hand to the touch hole, as for cannon. When the match was later mounted on an S-shaped lever called the "cock," the weapon became the match lock. A later development, the wheel lock, used a serrated wheel against a piece of iron pyrites, producing a shower of sparks for ignition. The simpler flint lock was developed in the 17th century and did not disappear completely until after the close of our Civil War, when the percussion system of ignition came into general use.

The first cannon were rolled along the ground but soon were placed on wagons or carriages for transportation. These early carriages supported the cannon at their center of balance and at the breech. Adjustments in elevation were secured by a wedge under the breech. To move the barrel, it was necessary to move the entire carriage.

Mobile artillery came on the field with the cart guns of John Ziska during the Hussite Wars of Bohemia (1418-24). The French further improved field artillery by using light guns, hauled by the best of horses instead of the usual oxen. The maneuverable French guns proved to be an excellent means for breaking up heavy masses of pikemen in the Italian campaigns of the early 1500's. The Germans under Maximilian I, however, took the armament leadership away from the French with guns that ranged 1,500 yards and with men who had earned the reputation of being the best gunners in Europe.

About 1525, the famous Spanish Square of heavily armed pikemen and musketeers began to dominate the battlefield. In the face of musketry, field artillery declined. Although artillery had achieved some mobility, carriages were still cum-

bersome. To move a heavy English cannon, even over good ground, required 23 horses.

Under the Swedish warrior, Gustavus Adolphus, artillery began to take its true position on the battlefield in the 17th century. It was he who combined the powder charge and projectile into a single cartridge to do away with the old method of ladling powder into the gun and so increased the rapidity of fire. Recognizing the need for mobile weapons, he made use of pieces which could be moved by only 2 horses and served by 3 men. In the past, 1 cannon for each thousand infantrymen had been standard. Gustavus brought the ratio to 6 cannon per thousand men.

About 1750 Frederick II, King of Prussia, succeeded in developing artillery that was light enough and mobile enough to accompany the army and be readily maneuvered on the battlefield.

1-4 Rifling Adopted

The principle of stabilization of an elongated projectile by rotation has been known a long time. However, difficulties in manufacture of the guns and ammunition retarded the development. In small arms there were some rifled muskets in use in the 18th century, utilizing projectiles which expanded at the base to fit into the rifling grooves of the muzzle loaders. The development could not be successfully applied to the manufacture of cannon and their ammunition until breech-loading was developed.

Early cannon were not made very accurately, and their accuracy of fire was correspondingly low. These weapons could not be made better than the tools which produced them, and good machinery capable of boring cannon was first made about 1750. Rifling had already been applied to small arms, but machinery of the necessary accuracy to make cannon in this fashion was not available until about a century later.

In 1846, Major Cavelli in Italy and Baron Wahrendorff in Germany independently produced rifled iron breech-loading cannon. The Cavelli gun had two spiral grooves which fitted the ¼-inch projecting lugs of a long projectile. About the same time, an enterprising British industrialist, Joseph Whitworth, developed the helical hexagonal-bore weapon. This weapon was one of many used during the American Civil War (1861-1865). It was an efficient piece, though subject to easy fouling that made it dangerous.

The American Civil War began with smooth-bore muzzle loaders and ended with rifled, muzzle loaders. When they wore out or were captured, smooth-bore weapons were replaced with rifled pieces. One specific weapon converted from a smooth-bore to a rifled bore is noted in the Rodman gun. Developed by Capt. T. J. Rodman (United States Army Ordnance) in the mid-1800's, this smooth-bore weapon was cast around a water-cooled core. Its inner walls thus solidified first and were compressed by the contraction of the outer metal as it cooled more slowly. By this process, it had much greater strength to resist explosion of the charge. The Rodman smooth-bore cannon, cast in 8-, 10-, 15-, and 20-inch calibers, was the best cast-iron ordnance of its time. During the Civil War and after, a number of the 10-inch Rodmans were converted into 8-inch rifles by enlarging the bore and inserting a grooved steel tube.

1-5 Breech Loading Developed

The first successful breech-loading guns were made less than a century ago. There were some breech-loading cannon made over 400 years ago, but judged by our standards, they were far from satisfactory and were not the forerunners of modern breech-loading guns.

The need for breech loading was obvious; to enable firing and reloading without exposing the gunners to the enemy. Solution of the breech loading problem depended primarily on finding a mechanism that would seal the propellant gases within the chamber. This was accomplished by using soft metal (brass) cartridge cases for the smaller guns and more complex expanding asbestos and metal seals for the larger ones. The first gun that may be called modern and in the sense that it had all the features now in use was the "French 75." This 75-mm gun, model of 1897, had modern sights, firing mechanism, recoil mechanism, and used cased ammunition. It was the backbone of the artillery of the allied armies in World War I (1914-18).

1-6 Early United States Developments

1-6.1 Fixed Artillery

Design characteristics of United States artillery have followed generally those of other nations.

Before the Civil War, there was little manufacturing of cannon in this country, and at the beginning of that conflict, it became necessary to purchase much of this equipment abroad. At that time, there were various models of various sizes of cannon for use in fortifications. These weapons included brass guns, brass mortars, iron guns, and iron howitzers.

A distinctly American development in fixed or harbor defense artillery was reached early in the 20th century with the adoption of the disappearing carriage. This enabled the gun to rise over a parapet to fire, but was withdrawn, by recoil forces, behind the parapet for reloading.

Another fixed artillery piece, the barbette carriage, was a permanently emplaced carriage which was capable of traversing through large angles except as limited by protecting turret or casemate.

1-6.2 Mobile Artillery

The appearance of the French 75 in 1897 spurred American designers to a series of notable developments, and many models were made in 3-, 4.7-, 6-, and 8-inch calibers with various carriage and recoil mechanism arrangements. Little money was available, however, to actually manufacture these guns for issue, so that, upon entering World War I in 1917, it was found desirable to adopt weapons for which production facilities existed. At that time, the French 75-mm, model of 1897, and the American 75-mm gun, model of 1916, were adopted. They were followed shortly by a 75-mm gun of similar but British design, the model of 1917.

Similar action brought into our Armed Forces the French 155-mm gun (Filloux). This weapon was more familiarly known as the G.P.F. after its French designation *Grande e Puissance Filloux* (gun of great power). There was also a French 155-mm howitzer of Schneider design adopted.

In order to facilitate coast defense, the railway mount was put into service. Large caliber guns up to 16 inches were mounted on specially built railway cars. The materiel was fired from the railway car mountings after suitable supports and outriggers were in place.

1-6.3 Small Arms

The flintlock rifle served the American pioneer, the Revolutionary War soldier and, to some extent, the Civil War soldier. Most flintlocks were converted to percussion locks prior to or during the Civil War. This was made possible by the invention of the percussion primer, which in turn made possible the metal cartridge case which provided effective obturation, which in turn resulted in adoption of the breech-loading system. Then the use of rifling became practicable in all guns.

As weapons improved and better ammunition became available, the magazine rifle was developed to meet the demand for increased firepower. The famous Winchester '73 was among the early successful magazine rifles. It provided a magazine which held several rounds of ammunition, and means for transferring them to the chamber. Reduction of caliber, improvement in propellants which permitted use of smaller charges, and reduction of size and weight of cartridges simplified the problem.

After the period of the Civil War interchangeability of parts was provided. This era had been ushered in by Eli Whitney (of cotton gin fame) who first applied the principle of interchangeable parts and mass production in the manufacture of a large number of rifles for the government.

The modern military rifle was perfected in all its essentials by about 1890. Since that time details have been refined, smokeless powder has replaced black powder, improved ammuntion has been provided, and better metals have become available. The trend has been toward higher velocities, greater firepower, and less weight. As will be noted below, American inventors pioneered in the development of machine guns.

1-7 Development of Automatic Weapons

The development of automatic features and of full automatic weapons was in response to the demand for increased firepower. The early weapons employed multiple barrels on a single mount, which could be fired simultaneously. Other arrangements which were developed permitted the firing of multiple barrels successively, or brought multiple chambers successively to a single barrel. These did increase considerably the volume or rapidity of fire but automatic loading had not yet been worked out. Moreover, they were very heavy and cumbersome.

The development of automatic weapons was hastened by the invention of the percussion primer, the adoption of breech loading, and introduction

of the complete round assembled in a metal cartridge case. The first practicable machine gun was the Gatling, invented by Dr. R. J. Gatling about the time of the Civil War. Its adoption was followed by others of the same general type, which in effect combined in one mount a considerable number of breech-loading rifles that could be loaded and fired mechanically.

In 1884 Sir Hiram Maxim, an American engineer, designed the first truly automatic machine gun. It employed a single barrel and utilized the principle of recoil operation to secure continuous and automatic functioning as long as the trigger was held down. This weapon was an immediate success; the soundness of its design and principle of operation were immediately recognized. It revolutionized machine gun tactics and stimulated the development of other automatic types. In modified and improved form it was still being used by the British, German and Russian armies at the beginning of World War I; it has appeared also among the variety of weapons used by the communist forces in Korea.

The principle of gas operation, utilizing a small portion of the expanding propellant gas, was first successfully employed by John M. Browning, an American, who brought out the Colt machine gun in 1889. This was followed by the Hotchkiss, employing the same system of operation. During the period covering World War I, Browning's short recoil machine gun, which was originally patented in 1901, reached the stage of development very much as it is today. The Browning Automatic Rifle, (BAR), answering the need to combine the light weight and flexibility of the conventional rifle with the greater firepower of the machine gun, has served also through the two World Wars.

1-8 Guns and History

Beginning with the formation of the individual American Colonies, guns of numerous types and sizes have played a major role in the history of the United States. Although the United States is not primarily a military nation, its fusion into a single nation, the expansion of its borders, the settlement of its land, its growth into the position of a major world power, and the keeping of law and order among its people have been closely linked with the story of guns, from the smallest pistol to the largest cannon. Similar statements could be made about other nations. Guns have now been augmented, and in some cases replaced, by rockets and other weapons; however, there is every indication that the gun, in various present and future forms, will continue to play a major role in the destiny of the world and its people.

1-9 Gun Terminology

Although one will readily recognize components and assemblies that perform identical functions in Army guns of different types and sizes, it must be borne in mind that design, development and use of guns has, to a considerable extent and for generations, been specialized according to types or sizes. A natural outgrowth of this condition has been the development of differences in terminology and nomenclature; in fact, it is due almost entirely to organized efforts that the basic nomenclature shows any degree of uniformity. Recent efforts have included Federal cataloging and assignments of Federal item names with identifying definitions. This effort requires time to reach agreements within a service, not to mention the necessary agreements between services. And even after agreements are reached and recorded, new names or new definitions for old names are not accorded general acceptance by users without a considerable period of reeducation.

In dealing with the broad subject of guns the authors have made every effort to use terminology which will not be confusing to the reader who may have only a limited acquaintance in the field of guns. The reader should bear in mind, however, that in some instances a single term is accepted as having different meanings in the general and specific senses, or different meanings with respect to, say, cannon and small arms. The terms and definitions given in the handbook should be noted carefully in order to effect a clear understanding of the text.

1-10 Major Elements of the Gun

1-10.1 Gun Tube or Barrel

The tube or barrel is the main part of a gun. It is essentially a hollow cylinder, usually of steel, which surrounds the bore and guides the projectile during its acceleration. In most designs the chamber is an integral part of the tube, the revolver type being a notable exception. *Tube* is the more general term and may be applied to all sizes, while *barrel*

is the term more often used in connection with small arms. The term *barrel assembly* may be used for all calibers to denote the tube and parts assembled thereto.

1-10.2 Breech Closure

A breech closure, as the term implies, is a general term denoting the closure of the breech end of a gun. This closure permits the hot propellant gases behind the projectile to act on it so as to impart the greatest possible kinetic energy for a given propellant charge. A closure may be of the permanent type or the mobile type. The latter type remains closed during the firing but may be opened afterwards to permit reloading from the breech. Permanent closures are applicable only to muzzle loaders, such as mortars. Another type, known as the open-breech closure, is used for recoilless guns. Breech closures are discussed further and illustrated in Chapter 3.

1-10.3 Breech Ring or Receiver

The breech ring is a principal unit of gun construction, is attached to the gun tube at the breech end and supports the breech closure and other parts of the breech mechanism. In cannon terminology the term breech ring is commonly used, while the term receiver is more frequently used in relation to small arms and automatic weapons. The terms are discussed further in Chapter 3.

1-10.4 Firing Mechanism

This is the mechanism which fires the primer to initiate propelling charge ignition. The principal types now in use are designated, according to the method of firing the primer, as percussion, electric, or combination percussion-electric. The subject is discussed further and several types illustrated in Chapter 3.

1-10.5 Extracting Mechanism

This refers to the mechanism, in a gun using cartridge cases, for pulling the empty cartridge case or an unfired cartridge out of the chamber.

1-10.6 Ejecting Mechanism

This refers to the mechanism, in a gun using cartridge cases, for automatically throwing out an empty cartridge case or an unfired cartridge from the breech or receiver.

1-10.7 Breech Operating Mechanism

This designates that part of the breech mechanism which must be operated to open or close the breech mechanism. This mechanism is discussed further in Chapter 3.

1-10.8 Loading Mechanism

This term includes all mechanisms used for placing the ammunition into the gun in position for firing. The process differs greatly, according to types and sizes of guns and ammunition. The term includes feeding mechanisms, ramming mechanisms and fuze-setting mechanisms when these are constructed so as to become part of the loading or ramming operation. The subject is discussed further and illustrated in Chapter 3.

1-10.9 Muzzle Devices

Muzzle devices, also called muzzle attachments, are used in a number of forms and for a variety of purposes. Devices presently in common use include flash hiders (Fig. 5-2), flash suppressors (Fig. 5-3), blast deflectors, muzzle brakes and bore evacuators. A combination of the last three named devices is shown in Fig. 6-1 and a schematic diagram of the bore evacuator operation is shown in Fig. 6-2.

CHAPTER 2

CLASSIFICATION AND DESCRIPTION BY MILITARY CHARACTERISTICS OR USAGE

2-1 General

There are many ways in which guns are classified. The most generally used method is that of classifying according to military characteristics or military usage. This involves sizes or shapes which are readily apparent to the eye and with which most military personnel are familiar. Because of differing general and specific meanings for the terms "gun" and "cannon," the reader should give special attention to the understanding of these terms in both senses.

2-2 Gun (General)

For the purposes of this handbook, a gun is a projectile-throwing device, consisting essentially of a projectile-guiding tube with an incorporate or connected reaction chamber, in which the chemical energy of a propellant is rapidly converted into heat and the hot gases produced expand to expel the projectile at a high velocity (kinetic energy). Guns in this general sense are separated, according to size and use, into the general categories of cannon and small arms. Launchers for rockets and missiles are purposely excluded from consideration in this handbook.

2-2.1 Cannon (General)

A cannon is a weapon conforming to the general gun definition, that is provided with a structure (mount) for mechanical support during firing, and that has a bore diameter exceeding the limit assigned to small arms. (The small arms bore limit is presently administratively set at 30mm.) The general category of cannon is further divided, in accordance with ballistic characteristics and use, into guns, howitzers, mortars, and recoilless weapons, as follows:

2-2.1.1 Gun (Specific)

In the specific sense used in ordnance supply, a gun is a complete weapon conforming to the general cannon definition; including the attached or closely related units necessary for operation as intended (recoil mechanism, mount, sighting system, accessories, but not ammunition), and designed for performance characterized primarily by relatively long range, high velocity, and relatively little curvature of the projectile trajectory within the intended range (see Figures 2-1 and 2-2).

2-2.1.2 Mortar

A mortar is a complete weapon conforming to the general cannon definition; including the attached or closely related units necessary for operation as intended (mount, sighting system, and accessories, but not ammunition), and designed for performance characterized primarily by relatively low velocity, short range, and a highly arched projectile trajectory at the ranges at which it is designed to fire (see Figures 2-3 and 2-4).

2-21.3 Howitzer

A howitzer is a complete weapon conforming to the general cannon definition; including the at-

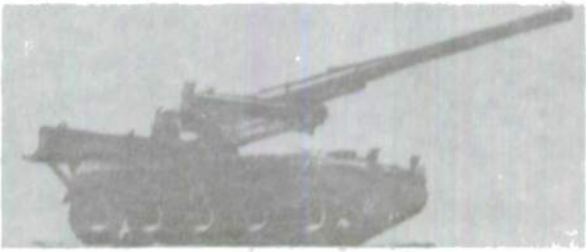


Figure 2-1. Typical Gun (Self-Propelled Mount)

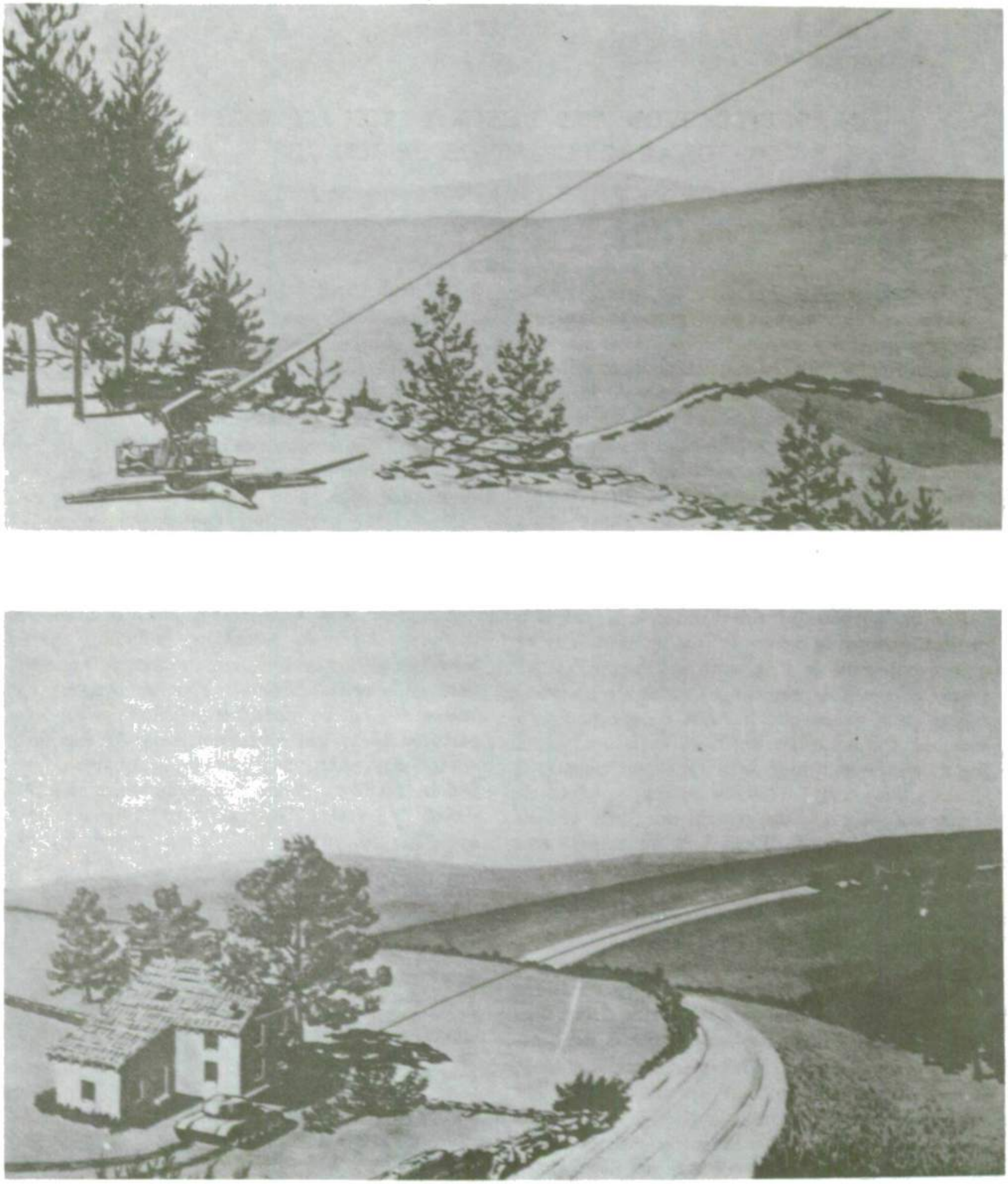


Figure 2-2. Typical Gun Trajectories

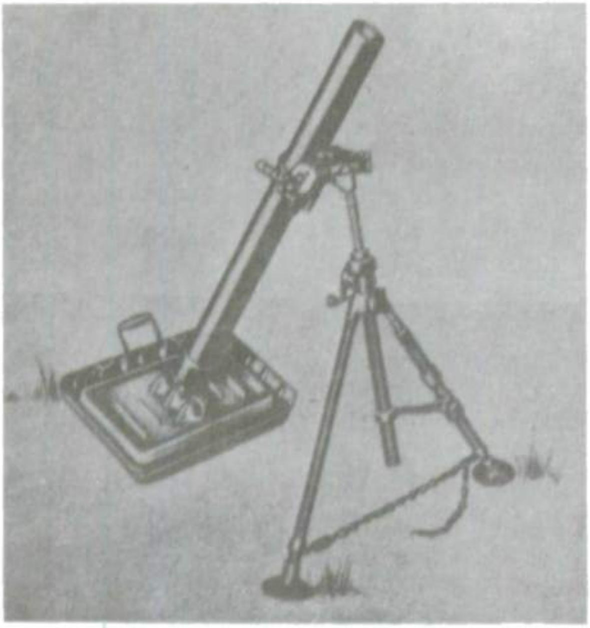


Figure 2-3. Typical Smooth-bore Mortar.

Figure 2-5. Typical Howitzer (Self-Propelled Mount)

tached or closely related units necessary for operation as intended (recoil mechanism, mount, sighting system, accessories, etc., but not ammunition), and designed for performance characterized by velocity, range, and trajectory curvature intermediate between those of a gun and a mortar (see Figures 2-5 and 2-6).

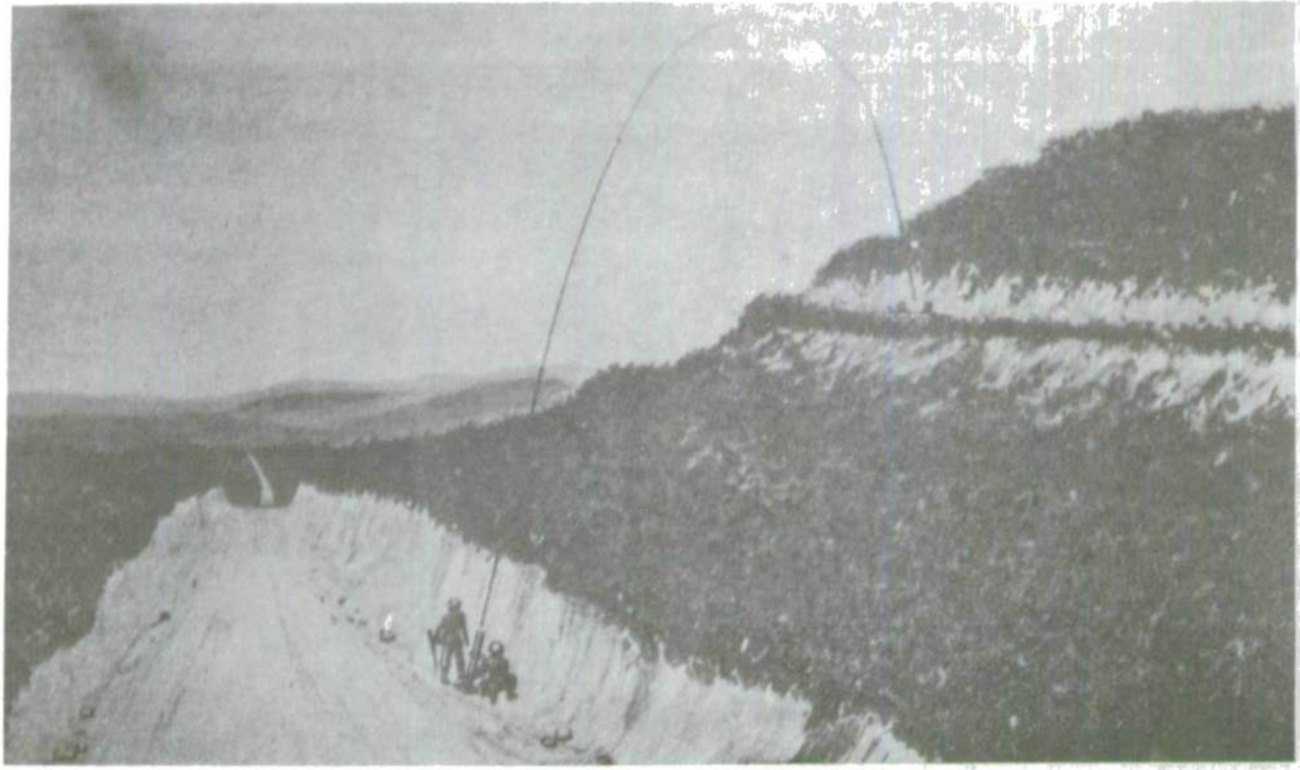
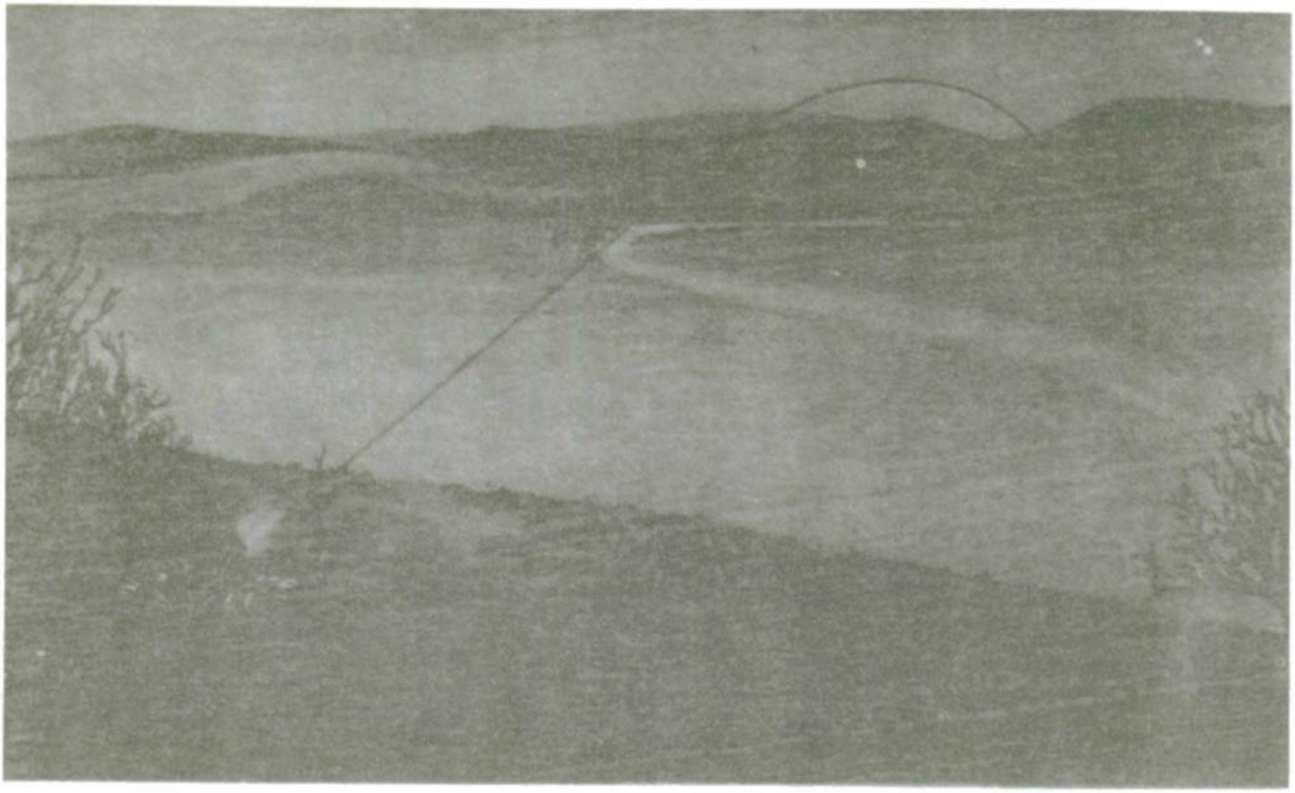


Figure 2-4. Typical Mortar Trajectory



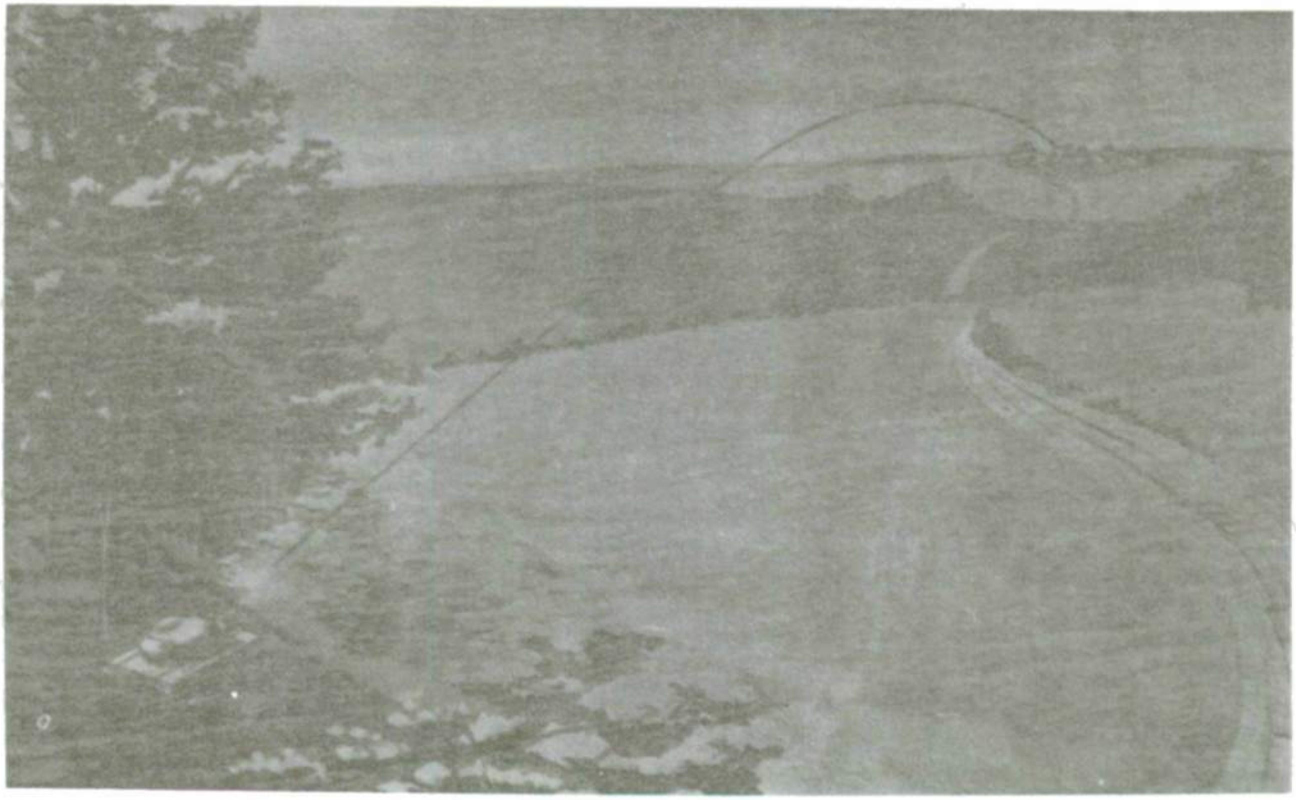


Figure 2-6. Typical Howitzer Trajectories

2-2.1.4 Recoilless Cannon

A recoilless cannon is a complete weapon conforming to the general cannon definition; including the attached or closely related units necessary for operation as intended (mount, sighting system, accessories, etc., but not ammunition), and designed to discharge the propellant gases in such a manner as to impart substantially no recoil impulse to the weapon. Recoilless cannon in current use are confined to recoilless rifles, designed to fire cannon-size projectiles, with low to medium velocity and high accuracy, from a weapon of relatively light weight and high portability (see Figure 2-7).

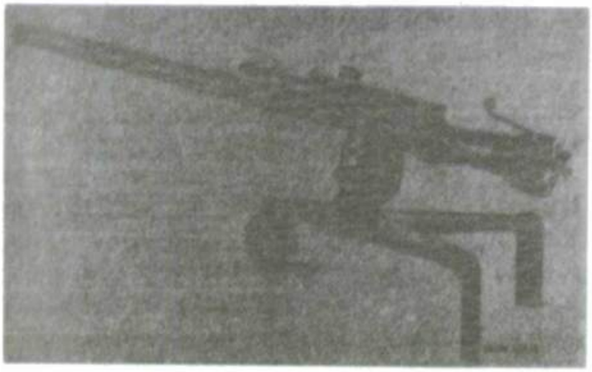


Figure 2-7. Typical Recoilless Rifle

2-2.1.5 Cannon (Specific)

The term "cannon" is used in a specific sense to denote the shooting part of a complete weapon (gun, howitzer, mortar or recoilless) comprising only the tube and breech structures and such mechanism as is supported thereon for opening and closing the breech and firing the propelling charge.

2-2.1.6 Automatic Cannon

No definite distinction, except as to caliber, is established between machine guns and automatic cannon. The designation "cannon" is generally not applied to guns of bore diameter under the small arms limit (30mm).

2-2.2 Small Arms

The small arms category of guns comprises those with bore diameter not exceeding an arbitrarily assigned limit (present limit is 30mm). Small arm guns include hand guns (pistols), shoulder guns (rifles, carbines, shotguns, submachine guns) and mechanically supported weapons (machine or automatic guns).

Figure 2-8. Typical Pistol

2-2.2.1 Pistol

A pistol is a short-barreled weapon held and fired with one hand, designed as an easily carried short-range weapon for individual use (see Figure 2-8). Current designs provide for rapid firing of six or more shots before reloading is necessary. Some models operate semiautomatically or automatically after the first shot (see paragraphs 3-6.2 and 3-6.3).

2-2.2.2 Shotgun

A shotgun is a short-range gun designed for firing from the shoulder, having a smooth bore suitable for expelling a group of pellets. Army shotguns, which are used chiefly for guard or police duty and for training purposes, are of a magazine type, capable of rapid firing of a limited number of shots without reloading.

2-2.2.3 Rifle

A rifle is a shoulder-fired gun having a relatively long barrel with the bore helically grooved to impart a spinning motion to the projectile about its longitudinal axis, for improved stability in flight. The rifle is designed to obtain relatively high velocity, long range, and a high order of accuracy with a projectile of small diameter. Present Army rifles have small-capacity magazines, with semiautomatic or automatic operation (see paragraphs

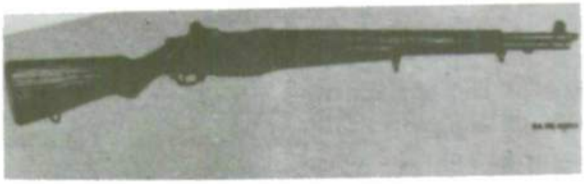


Figure 2-9. Typical Rifle (Semiautomatic)

3-6.2 and 3-6.3 and Figure 2-9). Some models capable of automatic fire are provided with a mechanical support to facilitate maintenance of alignment with the target while firing.

2-2.2.4 Carbine

A carbine is a shoulder-fired gun similar to the rifle, but reduced in weight, barrel length, and effective range. It replaces the rifle in uses where increased ease of portability is of greater importance than the higher power and longer accurate range of the rifle.

2-2.2.5 Submachine Gun

This term is applied to a short-barreled, automatic-firing weapon using a larger, heavier bullet than the shoulder-fired rifle, but producing a relatively low projectile velocity effective only at short ranges. It is furnished with a stock and hand grip to permit firing either from the shoulder or from two-hand support at the side of the operator. The submachine gun employs a magazine of several times the capacity of the standard shoulder-fired rifle, and is used for rapid firing of a large number of projectiles against personnel at short ranges, where high accuracy of fire is not essential.

2-2.2.6 Machine Gun

This term applies both to automatic guns of bore size, power and effective range comparable to the shoulder-fired rifle, and to more powerful automatic guns, when the mechanism is designed to extract successive cartridges from a belt or equivalent means of continuous feed, instead of from a magazine of limited capacity (see Figure 2-10). Partial or complete mechanical support is provided, and the amount of support and type of supporting structure depending on the weight and power of the gun and the resultant aid needed by the operator for directional control of fire.

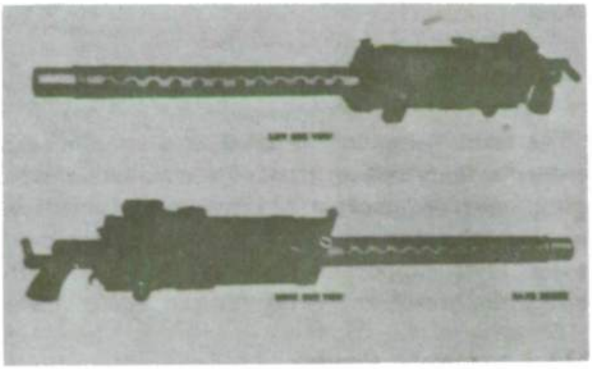


Figure 2-10. Typical Machine Gun

CHAPTER 3

CLASSIFICATION AND DESCRIPTION BY DESIGN FEATURES

3-1 Common Features

While development of guns for military uses has resulted in a varied assortment of sizes and types of construction and mechanism, a number of constructional features and terms are common to many types. Figure 3-1 illustrates and identifies some such features and terms for gun tubes, cartridge cases and projectiles.

3-2 Methods of Classification

In a previous chapter we have taken up the classification of guns by military characteristics or usage. Guns are also frequently classified according to design features. Such features include the type of ammunition for which designed, as well as characteristics of the bore, the breech, and the operating mechanisms.

3-3 Classification by Ammunition Type

Since performance results from interaction of gun and ammunition, design and development of the two are closely interdependent. As a result of this relationship, there have evolved several general types of complete round ammunition units for use in guns, and corresponding appropriate gun designs. The gun design requirements differ, mainly, in the types of breech closure. One method of classification of guns is by designation of the type of ammunition for which designed. Several types of ammunition design, used for such classification, are given below.

3-3.1 Fixed Ammunition (see Figures 3-2 and 3-3)

This term applies to ammunition of which all parts of each round are mutually attached, so that the round is handled and inserted into the gun as a single unit. All recent small arm guns fall into this category; also current cannon of such size that the assembled ammunition unit is not excessively unwieldy. In current breech-loading weapons, the propellant and primer are contained in a cartridge case with rear end closed and front end crimped or tightly fitted to the base of the projectile. The case fits the chamber closely, and pressure of the ignited propellant expands it against the chamber walls to seal against rearward escape of gas. Hence, the breech-closing structure of the gun need not be gas-tight, but must support the case to prevent its rupture or rearward displacement, and must open to permit insertion of the round and removal of the case after firing. Means must be provided to fire the primer, and to remove the case.

3-3.2 Semifixed Ammunition (see Figure 3-4)

For breech-loading weapons, semifixed ammunition differs from fixed in that the case is removably fitted to the projectile, so that the latter may be removed to adjust the quantity of propellant in the case, then reassembled prior to insertion of the round into the gun. Guns utilizing this type of ammunition are such cannon as require various quantities of propellant for effective firing into variously distant zones. Breech closure requirements are similar to those for fixed ammunition.

A variant of semifixed ammunition is used in muzzle-loading mortars incorporating a permanently closed breech. This round uses no cartridge case about the propellant, but embodies a primer fixed in a rearward-extending axial boom on the projectile, and a series of bags containing definite quantities of propellant, each separately and removably attached to the projectile boom. For this

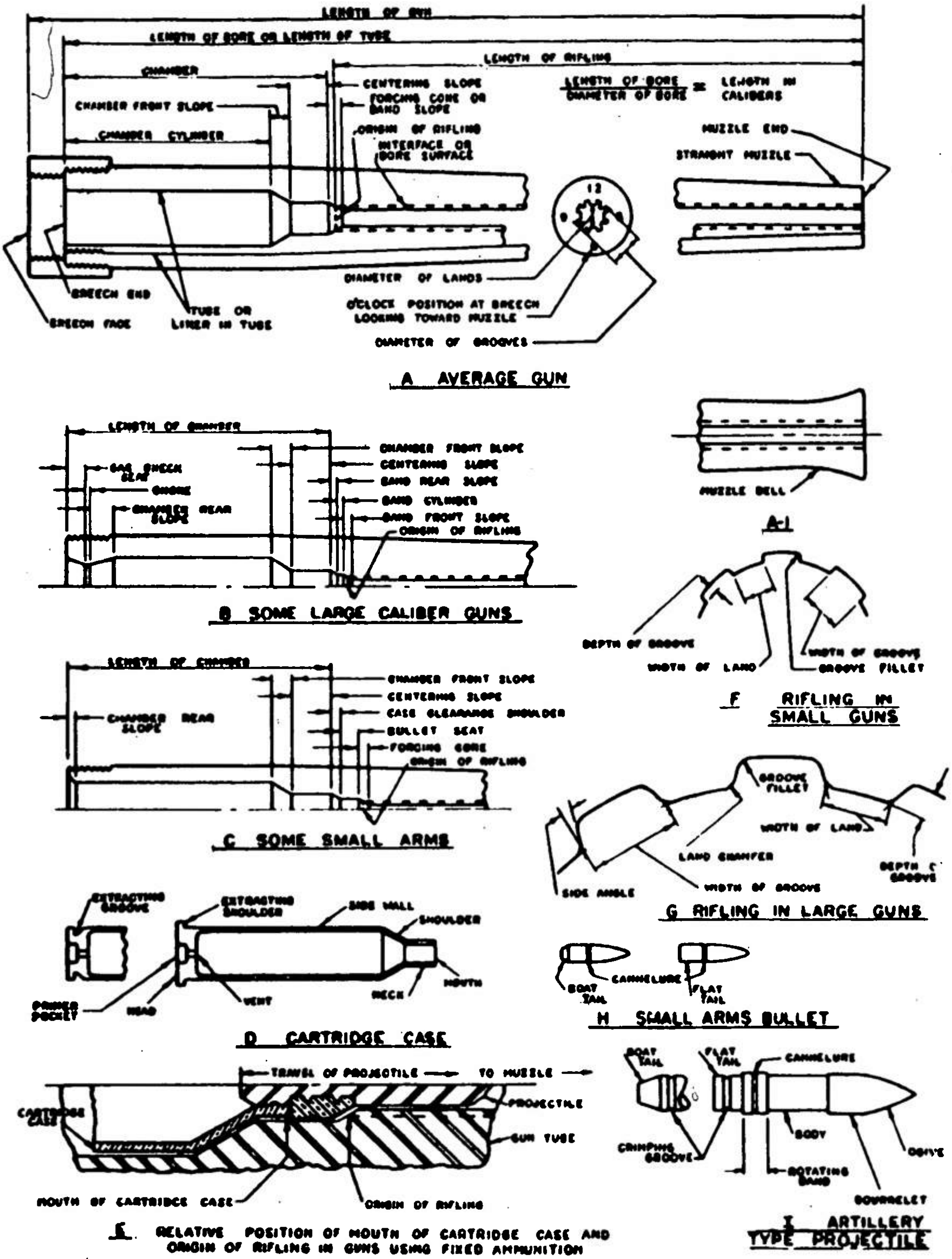


Figure 3-1. Gun Tube (Barrel), Cartridge Case and Projectile—Typical Features and Terminology.

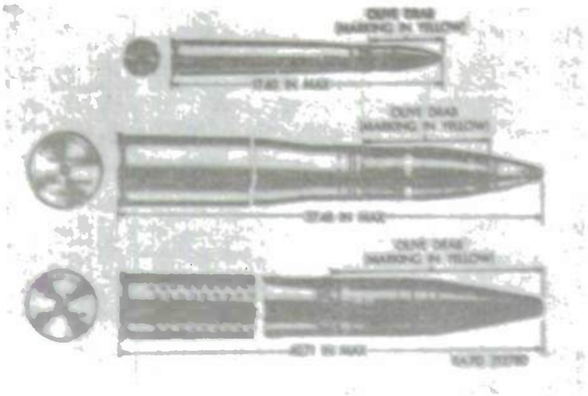


Figure 3-2. Typical Fixed Artillery Ammunition

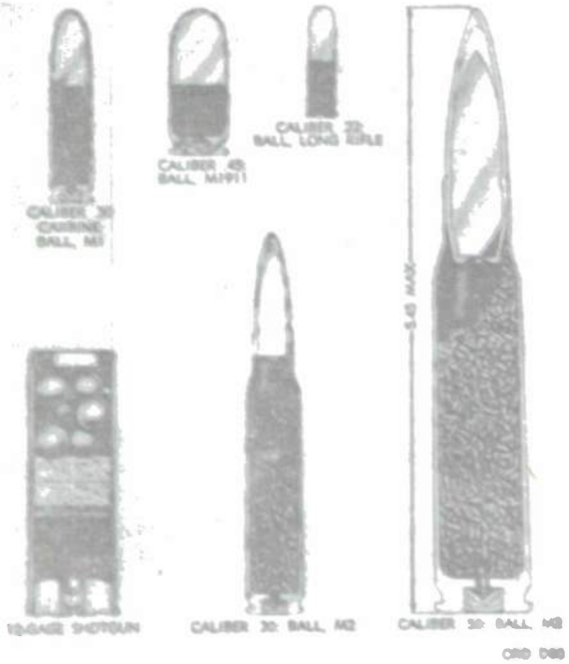


Figure 3-3. Typical Fixed Small Arms Ammunition

ammunition the breech closure must be gas-tight and provide means for firing the primer.

3-3.3 Separated Ammunition (see Figure 3-5)

In this type, the propellant and primer are sealed in a cartridge case, separate from the projectile,

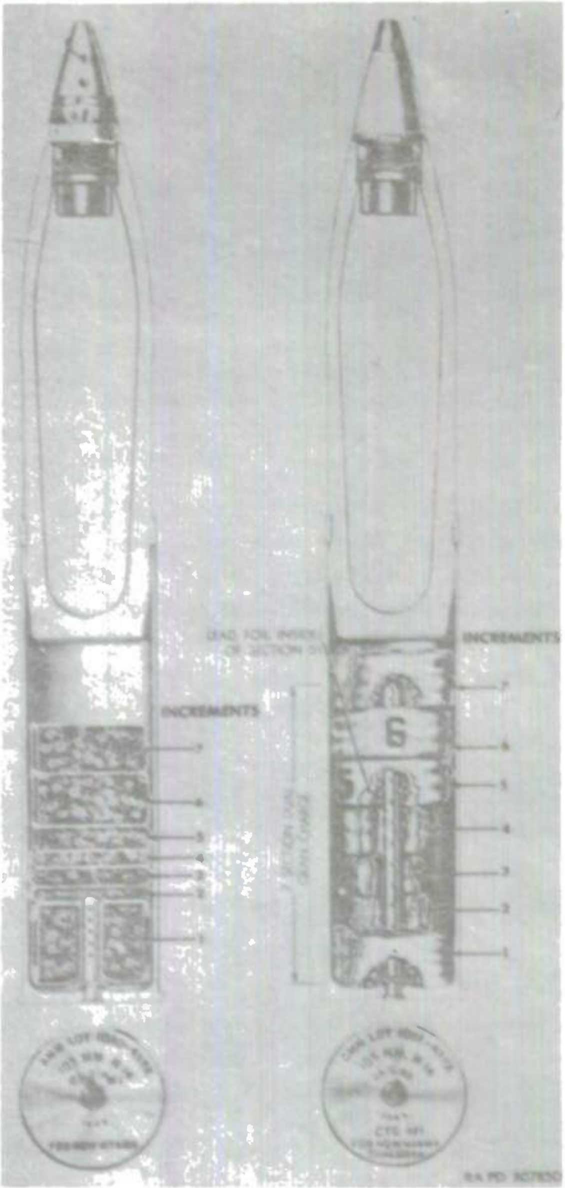


Figure 3-4. Typical Semifixed Artillery Ammunition

for separate handling of propellant and projectile when these units are of such size that a fixed round would be excessively unwieldy. This construction permits either separate manual loading and ramming of the projectile and case, or placement of the case behind the projectile on a loading tray and insertion of both into the gun by one stroke of a powered mechanical rammer. Breech closure re-

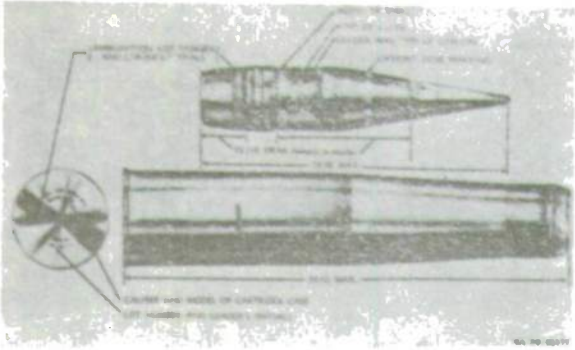


Figure 3-5. Typical Separated Artillery Ammunition

quirements are essentially similar to those for fixed ammunition.

3-3.4 Separate Loading Ammunition (see Figure 3-6)

This term denotes ammunition of which each round consists of a projectile, propellant in one or more bags, and a small metal-cased primer, all separately inserted into the gun. This type of ammunition is used where size and weight of the components precludes use of a fixed round. For breech loading, the closure must open for insertion of the ammunition components, and provide a gas-tight seal when closed. Necessity for removal of a large metallic cartridge case is obviated, but provision must be made for insertion and support of the primer, and removal of its case after firing.

3-4 Classification by Shape of Bore

Guns may be classified according to the shape of the bore, as (a) *cylindrical bore* or (b) *tapered bore (including squeeze and choke bores)*. Most military guns fall into the first category.

3-4.1 Cylindrical Bore

This classification includes those bores of basically circular cross section having the same size at all cross sections from the chamber to the muzzle. (The size and contour of the chamber are not considered.) Longitudinal grooves for control of projectile rotation are disregarded; hence, the cylin-

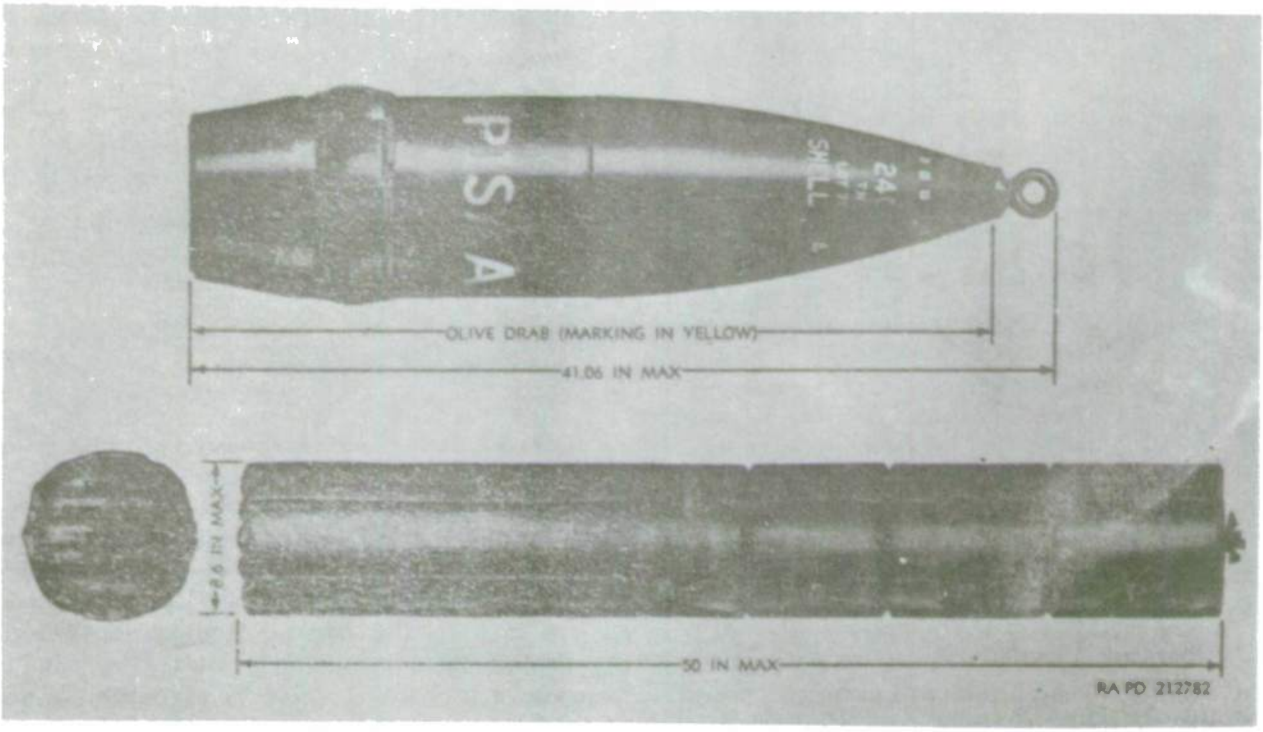


Figure 3-6. Typical Separate Loading Artillery Ammunition (Primer Not Shown)

drical bore classification is considered to include both smooth bores and rifled bores. At present, all U. S. Army standard guns using bore-fitting projectiles are of the cylindrical-bore type.

3-4.2 Tapered (Squeeze) and Choke Bores

These terms designate guns in which the bores are tapered in the whole or some portion of their length. The tapered portion may be intermediate between two cylindrical sections of unequal diameter. Such bores may be smooth or rifled, or part rifled and part smooth.

3-4.2.1 Tapered (Squeeze) Bore

This term is used to denote a bore incorporating a taper designed to reduce the diameter of a bore-fitting projectile as the latter passes through from breech to muzzle. This form of bore has made a favorable showing in some aspects of performance in experimental high velocity guns. For a given diameter of projectile as expelled from the muzzle, a greater area of projectile is acted upon by the propellant pressure through the earlier part of travel through the bore.

3-4.2.2 Choke Bore

The term is commonly applied to shotguns in which the bore is cylindrical except that, in a short portion near the muzzle, the diameter is slightly reduced by taper (choked) to lessen the lateral spread of the group of pellets after they have left the bore. Commercially, the degree of choke is measured by the percentage of pellets of a standard load striking within a 30-inch diameter circle at a range of 40 yards, and denoted as follows:

Full choke 65% to 75%
Improved modified 55% to 65%
Modified (1/4 choke) 45% to 55%
Improved cylinder 35% to 45%

3-4.3 Classification by Surface of Bore

Categories under this classification are (a) *smooth bore* and (b) *rifled bore*. The latter category includes the majority of military guns (see also par. 4-3.3).

3-4.3.1 Smooth Bore

This term denotes a bore that is without grooves, lands, or other contour intended to produce or control rotation of the projectile. Smooth bores, replaced for decades by rifled bores, except in shotguns, mortars and certain signal-projecting devices, have been used in a number of experimental high velocity guns for projectiles incorporating fins for stabilization in flight.

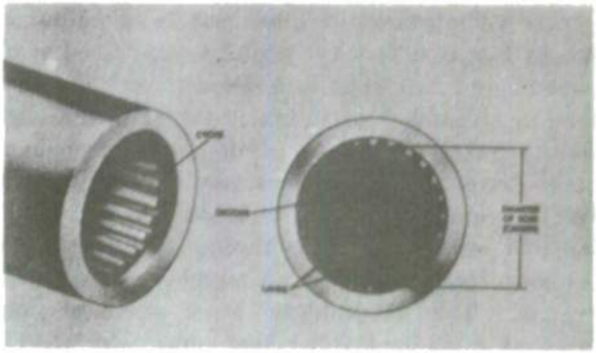


Figure 3-7. Rifled Bore (Muzzle)

3-4.3.2 Rifled Bore

This type of bore, used in the great majority of recent cannon and small arms, is characterized by grooves cut in the bore surface, each groove following a helical path about the axis of the bore, for the purpose of imparting spin to the projectile about its longitudinal axis for stabilization in flight. The helical path of the grooves may be either right-hand or left-hand, and the twist may be uniform or increasing as it approaches the muzzle. Current practice generally employs right-hand twist, which produces a clockwise rotation of the projectile as viewed from the rear (see Figure 3-7).

3-5 Classification by Degree of Propellant Confinement

This means of classification according to degree of propellant confinement, or degree of breech closure, is used to distinguish recoilless (open-breech closure) guns from the more conventional (closed breech) guns.

3-5.1 Open-breech Closures (Recoilless)

The open type of breech closure is employed on recoilless weapons. In these weapons a controlled rearward discharge of propellant gases is employed to give the gun a forward impulse opposing the rearward recoil impulse incurred in discharge of the projectile, and so to virtually eliminate transmission of recoil forces to the gun mount. A typical recoilless rifle (see Figures 2-7 and 3-16) uses fixed ammunition with a perforated cartridge case

having a nonperforated liner (see bottom illustration of Figure 3-2). The round is supported at its forward and rear ends in alignment with the tube bore, in a chamber considerably larger in diameter than the case. On firing a portion of the propellant gas is driven through the perforations of the case. into the annular space between the case and chamber side wall, and thence through orifices in the chamber rear wall to the atmosphere behind the weapon. The breechblock is a sectored and threaded cylindrical plug that closes the central cartridge insertion opening in the rear of the chamber and blocks rearward movement of the case. It houses the firing pin in a central bore and carries the immediately related firing mechanism parts. The breechblock is supported in an arm hinged to lugs on the exterior of the chamber forging and is swung rearward and away from the gun axis in opening. An extractor hook carried in one side of the block extracts the case as the breech is opened. The clearance channels in breechblock and chamber are contoured to form gas discharge vents when the breech is closed and locked. The vents are inclined slightly from a normal through the rear wall, so the reaction from the discharged gases will counteract the rotating force exerted on the rifled tube by the moving projectile. Opening and closing of the breech is accomplished manually by means of an operating lever fulcrumed at the breechblock hinge pin and suitably linked through the breechblock supporting arm to effect rotation and swinging motions of the breechblock in the proper sequence. An alternative arrangement for recoilless operation utilizes a chamber fitting the cartridge case throughout its length, rearward discharge of the necessary portion of the propellant gases being effected through the base of the cartridge and a nozzle centrally located in the gun breech.

3-5.2 Closed Breech

In order to impart to the projectile the greatest possible kinetic energy from a given charge of propellant, it is usual practice to provide for complete closure of the breech of the gun, so as to confine the hot propellant gases behind the projectile until the latter is expelled. Various means and methods are employed for breech closure, in accordance with the functioning and operating characteristics required. Closures are either permanent or mobile.

3-5.2.1 Permanent Closures

A permanent or fixed closure is a structurally closed breech that remains closed throughout gun operation, though it may be removable for maintenance or repair. It may be obtained by securing a plug or cap in or on the rear end of the bored tube. The round of ammunition is necessarily inserted through the muzzle. In present practice, a percussion primer is fixed in the round, and a forward projecting pin or stud is supported in the breech structure, aligned with the primer. The pin may be fixed, in which case the primer is initiated by impact when the round drops to the breech (drop fire); or the pin may be retractable, spring driven, trigger- or lever-operated, to permit a time interval between loading and firing. In some experimental weapons, a spring-actuated pin with a locking device provides an option between drop firing and lever firing. Some early designs used a small vent hole for ignition by fuse or heated rod. Formerly widely used, permanent closures at present appear in only relatively small muzzle loading smooth-bore mortars, for use with the noncased type of semifixed ammunition.

3-5.2.2. Mobile Closures

The numerous advantages of breech loading induce the use of a movable closure, i.e., one operable to close for containment of pressure while the round is fired and to open for removal of any residual ammunition components and insertion of the next round. The mechanism for opening and closing, termed the breech mechanism, is considered to include any necessary cartridge case extraction mechanism and firing mechanism. While a wide variety of mechanisms have been devised for closure and the related functions, the majority may be appropriately considered as employing either of two types of action: one in which the closing or opening is accomplished principally by moving the closing member forward to or into the chamber opening; or one in which closing or opening is effected principally by moving the closing member at right angles to the chamber axis, to cover or uncover the chamber opening. For either of these methods, the closure is usually supported on a major gun component known as the *breech ring* (cannon) or the *receiver* (small arms). These terms denote a principal unit of gun construction that is joined to the rear of the tube or barrel for

Figure 3-8. Plug-type Cannon Breech Closure—Stepped Thread, Horizontal Swing

support or housing of the closure and other parts of the breech mechanism. The term breech ring is commonly used in reference to nonautomatic cannon, while receiver applies to the corresponding part in automatic cannon, in machine guns, and in most types of small arms. The member usually serves also as a principal or supplementary support of the tube or barrel in its mount or stock, and in some cases reinforces the tube wall about the chamber against internal radial pressure. The common feature of all types is a bore or socket to receive the tube; otherwise the shape varies widely, in accordance with the purposes served and the design of the mechanism supported.,

Mobile closures may be classified into types as (a) plug, (b) bolt, (c) sliding breechblock, and (d) eccentric screw.

3-5.2.2.1 Plug-type Breechblock Closures (see Figure 3-8)

This type is often called the *interrupted screw* or the *slotted screw* type. Closures incorporating plug-type breechblocks are applied to cannon employing separate loading ammunition. In this type an opening (breech recess) is formed in the tube at the rear of the chamber, or partly in the tube and partly in the breech ring, for ammunition insertion. The opening is closed by a closely fitting plug, which is carried axially (or nearly so) to a nearly seated position, then rotated to complete the closure. The rotation engages mating interrupted threads on the plug and within the recess to seat the plug and retain it in position against the pressure developed by the propellant.

3-5.2.2.1.1 Obturation

Gas leakage past the plug is prevented, in current designs, by an obturator, consisting of a resilient circular pad (gas check pad) mounted between the flat front face of the plug and the head of a mushroom-shaped obturator spindle whose stem extends rearward, slidably supported in an axial bore in the plug. Propellant gas pressure forces the head of the spindle rearward, compressing the pad against the nose of the plug and thereby forcing the pad to expand radially against the inner surface of the tube. The peripheral sealing surface of the pad is protected at the front and rear edges by steel expanding rings.

3-5.2.2.1.2 Locking Arrangement

To obtain sufficient strength in the breechblock threads to withstand propellant pressure, to avoid excessive size and weight of the breechblock, and to minimize the motion required to seat the block, an interrupted, or sectored, thread is employed. That is, the exterior of the breechblock and the interior of the breech (breech recess) are formed with equal numbers of threaded arcs alternating with longitudinal clearance channels. Alignment of the threaded arcs of the breechblock with the clearance channels in the recess permits insertion or withdrawal of the breechblock by simple forward or rearward movement and locking or unlocking by rotation through a fraction of one turn to engage or disengage the threaded areas. Loss of strength incurred by lack of threads in the clearance channels is compensated by increased length or increased diameter of the threaded area of the breechblock. In the Bofors breechblock increased threaded area has been obtained by making the breechblock markedly larger at the rear and giving it a conical or ogival taper forward. This construction presents an advantage in reduction of the straight line retraction needed before the breechblock can be swung out of the recess on a pivoted carrier. However, recent practice favors the Welin or stepped-thread type of construction (Figure 3-8), in which the radii of breechblock and recess cross sections are increased in a series of steps in successive sectors, each series being repeated an equal number of times in the circumference of both members. In each series, all breechblock sectors are threaded except the one of smallest radius, which is small enough to clear the smallest radius sector of the recess; and all recess sectors are threaded except the one of largest radius, which is large enough to clear the largest radius sector of the breechblock.

The increment of radius between threaded steps is such that each threaded sector of the breechblock will engage a corresponding sector in the process, but has clearance in the adjacent sector; hence, rotation of the breechblock through an angle equal to one sector serves to lock it, or disengage it for withdrawal. Thus, on a breechblock having three stepped sectors (two-threaded) in each quadrant, nearly two-thirds of the circumference is threaded, and rotation of slightly more than 30 degrees is needed to lock or unlock.

3-5.2.2.1.3 Ignition

In current weapons with plug-type closures, ignition of the propellant is effected by use of a cannon primer, resembling in appearance a small arms blank cartridge, and which is chambered in the rear portion of an axial bore piercing the obturator spindle. The primer, when fired, discharges hot gases through the spindle into the gun chamber. The primer is fired by either a percussion mechanism, an electrical circuit, or a combined arrangement enabling use of either percussion or electrical firing. (Electrically fired primers are fired by heat generated in a resistive conductor element within the case when an electric current is passed through it. Percussion primers are fired by a sharp blow of a firing pin on a primer cup containing a sensitive mixture, the mixture being thereby crushed against a firm metal face termed the anvil.) Firing mechanisms, or firing locks, used for insertion, rear support, firing and removal of the primer cartridge case after firing include screw- and sliding-block or sliding-wedge types as follows:

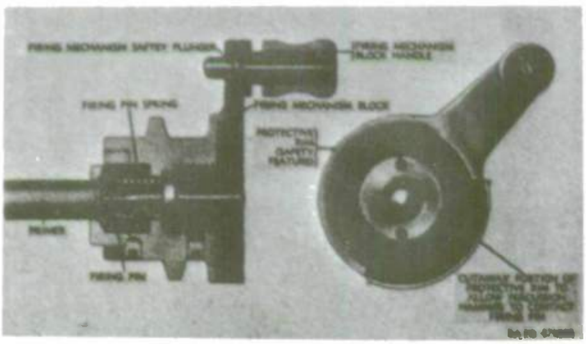


Figure 3-9. Percussion Firing Mechanism for Cannon, Screw-type

(a) The screw-type firing mechanism (see Figure 3-9) includes an externally threaded cylindrical firing mechanism block, having a socket holder at the forward end to support the base of the primer case, and a firing pin behind the socket. The block is seated in a threaded recess in the rear of the breechblock. To load, the firing mechanism block is unscrewed and removed manually from the breechblock (a radial arm with knob facilitates the operation), and the primer is inserted into the holder of the firing mechanism block. Then the block and primer are inserted into the breechblock as a unit, thus seating the primer in its chamber. The block latches when fully screwed in. Firing is effected by a pull on a lanyard attached to a hammer pivoted on a bracket on the breechblock, the hammer striking the firing pin to drive it against the primer. The firing mechanism block is again removed, thus withdrawing the attached primer case, and the empty case is manually removed from the socket. Suitable interlocks prevent insertion or removal of the firing block, or impact of the hammer on the firing pin, while the gun breechblock is not fully closed or locked.

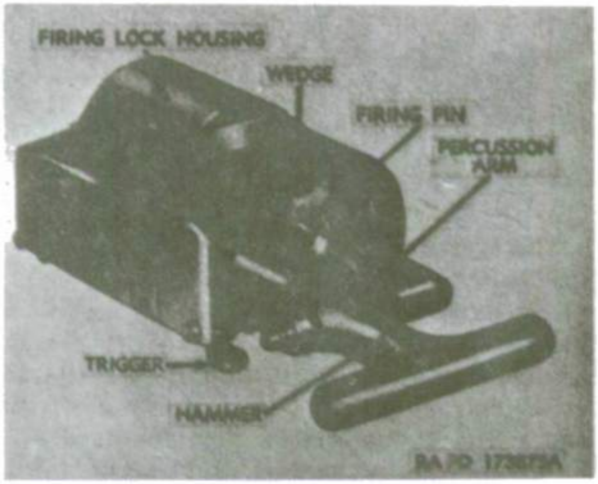


Figure 3-10. Cannon Firing Lock, Electric or Percussion Ignition, Sliding-wedge Type

(b) One sliding-block type of firing lock is shown in Figure 3-10 and consists of a small sliding-wedge mechanism attached to the rear of the gun breechblock. Its housing provides a longitudinal opening for insertion and withdrawal of the primer and supports a sliding block, which is moved trans-

versely (horizontally or vertically) to cover and uncover the primer chamber opening. The block is operated manually, by suitably connected knob, handle, rod, or lever, and on opening actuates an extractor lever to withdraw the primer case. Percussion firing is effected by a firing pin carried in the block, actuated by a spring-impelled striker controlled by a sear and trigger mechanism manually cocked. For electric firing, insulated conductors and contacts are incorporated to provide an electrical path through the firing pin, also insulated, to the primer. Firing is effected by closing the electrical circuit; hence, cocking of the striker is omitted, and the firing pin is moved into contact with the primer without significant impact. In older designs, for use of combined electric and friction primers having a protruding, insulated, friction wire with bare terminal button, the striker is omitted from the design, and a firing leaf incorporated. The leaf is a pivoted plate actuated by a lanyard and incorporates a slot and insulated clip to accept the covered wire and its bare terminal button, respectively. For friction ignition, a pull on the lanyard rotates the plate to pull the friction wire and so ignite the primer. For electric firing a conductor is plugged into the insulated clip and connected to a power source through a circuit breaker. Ignition is effected by closing the circuit.

3-5.2.2.1.4 Operating Mechanism

In cannon of recent design, the interrupted-thread (plug) breechblock is mounted on the carrier (see Figure 3-8), a combined housing and support member hinge-connected to exterior lugs of the breech ring in such a manner as to swing the breechblock rearward out of the breech. The type shown uses a horizontal swing. Some types employ a vertical swing. The breechblock support comprises a hollow cylindrical stud projecting from the carrier into the rear of the axial bore of the block. A lateral shaft supported in the carrier carries a crank and crosshead at its inner end to rotate the breechblock to locked and unlocked positions. An operating lever attached to the outer end of the shaft provides for manual rotation of the shaft, and for swinging the carrier to open and closed positions. In some designs separate handles are provided for swinging the carrier, and the operating lever is used only to lock and unlock the breechblock. A spring-loaded counterbalance mechanism is crank-connected to reduce the manual effort needed to swing the carrier, and the crank passes over center to secure the carrier in open position. Various interlocks are provided to insure that the breechblock is rotated to the correct unlocked position before the carrier starts its opening swing, that the breechblock is secured against rotation until it is again carried into the recess to proper depth for meshing the locking threads, and that the firing mechanism can operate only while the breechblock is closed and locked.

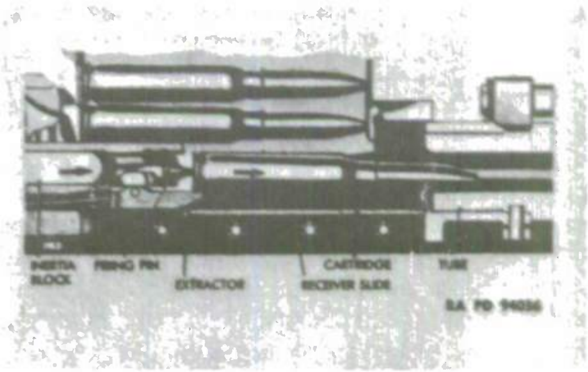


Figure 3-11. Bolt-type Breech Closure (Automatic Gun), Bolt Closing to Chamber the Cartridge

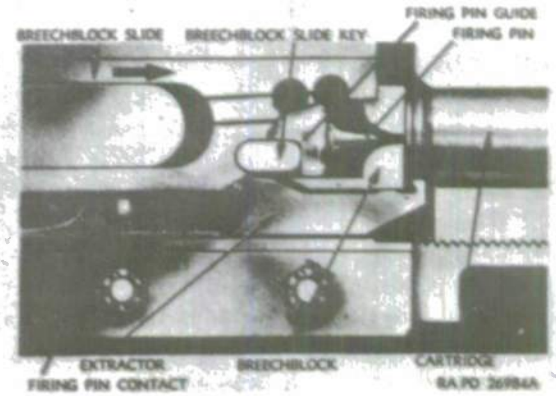


Figure 3-12. Bolt-type Breech Closure (Automatic Gun), Bolt Nearing Closed (Firing) Position

3-5.2.2.2 Bolt-type Breechblock Closures

Bolt-type closures are widely used on small arms rifles, machine guns, and on automatic cannon of small bore diameter. Fixed ammunition is employed. In this type (see Figures 3-11, 3-12 and 3-13), the opening and closing of the breech is effected principally through rearward and forward

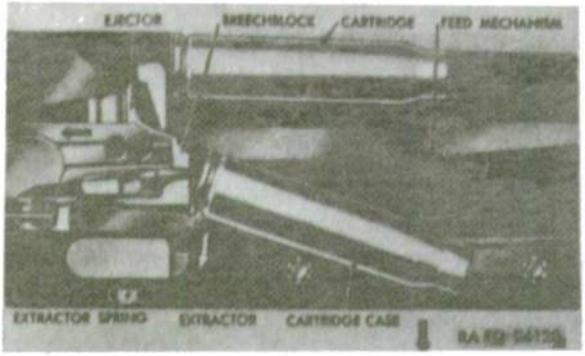


Figure 3-13. Bolt-type Breech Closure (Automatic Gun), Nearing Full Opening, Ejecting Fired Case

movement (parallel with the gun bore) of the bolt, a sliding component variously shaped, but generally elongated in the direction of motion. At closed position, the bolt blocks, but does not seal, the rear opening of the chamber; to open, it is moved rearward sufficiently for extraction of the fired case and insertion of the next cartridge. Forward movement then seats the cartridge in the chamber. Obturation is provided by expansion of the cartridge case against the chamber wall by propellant pressure. Movement of the bolt is guided and confined by a housing and support component termed the receiver. Percussion firing of the cartridge is effected by a firing pin carried within the bolt and actuated by a spring or spring-loaded hammer, controlled by manually operated sear-and-trigger mechanism, or automatically released; or by inertia of the pin (and other weights sliding with it) as the bolt is stopped at the end of forward travel. Electrically primed cartridges are fired by the closing of an electrical circuit that includes an insulated firing pin. Where used, the firing spring is compressed by the movement of the bolt, a typical arrangement comprising a cocking lever pivoted on the bolt and actuated by a cam surface in the receiver. Withdrawal of the fired case is effected by an extractor (hook or equivalent rim) on the bolt front end, which engages the rim or groove at the base of the cartridge case to draw the case as the bolt moves rearward. Ejection of the empty case is accomplished in some automatic mechanisms by lateral displacement by the incoming cartridge; in other designs a spring-loaded ejector lever on the bolt or in the receiver presses or strikes the base of the cartridge off center to tilt the case free from the grip of the extractor and throw it from the receiver as the bolt moves rearward. Bolts may be classified as *nonlocking, locking,* or *delayed action,* in accordance with the method of operation.

3.5.2.2.2.1 Nonlocking Bolts (Blowback)

While not widely applied, bolts that do not lock in the closed position have functioned reasonably satisfactorily in some automatic and semiautomatic weapons using relatively low power ammunition. In this method, the rearward pressure of the propellant on the cartridge case impels the bolt through its rearward travel, but the weight of the bolt is such that inertia delays the movement so that the projectile has left the gun muzzle before the breech is unsealed. In its rearward movement the bolt compresses a spring that returns the bolt to closed position to complete the cycle. To interrupt the firing, release of the trigger permits a sear to retain the bolt in retracted position.

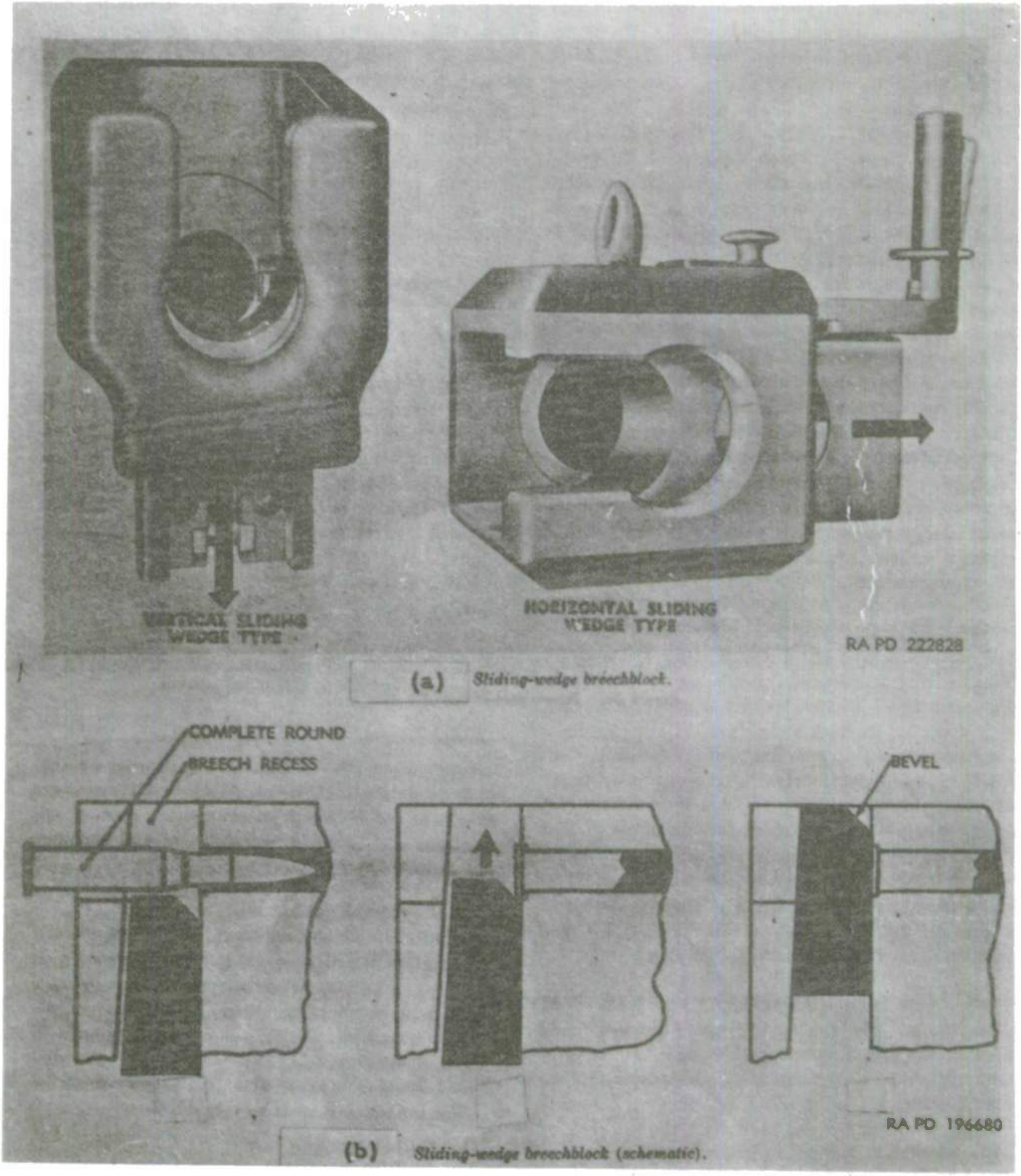
3-5.2.2.2.2 Locking Bolts

Bolts are locked in position by various means. Typical methods used include: rotation of the bolt through a small angle as it completes forward travel, to engage corresponding lugs, or lugs and grooves, on and in the bolt and receiver; tilting of a member hinged to the bolt, to engage a recess in the receiver as the bolt reaches closed position; lateral or vertical movement of a bar carried in a rearward extension member attached to the barrel, to engage a recess in the bolt; and slight tilting of the barrel to effect engagement of ribs on the rear end of the barrel with grooves in a forward extension of the bolt.

3-5.2.2.2.3 Delayed Action (Hesitation) Bolts

Not in current use in U. S. Army weapons, the delayed action bolt lock was formerly employed in some automatic weapons to prevent excessive rapidity of fire. These arrangements provide no positive lock of the closure; they permit the bolt to be moved rearward by propellant pressure, but delay the movement by forcing the pressure to overcome a mechanical disadvantage other than inertia. Delayed action bolts include:

(a) *Crank-type.* The bolt is linked by a connecting rod to a crank pivoted in the receiver, so that reciprocating movement of the bolt produces oscillation of the crank. At closed bolt position,



(a) *Sliding-wedge breechblock.*

(b) *Sliding-wedge breechblock (schematic).*

Figure 3-14. Typical Sliding-block Breech Closure, Cannon

the crank arm and connecting rod are nearly aligned, so that rearward pressure on the bolt produces a very small rotational component of force at the crank pin and initial rearward movement of the bolt is impeded.

(b) *Rolling-contact-type.* This is a modification of the crank-type, in which the end of the crank arm and the crank end of the connecting rod are rounded abutting surfaces held in contact by an additional link. The effect of this modification is to retard the increase of the rotational component of force on the crank arm during the initial stage of rotation, and so to produce a greater delay than the simple crank device.

(c) *Inclined-contact- or wedge-type.* In closed position, the bolt and receiver (or barrel) are connected by mating interrupted threads, or by a transverse sliding bar, with the engaged surfaces inclined at such an angle that a positive lock is not obtained. When the propellant pressure acts on the bolt, rearward movement is impeded until the small component of force parallel to the inclined surfaces rotates or slides the opposing members out of engagement.

3-5.2.2.3 Sliding Breechblock Closures

This term, through custom, applies to those designs in which opening and closing of the breech is accomplished principally by movement of a block in a direction normal to the axis of the chamber; i.e., across the face of the opening. Sliding breechblock types in service to the present provide no gas seal, obturation being effected by use of a cartridge case. Movement of the breechblock is guided by suitable slide surfaces in the supporting breech ring or receiver. Generally the bearing surfaces are inclined slightly to obtain a wedging action to ensure full seating of the cartridge, hence, this type of closure is often called *sliding wedge.*

3-5.2.2.3.1 Cannon Applications (see Figure 3-14)

In cannon, the typical sliding closure consists of a block (wedge) of roughly rectangular outline, which slides in a corresponding recess through the rear portion of the breech ring. The motion may be horizontal or vertical; however, the vertical, or drop block, arrangement is currently more generally used. Mating ribs and grooves on the block and within the breech ring recess are inclined slightly to wedge the cartridge forward into the chamber as the block moves to closed position, and the front edge of the leading end of the block (when closing) is beveled to push forward an incompletely inserted cartridge. This end of the block is also cylindrically grooved from front to rear to provide a guiding trough for the entering cartridge. A central bore in the block houses the firing pin (usually percussion type) and its immediate controlling mechanism. The artillery primer, as this type primer is called, is permanently inserted into the cartridge case at the loading plant and requires no separate action for insertion or removal at the gun.

Extractor levers pivoted or fulcrum-mounted in the breech ring recess are actuated through their integral follower lugs, which bear slidably in inclined camming grooves in the breechblock. Where closing is accomplished by spring action, the extractor lugs engage offset seats at the ends of the cam grooves to lock the breechblock in open position. Unlocking is then accomplished by insertion of the next cartridge, its rim striking the extractors to unseat the follower lugs and restore them to the camming groove. Motion of the breechblock is customarily effected by partial rotation of an operating shaft carrying the breechblock crank whose crank pin slides in an inclined slot on the breechblock to slide it in opening and closing travel.

3-5.2.2.3.2 Small Arms Applications

Applications of the transversely sliding breechblock principle in present Army small arms are limited to revolver-type mechanisms. Former applications, U. S. and other, military and commercial, include the following:

(a) *Drop Block*

A closure in which the breechblock slides upward to close, downward to open, guided by grooves in opposite sides of the receiver and actuated by suitable linkage connecting to an operating lever beneath the receiver. The lever handle is shaped to form a trigger guard. Typically, a spring-loaded pivoted hammer is released by the trigger to strike a firing pin carried in the breechblock.

(b) *Rolling Block*

The block swings rearward and downward about a transverse pivot below the chamber to open the breech.

(c) *Rising Block*

A closure in which the block is pivoted on pins at the sides of the barrel, forward from the breech face, and is swung upward and forward to expose the chamber opening.

(d) *Falling Block*

A closure in which the block is pivoted rearward from the breech face and is swung downward to open the breech.

(e) *Standing Breech, Hinged Frame*

This arrangement, used on some commercial designs of revolvers and shotguns and in military pyrotechnic pistols, presents a breechblock face formed as a fixed part of the gun frame, to which the barrel is hinged on a transverse pivot forward of and below the chamber. Opening is effected by manual release of a securing latch or bar, and swinging the rear end of the barrel upward. A percussion firing pin is carried in the breechblock, and the frame houses the hammer, trigger and remaining parts of the firing mechanism. Typically, the swinging of the barrel to open automatically actuates an extractor to partially withdraw the cartridge case(s) from the chamber(s).

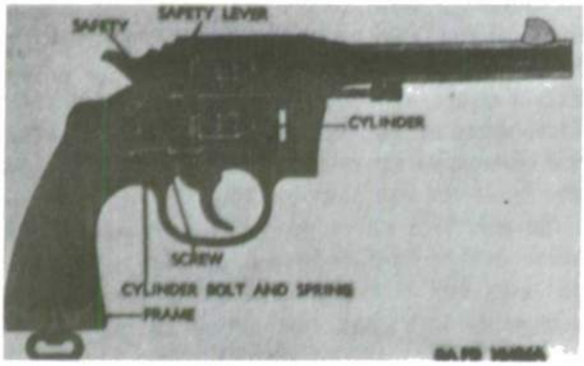


Figure 3-15. Typical Revolver, in Section, Cartridges Chambered in Cylinder

(f) *Standing Breech, Solid Frame*

In this construction (see Figure 3-15), used in commercial revolvers and formerly in military revolvers, the breechblock face is formed as a fixed part of the gun frame, and the barrel is rigidly mounted ahead of the breechblock face, with sufficient intervening space to receive the cylinder. The latter contains six chambers, equally spaced about the longitudinal axis, which is positioned below and parallel to the bore of the barrel, so that

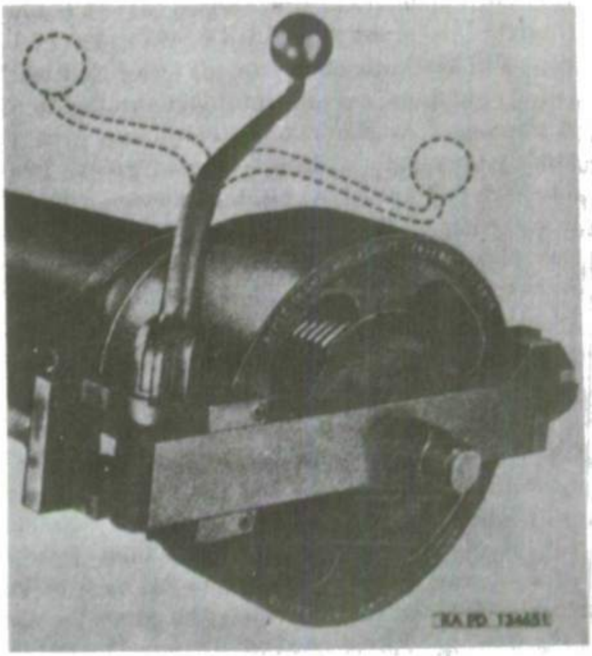


Figure 3-16. Typical Recoilless Rifle Breech, Breechblock Locking Threads Partly Engaged

on rotation of the cylinder each chamber is successively aligned between the breechblock face (with firing pin) and the barrel. The frame houses a spring-driven hammer and suitable mechanism for rotating the cylinder and locking it in successive positions to fire the cartridge in each chamber, all actuated by pull and release of the trigger. The pivot on which the cylinder rotates is hinge-mounted on the frame, and breech opening is effected by swinging the cylinder sideward and downward parallel to the breechblock face, to expose the breech ends of the chambers. Except for close positioning of the parts, no antileak provision is incorporated between the rear end of the barrel and the forward end of the aligned chamber, and the resulting loss of a fraction of the propellant bases at the unsealed junction necessitates use of relatively low power cartridges to avoid severe erosion of metal at the junction and escape of gases and unconsumed particles of propellant at excessively high temperature.

3-5.2.2.4 Eccentric Screw Closures (Nordenfeld)

This type of closure, little used at present and applicable only to cannon of relatively small bore diameter employing fixed ammunition, incorporates

a threaded cylindrical breechblock screwed into a cylindrical, internally threaded recess in the breech ring. The block diameter exceeds twice that of the chamber, and its axis of rotation, parallel to the chamber axis, is below the circumference of the chamber opening. A deep U-shaped groove is cut from back to front of the block to provide a channel for insertion of the ammunition. Rotation of the block through approximately ½ revolution then covers the base of the cartridge, the pitch of thread advancing the block to fully seat the cartridge. At the closed position the percussion firing pin, housed in the breechblock diametrically opposite the loading channel, is in line with the chamber axis, in position to strike the primer when driven by the firing hammer. When the reverse rotation is applied to open the breech, a forked extractor lever, pivot-supported in the breech ring, is actuated by a cam groove in the forward face of the breechblock to extract and eject the cartridge case as the loading channel reaches alignment with the chamber.

The large size and weight of the breechblock and breech ring necessary for this type of closure is an unfavorable factor where space and weight limitations are important.

3-6 Classification by Degree of Self Action

Guns may be classified in this manner as (a) *manual,* (b) *automatic,* and (c) *semiautomatic.*

3-6.1 Manual

This term indicates a type of gun in which the energy required to operate the breech mechanism through the movements necessary for loading, closing, firing, opening and case ejection is supplied by the operator. If the mechanism is designed for insertion of multiple rounds and successive feeding, positioning and firing of these rounds by manual operation of the mechanism, the weapon is termed a *repeating* type; if each successive round must be manually inserted into the mechanism after the previous one has been fired, the weapon is termed a *single shot* type.

3-6.2 Automatic

The term applies to firearms in which the mechanism, after firing is initiated by the operator, extracts or is fed successive rounds from a belt, hopper, or other suitable source, and continues to fire until stopped by manipulation of a control device by the operator or by failure of the ammunition supply. The energy for operating the mechanism to eject the empty case and insert and fire each successive round is derived from the firing of the preceding round. Preliminary insertion of the first round and cocking of the mechanism to fire the first round are accomplished by moving the mechanism through a portion of its cycle by hand or other outside power. The term automatic is sometimes erroneously applied to firearms that are not fully automatic; e.g., those requiring a manual trigger pull to fire each round, the remaining portion of the cycle being automatic.

3-6.3 Semiautomatic

This term is somewhat loosely applied to guns in which some portions of the cycle of insertion of ammunition, closing, firing, opening, and ejection of fired cases are automatically accomplished, and the remainder are performed manually or by external power manually controlled. In the field of small arms and cannon of relatively small bore, the term semiautomatic generally indicates that the mechanism, on firing a round, operates automatically through the functions of opening, ejection and insertion of the succeeding round, but does not fire the latter round unless the trigger or other firing control is again manipulated by the operator. In reference to cannon in general, the term may indicate automatic functioning through some smaller portion of the complete cycle. A typical example is the medium caliber gun with vertically sliding breechblock, in which breech opening, ejection of the case, and cocking of the firing mechanism is accomplished through cam action during counter-recoil movement of the cannon. The breech then remains open (locked by the extractors) but closes automatically when a round is inserted into the chamber with sufficient force to strike and unlock the extractors. The firing mechanism remains cocked after the breech closes and is released to fire the round only by separate action of the operator.

3-7 Classification by Source of Power Operation

Such classes include (a) *externally powered,* (b) *gas operation,* (c) *recoil operation,* and (d) *blowback.*

3-7.1 Externally Powered

This classification comprises guns in which mechanical or electric power is used to operate the breech mechanism through all or a portion of the loading, closing, firing, opening, and ejection cycle, the power being from a source other than the propellant used to discharge the projectile. The principal use of external power in recent practice has been to attain rapidity of firing not possible with propellant powered operation. By application of powered mechanism for feeding, fuze setting, ramming (chambering the ammunition), breech opening, etc., operation of the weapon may be as completely mechanized as the intended use may justify. In some uses, such as in tanks or aircraft, more efficient operation may be effected by application of external power to one or more phases of operation than by dependence on propellant-powered mechanism alone.

3-7.2 Gas Operation

This method, employed in automatic rifles, semiautomatic rifles, carbines and for unlocking 20mm automatic guns, consists of diversion of a minor quantity of propellant gas from the bore of the tube into a suitable small cylinder, where it drives a piston connected to the breech mechanism to accomplish the desired operation. In the rifle and carbine this action unlocks the bolt and drives it rearward to withdraw and eject the fired case and compress a spring which returns the bolt to closed position. After the bolt reaches its rearmost position, the next cartridge is pushed into a position ahead of the bolt. The bolt, when it moves forward, drives the cartridge into the chamber and rotates itself by cam action to lock the closure. The weapon is then ready to fire.

3-7.3 Recoil Operation

This method, employed in machine guns, semiautomatic pistols and shotguns and in the opening of sliding breechblock cannon, utilizes the recoil and counterrecoil movement of the gun, or parts thereof, relative to nonrecoiling parts, to operate the breech mechanism. Interaction between the moving and stationary parts to produce the necessary motions is obtained either as the recoiling parts are moving rearward or while the recoiled parts are being restored to the forward position by springs or gas compressed during recoil, or during both movements. Recoil operation is further classified as *short recoil* or *long recoil* according to the relative distance recoiled by the barrel.

3-7.3.1 Short Recoil

This system is widely used in Army machine guns and semiautomatic pistols. In the machine gun application, the barrel, on firing, is permitted to recoil a short distance into the receiver. In the first part of this movement the bolt remains locked to the barrel; in the latter part the bolt is unlocked, the barrel is stopped, and the bolt continues rearward with sufficient momentum to extract the fired cartridge case, withdraw a cartridge from the feed belt, cock the firing mechanism, and compress the driving spring, which returns the bolt forward to closed position. As the bolt moves forward it actuates the belt feed lever to advance the feed belt, operates the extractor to align the cartridge previously withdrawn from the belt and eject the fired case, strikes the rear of the barrel to chamber the cartridge and lock itself thereto, then drives the barrel forward to firing position and releases the firing tube. Breech ring and breech mechanism recoil as a unit in sliding ways in the mount. An interposed recoil mechanism dissipates a portion of the energy of recoil, but stores a sufficient portion (by compression of a spring or confined gas) to return the recoiling unit to its starting (firing) position. A camming device is so located in the stationary mount that, as the recoiled unit moves forward in counterrecoil, the cam engages the operating crank of the breech mechanism and rotates it to slide the breechblock to open position. This movement of the breechblock operates the extractor levers and cocking lever to remove the fired case, recock the firing mechanism, lock the breechlock in open position, and store energy in the breechblock closing spring. The breech is thus left open for insertion of the next round.

3-7.3.2 Long Recoil

In this system the barrel and the breechblock or bolt recoil the entire distance together. The bolt is then held open in the recoiled position as the barrel goes forward a sufficient length of time to permit extraction of the spent case and reloading. The rate of fire is necessarily slow and the method has little application to present military design.

3-7.4 Blowback Operation

The blowback principle, currently used in submachine guns and some automatic guns, derives energy from the pressure of the fired propellant on the cartridge case, causing its rearward projection, to drive the bolt rearward from the barrel. During this rearward movement, the bolt compresses a spring that, on completion of the recoil travel, returns the bolt to the closed and locked (firing) position. The barrel remains fixed in the receiver. The initial rearward movement of the bolt is delayed until propellant pressure in the barrel has dropped to a safe magnitude by inertia of the bolt, by mechanical disadvantage (see Delayed Action Bolts, paragraph 3-5.2.2.2.3), or by a positive lock. In a 20mm gun application (see Figure 3-17), a breechblock lock engages a fixed

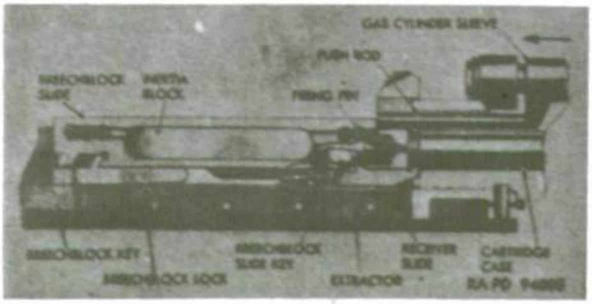


Figure 3-17. Bolt Unlocked to Permit Blowback Opening. (Lock Raised from Engagement with Breechblock Key)

cross member of the receiver (breechblock key) to latch the bolt-type breechblock in closed position. Sliding members in the breechblock (breechblock slides) bar disengaging movement of the lock. When the fired propellant has moved the projectile forward past a small lateral port in the bore, gas passes through the port to drive a piston rearward, this movement being transmitted by push rods to move the breechblock slides rearward and so permit disengagement of the lock. The lock, bearing on the breechblock key at an unfavorable angle, is forced upward out of engagement by rearward pressure of the breechblock, and the latter is then driven rearward by the residual propellant pressure on the cartridge case. In the submachine gun application, a bolt lock is not used, as bolt inertia provides sufficient delay for adequate drop in pressure of the relatively low powered propellant charge used.

3-8 Classification by Type of Feed

Because of variations between cannon and small arms in size and type of ammunition used, and in their current characteristic types of closure and breech operating mechanisms, feeding and loading methods and mechanisms for the two classes are considered separately.

3-8.1 Cannon Feeding Methods

3-8.1.1 Nonautomatic Feeding

Where complete rounds of fixed or semifixed ammunition, or the individual components of separated or separate loading ammunition, are not excessively large or heavy, the entire series of operations necessary to feed the gun successive rounds may be performed manually by the operator or operators, with the aid of hand manipulated tools or accessories where needed. The simplest operation is required to load a round of fixed ammunition, requiring no fuze adjustment, into a gun having a vertically sliding breechblock (Figure 3-14), a procedure consisting of sliding the round forward through the channel in the top of the breechblock and into the chamber with sufficient force to trip the extractors. (The breechblock then rises by spring action and the gun is ready to fire.) Where justified by size and weight of the round, a loading tray or trough carried by gun crew members may be used to transport the round and place it in position behind the breech ring, whence it is pushed into the chamber by a loading rammer in the hands of the gun crew. The hand loading rammer is a straight shaft with a cylindrical head sufficiently concave on the forward face to avoid contacting the cartridge primer. Where separated ammunition is used, the projectile and case are similarly handled in successive operations. Separate loading ammunition requires successive insertion and ramming of the projectile, insertion of bags of propellant, and manual replacement of a fired primer case by an unfired primer in the primer block. If a projectile requiring fuze adjustment is used, the fuze is manually adjusted (using an appropriate wrench) to the proper interval before the projectile is inserted. The closing of the interrupted screw-type breech used with separate loading ammunition is also initiated by manual operation of a lever.

3-8.1.2 Automatic Feeding and Loading

Various powered mechanisms have been devised to obviate or minimize the manual effort required in feeding and loading operations for cannon. Recent designs in service include power operation in: mechanical ramming of the projectile only (for separate loading ammunition), mechanical fuze setting and ramming of the projectile and case (for separated ammunition), and automatically controlled mechanical feeding and ramming of fixed ammunition. The latter combines with the automatic actions of vertically sliding breechblock guns or of bolt-type breech mechanisms to provide continuous overall cycling (automatic firing) or cycling complete except firing (semiautomatic firing). (The continuously cycling weapons should be termed automatic only if power for all the mechanism is derived from the propellant, by recoil, or other means, see paragraph 3-6.2.) General features of typical mechanical feeding, loading or combined devices are as follows:

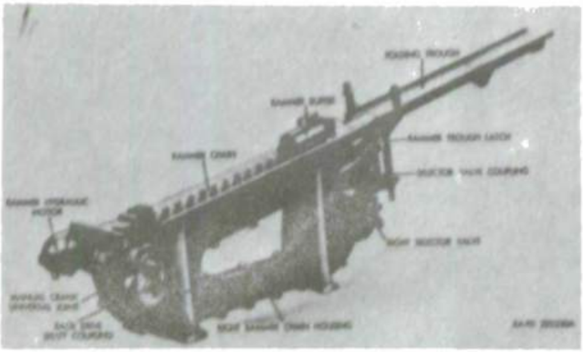


Figure 3-18. Ramming Mechanism, Chain Rammer, Hydraulic Power

3-8.1.2.1 Powered Chain Rammer

A typical arrangement (Figure 3-18) suitable for large bore cannon using separate loading ammunition rams the projectile only. Its principal elements are a chain casing of straight-sided loop profile, with pedestals for fixed mounting, serving as support for the operating parts; a rammer chain with a buffer head, meshed with a sprocket supported in the rear end loop of the casing; a reversible hydraulic motor attached to the chain casing and driving the chain sprocket to push forward, and to retract, the chain and buffer head; a hydraulically operated folding trough hinged to the forward end of the casing to guide the projectile into the chamber; and suitable hydraulic control piping and valves to govern the sequence of extension of trough, advancement and retraction of rammer chain and head, and folding withdrawal of the trough to clear the path of gun recoil. Hydraulic pressure is supplied by the gun elevating system. The upper straight section of the chain casing is open and channeled to guide the rammer chain and head in line with the gun bore; the trough, in unfolded position, forms an extension of the guiding channel. The rammer chain links are so hinged together as to prevent buckling when pushing the head in the straight channel, but to permit meshing with and flexing downward around the sprocket, so that on retraction of the chain, its rear end slides forward in the lower section of the chain casing. The rammer head incorporates a hydrospring-type buffer to reduce shock at the end of the rammer stroke. A system of shaft, clutch, stops and rods connected to the rammer operating mechanism provides for automatic cut-off of ramming force at a preset length of stroke. The ramming and withdrawal strokes are initiated by manipulation of a control handle. For placing heavy projectiles in the trough, a manually operated winch and davit are used. The propellant is manually inserted after the projectile has been rammed.

3-8.1.2.2 Powered Hydraulic-spring Rammer

A typical hydraulic-spring rammer (Figure 3-19) comprises a hydraulic cylinder and piston that

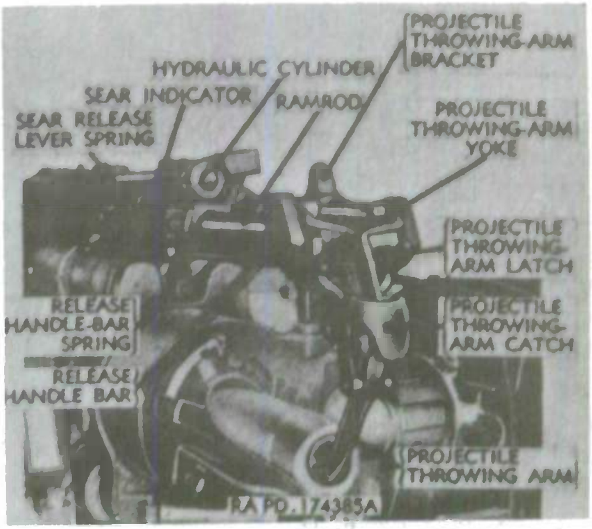


Figure 3-19. Rammer, Hydraulic-spring Type

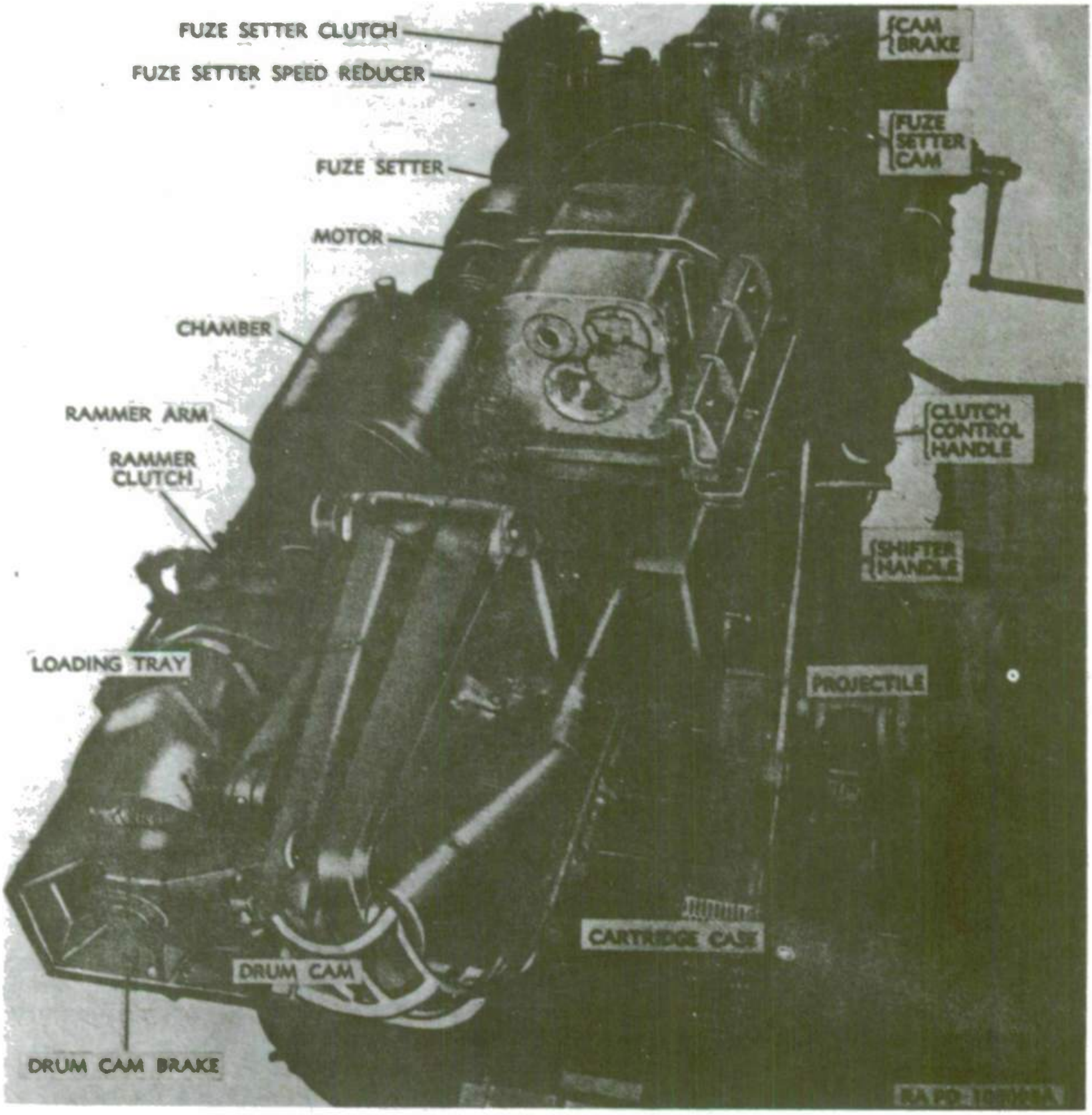


Figure 3-20. Power-Rammer, Arm Type, With Separate Fuze Setter Unit, Single Electric Motor Driving Both Units.

force a ramrod rearward against a spring, which, on release of a sear that engages the extended ramrod, drives the ramrod forward to propel the projectile into the cannon bore. Hydraulic power is provided by an electric motor, hydraulic pump and reservoir tank. The cylinder and ramrod are mounted above the gun breech; the ramrod moves parallel to and above the axis of the bore, carrying on its rear end a rammer head. This head consists principally of a folding arrangement of links, yoke and arm that extended downward terminates in a pad aligned with the gun axis, in position to drive the projectile forward into the bore. Folded, the head clears the space back of the gun breech. In operation, a hand-carried tray is positioned in the breech recess and the projectile placed upon it. One switch is thrown to start the motor-driven pump and a second to open a solenoid-operated valve and admit pressure to the cylinder. The pressure moves the piston, ramrod and folded head rearward to sear engagement. A lever on the head is then operated manually, to unlatch the folded member and extend the projectile-driving arm downward to latched-open position. The sear is then disengaged by hand lever to permit the spring to drive the ramrod and head forward. As the head completes its forward travel, the latch holding the head extended is automatically tripped and the head folds into retracted position. The propelling charge is then inserted by hand.

3-8.1.2.3 Power Rammer and Fuze Setter—Separate Units

An arrangement of this type (Figure 3-20) has been used for inserting the two units of a round of separated ammunition, i.e., a time-fuzed projectile and a cartridge case containing primer and propellant. The rammer and mechanical fuze setter are individual units, each having a speed reducer, clutch and appropriate controls, but driven by a single electric motor, and with control mechanisms interconnected to enable the two units to be operated separately or in combination. A gun of the vertically sliding breechblock type, with rammer and fuze setter units as indicated below, requires manual operations to place the ammunition components on the tray, to engage the fuze setter clutch, and to fire the weapon.

3-8.1.2.3.1 Fuze Setter

The fuze setter housing is mounted above the gun, near the breech, on ways that permit it to slide rearward to encircle the nose of the projectile (held on the rammer tray) for rotation of the time-setting ring on the projectile, then slide forward to free the projectile for alignment with and insertion in the bore by the rammer unit. The rearward and forward movement of the fuze setter is effected by a cam mounted ahead of the fuze setter and operating through an adjustable connecting rod. The cam is rotated by the driving motor, through a speed reducer and clutch, the latter having a combined automatic and manual engaging and disengaging mechanism. On manual engagement of the clutch, the cam is rotated through a half revolution to push the fuze setter rearward, then is automatically disengaged until the projectile fuze has been set. Full entry of the projectile nose into the recess of the fuze setter closes a circuit to energize the fuze setter and so rotate the fuze setter ring in accordance with data received from the director. On completion of the fuze setting, a solenoid automatically operates to effect re-engagement of the cam clutch to rotate the cam a half revolution, then disengagement of the clutch. The cam action withdraws the fuze setter to forward (rest) position, and the clutch disengagement completes the cycle. A brake interlinked with the clutch prevents over-rotation of the cam and holds the fuze setter firmly at each extremity of travel.

3-8.1.2.3.2 Rammer

The essential components for receiving, aligning and ramming the ammunition are a tray supported on trunnions parallel to the gun bore and a surmounted, pivoted rammer arm that sweeps the tray surface. The tray, in its idle position, is approximately level laterally and is situated rearward, above, and to the left of the breech ring of the gun. Its inner edge is bounded by a trough-shaped rim projecting upward, into which the ammunition is laid manually with the projectile placed foremost, against suitable locating stops, where it is held by a spring-loaded hold-down lever. The projectile in this position is behind and in alignment with the fuze setter and is so held until the fuze setter has completed its operation. On its forward withdrawal the fuze setter actuates engagement of the rammer clutch to connect the driving motor,

through the rammer speed reducer, to the tray-operating cam under the tray. A partial revolution of the cam swings the tray sideward and downward about its trunnions to align the projectile with the gun bore. The tray then dwells while the rammer arm, pivoted on the outer front corner of the tray, swings across the tray and sweeps the cartridge, and the projectile ahead of it, forward into the gun chamber. Entry of the cartridge trips the extractors to permit the closing spring to raise the breechblock and to close the breech. The completion of one revolution of the cam then effects return of the rammer arm and tray to starting position, and actuates a linkage to disengage the rammer clutch. A brake and positive lock arrangement prevent over-rotation of the cam and accidental repeat cycling.

3-8.1.2.4 Combined Fuze Setter-Rammer

Another typical example (Figure 3-21) of powered fuze setter-rammer combination (for time-fuzed fixed ammunition) presents a somewhat closer integration of the fuze setting and ramming operations. When applied to a vertically sliding breechblock type of gun, the combination effects automatic operation through the cycle for each round, with manual operation required only to place the round in the feeding trough to slide it forward into engagement between the rammer rollers, and to trip the firing mechanism after the breech closes. A manual fuze setter release arrangement is included to enable use of ammunition not requiring the fuze setting operation, and manual loading is feasible in case of malfunction of the power rammer mechanism.

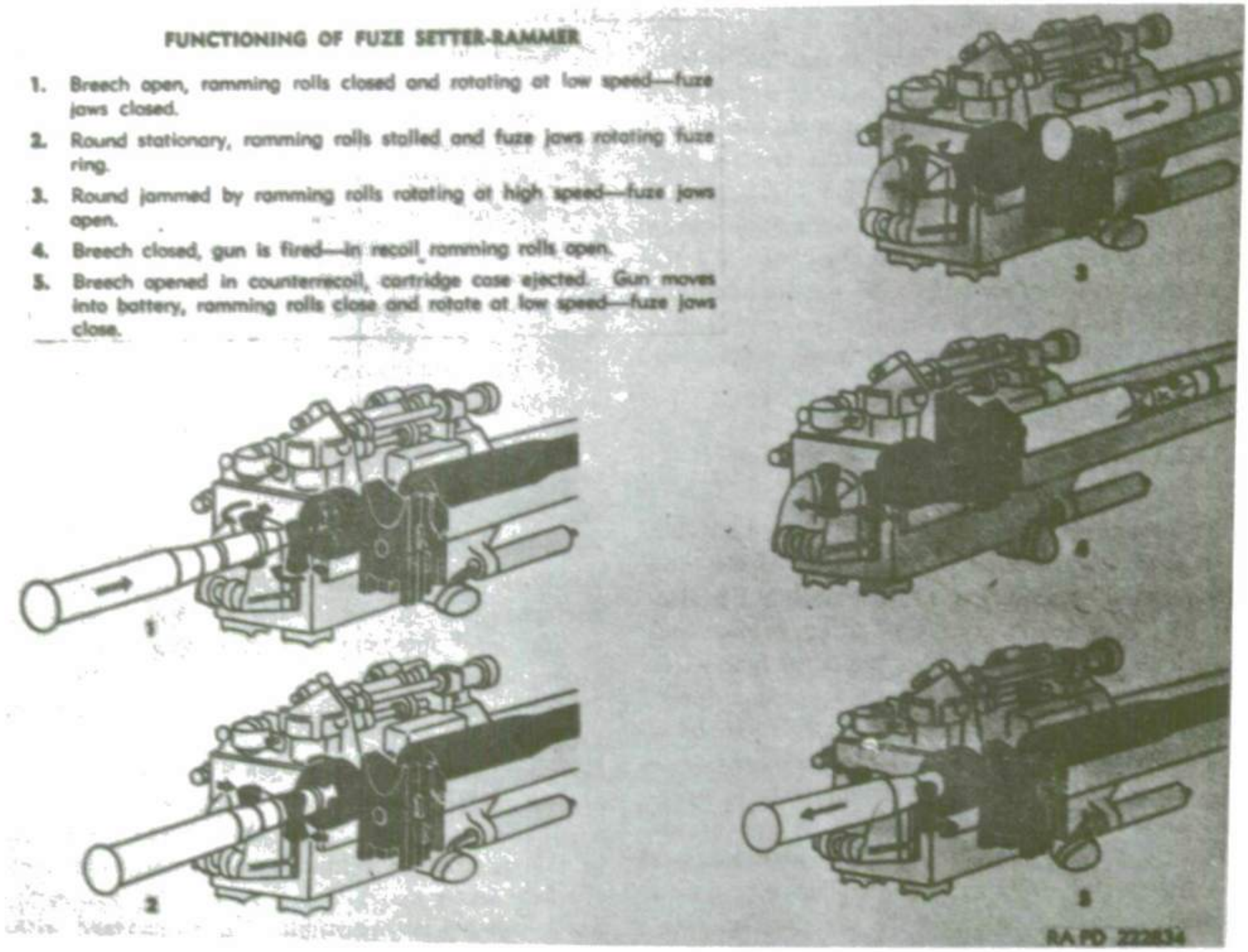


Figure 3-21. Combination Fuze Setter and Rammer (Schematic)

(a) *Arrangement and Functioning*

Power for all mechanical operations is provided by an electric motor, through a transmission case, both mounted above the gun, forward of the breech, on the nonrecoiling recoil cradle. A housing supporting the ammunition-contacting parts of the fuze setter and rammer, final drive gears and shafts, opening and closing devices, operating control rods, and a feeding trough is attached to and partially encloses the breech ring. A drive shaft and control rod for each unit (setting and ramming) extend forward to appropriate connections with the transmission case, the connections being arranged to disengage as the gun recoils and re-engage at completion of counterrecoil. The feeding trough is aligned with the gun bore, sufficiently behind the breech ring to accommodate the fuze setting and ramming operations in the intervening space. The ramming is accomplished by gear-rotated hourglass-shaped rubber rolls, mounted on pivoted arms, on opposite sides of the gun line of bore, immediately forward of the trough. A spring-cushioned plunger linked to the supporting arms governs lateral distance between the rolls, release of the plunger on gun recoil increasing the separation, and depression of the plunger, on the gun's return to battery, narrowing the space to cartridge-gripping distance. The increase of separation provides clearance for fired case ejection. Two automatically shifted speeds of roll rotation are provided: slow for feeding the cartridge into the fuze setter and fast for subsequently propelling it into the chamber. The fuze setter presents, forward of the ramming rolls, a gear-driven ring with internal retractable jaws to seat the nose of the round and rotate the time-fuze ring to the desired setting. The fuze setter and ramming roll drive shafts are connected by a differential mechanism in the transmission case, and the amount of rotation permitted the fuze setter is governed by a data receiver on the side of the case. This unit operates through suitable linkage to disengage a clutch on the fuze-driving transmission shaft when the fuze has been set. Retraction of the fuze setter jaws then provides clearance for the cartridge to pass through the ring into the gun bore. Retraction and closing of the jaws is effected by a rack shaft (control rod) actuated from the fuze setter shaft in the transmission case. The jaws remain retracted (open) from completion of fuze setting until the gun returns to battery after recoil.

(b) *Sequence of Operations*

Starting with the gun breech open and the fuze setter-rammer motor running, the procedure is as follows:

(1) The round is placed manually nose forward on the loading trough and pushed gently forward into the slowly rotating rammer rolls.

(2) The ramming rolls move the round forward to seat the nose firmly in the fuze setter jaws. When the round is seated the rolls are stalled.

(3) Stalling of the rammer rolls actuates operation of the differential in the transmission to produce rotation of the fuze setter drive shaft and set the fuze.

(4) Completion of the fuze setting actuates the fuze jaw retracting rod to open the fuze setting jaws and shifts the rammer rolls into high speed.

(5) The rapidly driven rolls impel the round into the chamber, tripping the extractors, and the breech closes.

(6) The firing control is actuated by hand.

(7) The gun recoils and the ramming rolls open.

(8) The gun returns to battery, opening the breech, ejecting the fired case and cocking the firing mechanism. The final action actuates shift of the rammer rolls to feeding position and slow speed, and the closing of the fuze setter jaws. The gun is then ready for the next round.

3-8.1.2.5 Magazine Type Loader-Rammer

This type (Figure 3-22) of powered feeding device has been developed for vertically sliding breechblock cannon using fixed ammunition. It transfers the round from a previously loaded magazine, rams it into the chamber, and actuates the firing mechanism, requiring only that the operating control be retained in the firing position. A typical design combines a scroll-shaped magazine above and rearward of the gun breech, feeding rounds sideward from either right or left to the center; a centrally located rammer tray, crank supported, that receives each successive round from the magazine, lowers it to alignment with the gun bore, and impels it into the gun by means of an endless chain rammer; and a cased motor driven transmission unit centrally mounted above the gun, forward of

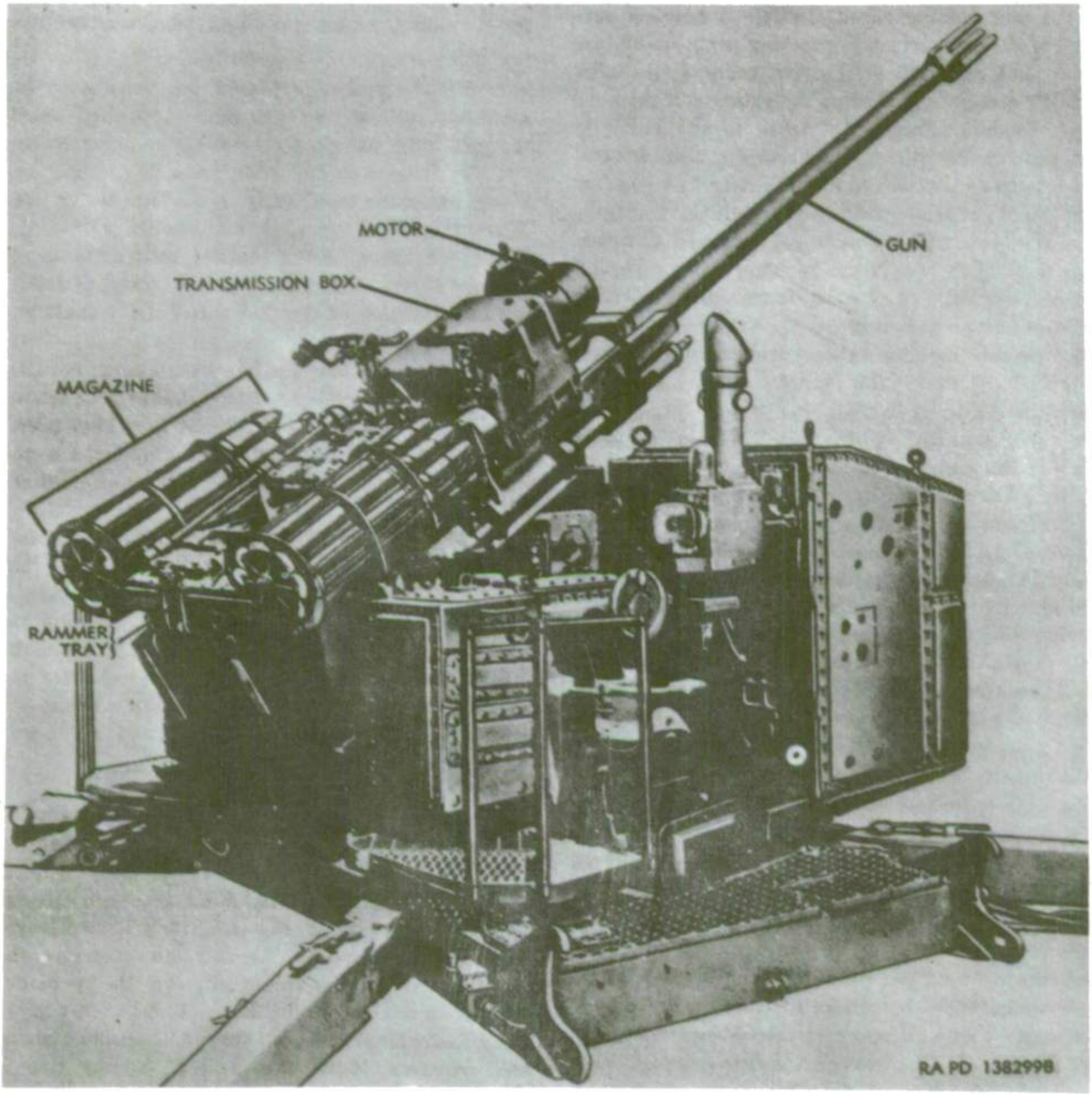


Figure 3-22. Magazine Type Loader-Rammer

the magazine, that provides power operation for both magazine and rammer tray mechanisms. These principal units are all mounted on the nonrecoiling gun cradle. General construction and functioning as as follows:

(a) *Transmission*

The stub shaft driven by the motor rotates, through helical gears, a longitudinal shaft incorporating a limited-torque safety clutch and a worm. The worm drives a worm gear incorporating a self-releasing pin clutch carried on a transverse cam shaft. The clutch, when engaged, drives the cam shaft one complete revolution, then disengages itself. Plungers linked to the gun breech mechanism prevent re-engagement until the gun has completed its cycle and is in battery, breech open, ready for the next round. The cam shaft carries three cams; one oscillates an arm on the right exterior of the case, to actuate the lowering and raising of the rammer tray; a second oscillates an arm on the left exterior of the case to drive the rammer chain; and the third oscillates a gear sector that drives the groups of pawls employed to feed rounds from the magazine into the rammer tray.

(b) *Magazine*

A cylindrical skeleton frame, with axis parallel to the gun bore, is mounted on each side of the gun cradle. An axial shaft in each cylinder carries front and rear star wheels that support the rounds with their axes parallel to the gun bore. Rotation of the wheels feeds the rounds from the lower side of the cylinder into a horizontal frame that guides the rounds laterally to the centrally located exit into the rammer tray. Feeding is accomplished by laterally reciprocating racks carrying spring-loaded pawls, the racks sliding in the horizontal frame and driven by gear train from the cam-operated gear sector in the transmission box. Spring-loaded pawls prevent reverse travel of the rounds. A manual lever actuates a shifting device in the transmission to effect feeding from the right or left half of the magazine, as desired. When one side is emptied, the shift is effected automatically to feed from the opposite side. Rounds are inserted into the cylindrical sections of the magazine by removal of the top half of the cylindrical frames, or singly by unlocking the circular retainer plate at the rear of the cylinder, and rotating the plate until its loading aperture is aligned with an empty notch in the star wheel.

(c) *Tray and Rammer*

The tray is a flat-sided trough with the bottom formed by an endless chain running over sprockets at the front and rear ends. The chain carries supporting blocks for the cartridge and a head for pushing the base of the case. Chain drive is through the rear sprocket, which is mounted on a transverse shaft connected, by gear train, gear sector and connecting rod, to the cam-actuated oscillating arm on the left side of the transmission case. The tray is supported by the sprocket shafts in journals at the outer ends of two parallel arms pivoted on the side frame of the loader-rammer, below the horizontal section of the magazine. When the supporting arms extend vertically below their pivots, the tray is aligned with the gun bore in position for ramming action by the chain; when the arms are rotated upward 180 degrees, the tray is thereby lifted to the exit of the horizontal (cross feed) section of the magazine, where it comes to rest embracing the next round to be rammed. Rotation of the rams from upper to lower position and return is effected through a spur gear on the pivot shaft of each arm, both being meshed with

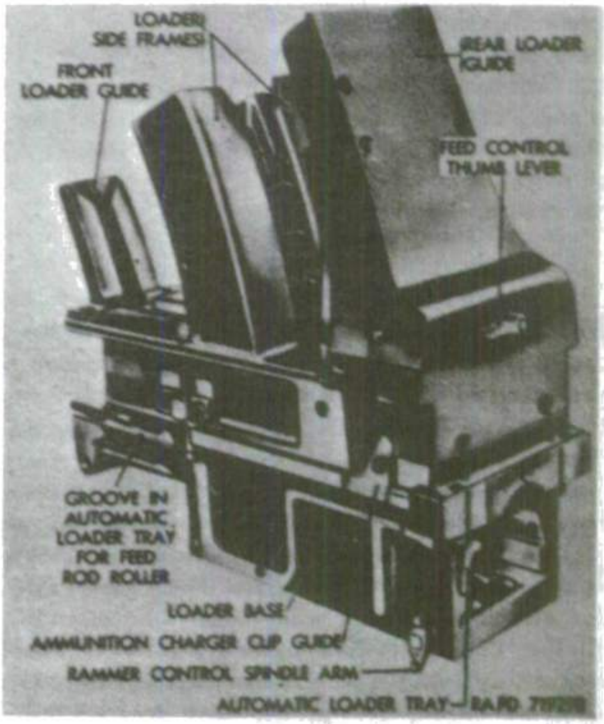


Figure 3-23. Automatic Loader for Clip-held Cartridges. (Left-Rear View).

a gear sector connected by rod to the cam-oscillated arm on the right side of the transmission case.

3-8.1.2.6. Automatic Loader for Clipped Ammunition (see Figure 3-23)

For drop block cannon of relatively small bore diameter using fixed ammunition in clips, current practice is represented by an automatic feeding and loading device, operated by movement of the gun in recoil and counterrecoil and by action of a spring compressed during counterrecoil. The mechanism receives the cartridge in clips, disengages the cartridges from the clips, ejects the clips, feeds one cartridge at a time downward to a loading tray affixed to the gun breech ring, and rams the cartridge into the chamber after counterrecoil, thereby tripping the extractor to effect the closing of the breech. A hand lever and suitable linkage are provided for manual operation of the rammer to initiate the automatic cycle or for single-shot operation when desired.

(a) *Loading Tray*

The tray is a trough rigidly attached to the breech ring in alignment with the gun bore. The tray sides incorporate cam grooves that impart a vertical reciprocating motion to ammunition feed rods as the tray moves with the gun in recoil and counterrecoil. Each side of the tray features also a cam slot for guidance of the two rammer levers that are supported in the rammer shoe and extend through the slots to clasp and drive the cartridge forward during the ramming motion of the shoe.

(b) *Rammer*

The principal parts of the rammer, contained within the housing in the under side of the tray, are a rod and helical spring, a shoe attached to the rear end of the rod and slidably supported in longitudinal grooves in downward-extending side flanges of the tray, and the two rammer levers, which are pivoted in the shoe and extend upward through the cam slots in the sides of the tray to clasp the rear end of the cartridge with a tong action. The upper ends of the levers are grooved for straddling engagement of the cartridge rim. As the gun recoils, the rammer is carried rearward by the tray. As the gun counterrecoils, the rammer shoe is retained in the rearward position by a catch lever mounted on the stationary breech housing. The forward movement of the tray then compresses the rammer spring. The next cartridge is meanwhile fed downward into the tray, its rim resting in the grooves of the rammer levers. As the tray terminates its forward motion, it trips the rammer catch lever and the rammer spring drives the rammer rod forward, pulling the shoe, levers and cartridge. When the rammer shoe nears its forward limit of travel, the cam slots swing the ramming levers outward sufficiently to release the cartridge, which is carried into the chamber by its own momentum.

(c) *Feeding Mechanism*

The feeding device, which serves also as a small-capacity magazine, is supported in the nonrecoiling breech casing above the tray and rammer. Front and rear frame members are channeled to guide the nose and base of the cartridge downward into the tray in proper position, with the rim of the base entering the slots in the levers of the cocked rammer shoe. Right and left side frame channels house the upper portions of the reciprocating feed rods, which carry spring-loaded pawls to pull the cartridges downward as the cam grooves of the tray, in engagement with the lower ends of the rods, force the rods downward. Also in the side frames are fixed pivot pawls to hold the cartridges downward while the feed rods return to upper position. The rear frame member incorporates a cam that disengages the hooks of the cartridge clip from the rim of successive cartridges as the latter are pushed down and deflects the freed clip into an ejection chute. The lower end of the feed mechanism, jnst above the rammer tray, incorporates two parallel, longitudinally disposed feed rollers, each having four cylindrically concave sides. The space between rollers is such as to permit one cartridge at a time to pass downward between them onto the tray, by rotation of the rollers toward each other through 90 degrees. An interlocked catch system limits roller rotation to one such quarter-turn in each recoil cycle of the gun and to that period when the feed rods are pulling the stack of cartridges downward.

3-8.2 Small Arms Feeding Methods

3-8.2.1 Manual Feeding

Because of the growing demand for increased rates of firing, the simple manual method of placing each successive round in the receiver, in position

for chambering by the operation of closing the breech, has been superseded by mechanical methods. Current small arms guns for uses in which rapidity of fire is of no particular advantage (signal pistols, for instance) are designed for manual insertion of the round into the chamber and feeding, in the sense indicated above, is not an individual action in operation of the gun. The multiple chambers of a revolver are also filled by hand, either individually or in groups of three held by a thin flat curved clip, or charger, which supports the cartridges parallel and properly spaced to enter three adjacent chambers of the revolver cylinder.

3-8.2.2 Magazine Feeding Methods

One means of continuous supply of cartridges to a rapid-firing weapon is the magazine. This is essentially a container, with an outlet so located or with such post-outlet mechanism as to place successive cartridges in position for chambering. In various forms, it may be incorporated in the gun structure, may consist of a unit affixed to the gun, or it may be a unit for insertion, filled, in a receptacle in the gun and removal when empty. Energy for movement of cartridges through the outlet and to pre-chambering position may be provided by the gun, by an external power source, or by a spring within the magazine, compressed in the process of charging the magazine. Examples of several arrangements follow:

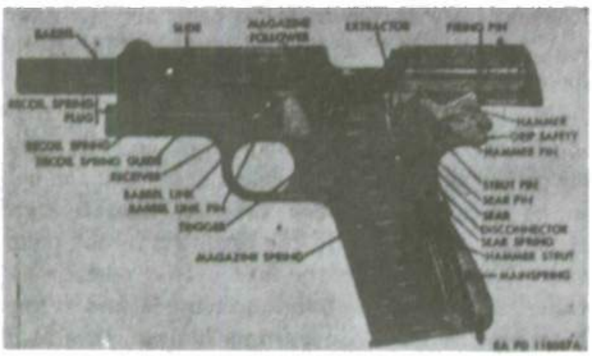


Figure 3-24. Automatic Pistol, Sectioned, Cartridge in Mouth of Magazine

3-8.2.2.1 Short Type Magazine

The magazine used in the standard automatic pistol (Figure 3-24) is a relatively short flat-sided metal tube that is loaded, then inserted upwardly into the handle of the pistol and latched in position. In the closed lower end is seated a coiled wire spring capped by a follower plate. Above the follower plate one column of cartridges is inserted, depressing the follower and compressing the spring. The mouth of the magazine, at the upper end, has inwardly curved lips on the sides to prevent upward ejection of the top cartridge, and is cut away at front and rear to permit the lower front face of the slide of the pistol, in counterrecoil, to strike the upper portion of the cartridge base and push the cartridge forward axially out of the magazine mouth, up a short ramp and into the chamber. When, on firing, the slide again recoils to clear the magazine mouth, the spring and follower raise the cartridge stack to place the top remaining cartridge in the magazine mouth, ready for chambering. A variation of this type of magazine, for automatic rifles, uses two columns of cartridges, staggered and feeding alternately into the mouth of the magazine.

3-8.2.2.2 Long Type Magazine

Magazines used in various automatic or semiautomatic rifles operate similarly to the short magazine but differ in having a greater length and resulting greater cartridge capacity. Variations include an arc shape for more compact containment of tapered cartridges or a drum enclosing a spiral or helical arrangement of cartridges, with a spiral spring actuating the follower.

3.8.2.2.3 Tubular Magazine

For a limited number of cartridges the tubular magazine is usually an integral part of the gun, positioned below and substantially parallel to the barrel. The cartridges, axially aligned, base to nose with noses forward, are fed by a compressed spring to emerge endwise from the tube into the lower part of the receiver. On emergence, the cartridge is below and behind the chamber, approximately parallel to it and resting on a carrier lever pivoted at the upper rear of the receiver. As the bolt reaches rear position, the carrier is actuated to swing upward and lift the cartridge sufficiently to be engaged by the bolt and pushed into the chamber as the bolt moves forward. The closing movement of the bolt releases the carrier, which is returned to its lower position by spring action for reception of the next cartridge released from the magazine.

3-8.2.2.4 Clip Feeding

The clip method of feeding, exemplified by the U. S. Rifle, Cal. .30, M1, presents a compromise between the wholly integral and the separate unit magazine. The clip compromises a thin spring-steel casing bent to a flat-based U, forming (as inserted in the gun) two sides and rear wall, all vertical. The free forward edges of the sides press inward to clasp the sides of two vertical columns of four horizontal cartridges each, staggered, with bases against the rear of the clip. The cartridges project from the open front and are retained at top and bottom by inwardly curved lips on the sides. The loaded clip is inserted downward through the top of the gun receiver into a recess in the lower part of the receiver, depressing the spring-loaded follower within the recess. The follower presses upward on the group of cartridges so that each time the bolt moves rearward sufficiently to clear, the topmost cartridge is moved upward into the mouth of the clip. In its subsequent forward movement, the bolt then pushes this top cartridge forward lengthwise between the lips of the clip until free of the clip and on into the chamber. When the last cartridge of the clip has been fired the empty clip is ejected on completion of the rearward travel of the bolt.

3-8.2.3 Belt Feeding

For continuous feeding of a greater number of cartridges than can be contained in a magazine of practical size, a belt system is used. Belts are usually made either of fabric or of metal. The belt consists of two layers of fabric strip stitched together transversely at intervals to form a succession of loops to carry cartridges parallel to each other and at right angles to the length of the belt or of a succession of articulated metal links formed for transverse insertion of cartridges to provide a chain of rounds of the desired length. In a typical application the belt is mechanically fed through the gun receiver, where the cartridges are successively extracted from the belt and pushed into the chamber by the reciprocating bolt. Individual operations of belt feed and cartridge extraction from the belt are effected by lever and pawl mechanisms attached to, or actuated by the moving bolt. In a variation from this system, the belt is fed through a separate feeding mechanism attached to the gun receiver. The mechanism advances the belt, extracts the cartridges and feeds them successively into the gun receiver in front of the retracted bolt, whence they are chambered by the forward bolt movement. The feed mechanism may be powered by gun recoil or by a separate power source.

3-8.2.3.1 Fabric Belts

Practical use of a fabric belt necessitates a mechanism that will withdraw the cartridge rearward from the belt then move the round at right angles to its axis to clear the belt and align with the chamber prior to ramming action by the bolt. In a typical mechanism, the movement of the belt centers the incoming cartridge over the closed bolt, with the base groove of the case engaged under a hooked extractor lever mounted on the bolt. As the bolt moves rearward, the extractor pulls the cartridge from the belt then is cammed downward to push the cartridge base into a vertical tee slot in the front face of the bolt. In the same bolt movement, the fired case, with its base engaged lower in the tee slot, is withdrawn from the chamber. As the bolt returns forward the extractor is cammed downward further to push the live cartridge down to alignment with the chamber, displace the fired case and eject it from the bottom of the tee slot.

3-8.2.3.2 Metallic Belts

Permanently linked metallic belts may be operrated in a manner similar to that indicated for fabric belt. However, by reducing the cartridge-holding loops to a C-shape with slightly more than a half-circle of grip, and disposing the loop openings on the side of the belt nearest the bolt, the bolt can be arranged to push the cartridge forward out of the loop and into the chamber in the counterrecoil movement of the bolt. This permits desirable simplification of the mechanism and action. The open-side loop also permits lateral removal of the cartridges from the belt, a method advantageous when used with a disintegrating belt.

The disintegrating belt is one in which each link, as its cartridge is removed, is disconnected from the following portion of the belt and is individually rejected through a suitable chute, while the cartridge is guided into ramming position. In a typical disintegrating belt, a cartridge functions as the hinge pin to provide an articulated joint between

each link and the next; removal of the cartridge breaks the connection. To provide satisfactory aircraft use of guns designed for magazine feed, a disintegrating belt with lateral extraction of cartridges is used with an attached feeding mechanism on some 20mm automatic guns. In this application the cartridges are fed downward by twin star wheels into the feed way in the top of the gun receiver. Prior to the entrance of the cartridge into the receiver, the link is separated from the cartridge by stationary fingers over which projecting ears of the link ride as the cartridge is forced downward. The pressure on the cartridge forces the open side of the loop to spring open sufficiently to release the cartridge, and the link is shunted into the rejection chute of the feeder. While links of disintegrating belts once used may be serviceable for a second feeding, they are generally considered expendable, except for practice firing.

3-8.2.4 Hopper Feeding

The use of a simple hopper to feed loose cartridges into the gun feedway has not to date proved satisfactory for rapid-firing guns. Current weapons utilize some form of power feeding to obtain positive action and maximum freedom from undesired interruptions.

CHAPTER 4

GUN INTERIOR REGIONS AND CHARACTERISTICS

4-1 Major Divisions and General Functions

The interior of a gun tube (Fig. 3-1), with a few exceptions noted below,* may be considered to consist of three general divisions, identified by use or function as follows:

a. The *chamber:* The inclosed space in which the charge of propellant is placed and ignited to generate pressure for driving the projectile.

b. The *bore:* The passage through which the projectile is driven by propellant pressure. The bore provides confined space for expansion of the propellant gases during acceleration of the projectile and guides the projectile to exit.*

c. The *transition region:* The connecting passage between the chamber and the bore, with contours designed to insure correct entry of the projectile into the bore and to provide such sealing surfaces against the projectile and cartridge case as are required to prevent leakage of propellant gases.

4-2 Chamber Characteristics (References 5, 9 and 12)

4-2.1 Size of Chamber

The volume to be provided in the chamber is based on its service as a combustion chamber and as a portion of the propellant's working expansion space. Pertinent factors include the energy required to be transmitted to the projectile; the maximum propellant pressure permitted in the gun structure; the rate of reduction and total reduction of propellant pressure as the projectile advances through the bore to the muzzle; and the quantity of propellant to be burned to impart the required velocity to the projectile and supply all losses. (The losses include projectile engraving, friction, acceleration of gases, acceleration of the gun in recoil, heat lost to the gun, gas leakage, and heat remaining in the propellant after the projectile emerges from the gun muzzle.)

For a given quantity of propellant, the chamber size may be varied somewhat to obtain desired modifications in the shape of the pressure-travel curve. (Typical pressure-travel curves are shown in Fig. 5-1 and are discussed in Chapter 5.) In current practice, however, the density of loading (number of grams of propellant per cubic centimeter of chamber capacity) is generally limited to a maximum of 0.75 for cannon, and 1.0 for small arms, to avoid the increase of pressure variation resulting from small differences in loading density when the above figures are exceeded. Reduction in loading density has a reducing effect on the maximum pressure produced, but extremely low loading densities also tend to induce nonuniformity of maximum pressures. Hence, both extremes are avoided wherever practicable, in order to limit round-to-round velocity variations to those resulting from unavoidable variations in gun and ammunition manufacture, or those occasionally resulting from abnormal and unpredictable circumstances encountered in service.

* Because of the coaxial positions and continuity of the inclosed space of the chamber, transition region, and bore, the term bore is sometimes used to denote the entire interior of the tube or barrel. However, the restricted meaning indicated in b. above is preferred, except in reference to certain designs typified by the muzzle-loaded smooth-bore mortar. In such mortars the chamber and the projectile-guiding portion of the bore are merely zones of a uniform cylindrical bore, and no transition region is needed. For this type of weapon the transition features described in subsequent paragraphs do not apply, and variations in chamber proportions are practically limited to the variations in length that may be made without excessive departure from optimum chamber volume.

4-2.2 Shape of Chamber

Optimum chamber contours are established through appropriate consideration of the effects of chamber shape on propellant performance and on gun structure, and of the details of contour best suited to the type of round to be used and to the manner of operation of the gun mechanism. Where various factors exert opposing influences, a compromise is determined in accordance with the relative importance attached to the opposing factors in the specific gun being designed.

4-2.2.1 Effect on Propellant Performance

Round-to-round uniformity of propellant action requires uniformity of propellant ignition, combustion, and resultant pressure generation. The requisite rapid and complete ignition of all portions of the propellant is promoted by a compact shape of chamber, which shortens the necessary travel of the igniting flame from its origin to the remotest portions of the propellant.

While breech loading requires that the chamber diameter exceed the bore diameter sufficiently to permit insertion of the projectile, comparative firing tests indicate that projectile velocity is increased somewhat by making the chamber diameter substantially larger than the bore. Ratios in use range up to roughly 1.5 to 1. The considerations favoring large chamber diameter must be reconciled with opposing factors indicated below.

4-2.2.2 Effect on Gun Structure

For safe containment of a given pressure, the larger the chamber cross section, the greater the required wall thickness in the breech end of the tube or barrel and in the breech closure. The resultant greater weight in the breech closure also necessitates the use of greater force in opening and closing the breech. Influence of these factors tends to limit the maximum diameter of the chamber. Opposing this consideration, in some cannon designs, is the desirability of limiting the length of gun structure behind the supporting trunnions, to minimize the clearance required for loading and firing at high angles of elevation, or to reduce the required size of an enclosing turret.

4.2.2.3 Effect on Other Features of Design

(1) In guns using cartridge cases (excepting some recoilless weapons), the chamber shape must conform to that of a manufacturable case, and be tapered as required to facilitate extraction of the case after firing.

The determination of length-to-diameter ratio of chambers for cartridge cases should include due consideration of the effect of the case proportions on practicability of case manufacture, suitability of ammunition units for storage and transportation, and ease of handling the rounds in firing operations.

(2) In guns using separate loading ammunition, the main cavity is commonly cylindrical, with a slight flare near the rear end to provide a conical seat for the obturating parts on the nose of the breechblock. If the diameter of the chamber substantially exceeds that of the projectile, the rear portion of the chamber may be conically reduced to near projectile diameter to permit use of a smaller obturator and breechblock. Such a conical reduction of the chamber is designated as the *chamber rear slope* (see Fig. 3-1(B)), and the resulting restriction of diameter is termed a *choke*.

(3) In recoilless guns, the required shape of chamber may be such as to fit the cartridge closely throughout, or to fit only at specified zones, the requirement being dictated by the design of the case and the intended path of gases to the breech nozzle or nozzles. While current designs are based on a maximum propellant pressure substantially lower than that employed in closed-breech guns, the chamber retains its function as a pressure-containing vessel, and is subject to essentially the same mechanical design considerations as are closed breech chambers. Hence, the chamber is basically cylindrical or moderately tapered. The ratio of diameter to length, degree of taper, and details of contour of front and rear ends are subject to the requirements established by the interior ballistics designed to obtain the desired projectile acceleration, accompanied by balanced forward and rearward impulse on the gun.

4-3 Bore Characteristics

The basic bore functions of guiding the initial movement of the projectile and providing expansion space for the propellant to perform its work of acceleration indicate that the bore should, in all cases, embody the closest practical approach to providing: (1) at any cross section, a balanced distribution of cross sectional area about a straight

longitudinal axis; and (2) a continuity and smoothness of bore surface to enable maintenance of an effective seal against escape of propellant gas around the projectile before the latter emerges from the muzzle. Other bore characteristics, subject to variation in accordance with the intended use of the weapon, are (a) caliber, (b) bore length, and (c) bore surface detail.

4-3.1 Caliber

The term *caliber* denotes the diameter of the bore, exclusive of rifling grooves if such are present. (It is also used to indicate the nominal diameter of the projectile.) In former U. S. Army design practice, caliber was usually expressed in inches and decimal fractions thereof; in recent practice, the measurement is expressed in millimeters and decimal fractions thereof. (The significance of caliber as the bore diameter dimension should not be confused with the practice of indicating the length of bore or gun in calibers, for example, a "6 inch 50 caliber gun" indicates a caliber of 6 inches and a length of $6 \times 50 = 300$ inches.)

The caliber, as a determinant of the sectional area of the projectile exposed to propellant pressure, is a major factor in projectile acceleration, and in the rate of change of propellant gas volume as the projectile moves through the bore.

Caliber may be characterized as follows:

(1) *Constant Caliber (Cylindrical Bore).* Constant, or uniform, caliber denotes a bore having the same caliber throughout its length. This is the prevailing type in current military gun design (see also par. 3-4.1).

(2) *Decreasing Caliber (Tapered Bore).* In some experimental designs, bores having a larger caliber at the rear than at the front have been used for attainment of high velocity. In such designs a deformable ring or skirt is used on the projectile to seal against propellant gas loss, and this is compressed or collapsed to smaller diameter as it moves through the bore. The reduction in bore size may be continuous through the bore length or confined to some forward portion of the length. The larger area subjected to gas pressure in the zones where pressure is at or near peak pressure effects an increase in acceleration of the projectile. A slight reduction in caliber (choke) near the muzzle of some shotguns is used to reduce the lateral spread (scatter) of the pellets after they have left the bore (see also par. 3-4.2).

4-3.2 Bore Length

The length of the bore, from chamber to muzzle, combines with the bore diameter and chamber volume to determine the ratio of expansion (final volume/initial volume) of the propellant gases during their action of propelling the projectile through the bore. All these factors, as well as projectile weight and the amount and rate of pressure production by the propellant charge, must be considered in various combinations to obtain the proportions for a new design of gun to meet most satisfactorily the specified performance, dimensional and weight requirements.

4-3.3 Bore Surface Detail

Bores are generally designated in accordance with surface characteristics as follows:

(1) *Smooth Bore.* This designation indicates that the bore is circular in cross section, without any pattern of grooves or ridges designed to produce rotation of the projectile. Its chief military use at present is in muzzle-loading mortars (see also par. 3-4.3.1).

(2) *Rifled Bore.* This designation indicates that the bore contains multiple, parallel grooves following helical paths about the bore axis, designed to engage the periphery of the projectile (or a band fixed thereon) and so impart a desired rotational velocity to the projectile as it is propelled through the bore (see Fig. 3-7). The rotation serves to maintain the axis of the projectile closely coincident with the direction of projectile travel, to reduce the amount and variations of air resistance, and to insure a nose-first impact on the target.

The number of and cross section of rifling grooves must be made sufficient to provide the bearing area necessary to impart the required projectile rotation without excessive stress in the materials of the bore and projectile, in order to avoid rapid wear and the possibility of stripping (shearing) the lands (ridges) of either projectile or bore. The needed number and size of grooves increases with increases in the weight of projectile and in the rotational acceleration necessary to attain the rotational velocity required for stability. Designs in current U. S. Army use show the number of grooves

and depth of grooves roughly proportional to caliber.

The pitch of the helical path of the rifling grooves, generally expressed as "one turn in (applicable number) calibers," may be uniform through the bore length, or the rate of turn may be increased from a low value near the origin to the required final value at or near the muzzle. The increasing twist method reduces the rotational loading on the rear portion of the bore, which is subject to more severe erosive condition than is the portion nearer the muzzle. However, increasing twist requires alteration of the angle of the engraved grooves in the projectile as the projectile moves forward, and this limits the width of rotating band that may be used without undesirably increasing the force required to engrave the projectile. It also increases the rotation-accelerating forces to be applied by the rifling in the forward portion of the bore. U. S. Army design practice at present generally favors uniform twist in cannon and increasing twist in small arms guns (see also par. 3-4.3.2).

4-4 Transition Region

This region comprises the forward portion of the chamber, from the rear of the chamber front slope (see Fig. 3-1) through the forcing cone.

4-4.1 General Contours and Functions

The transition region consists of a series of tapered sections (one or more cylindrical sections may be included) connecting the forward section of the principal cavity of the chamber with the rear section of the main bore (rifled or smooth). The general functions of the contours are:

(1) To center the projectile at the entrance to the main bore, so it may enter the bore in proper alignment, without undesired deformation, and with the uniformity of round-to-round resistance necessary to maintain uniform development of propellant pressure and resultant muzzle velocity.

(2) To provide for such seating of the projectile, in loading, as will prevent leakage of propellant gases past the projectile into the bore before the projectile has completed its entry into the bore under propellant pressure.

4-4.2 Details of Contour and Function

Typical transition contours of breech-loading guns are shown in Fig. 3-1. Their designations and functions are as follows:

4-4.2.1 Forcing Cone

(1) This tapered section, immediately back of the bore, is designed to accomplish a centered, gas-sealing entrance of the rearward section of the projectile jacket or band into the main bore, by forcing a slight reduction in diameter as that section of the projectile enters the bore. In loaded position the fit is sufficiently snug to provide an initial seal, except in some small arms using bullets designed to be expanded to sealing diameter by initial pressure of the propellant. In cannon using separate loading ammunition, the taper must be gradual enough to retain the rammed projectile in proper firing position as any angle of gun elevation at which the weapon may be fired.

(2) For rifled bores (except recoilless rifles) the forcing cone effects a distribution of the work of engraving the projectile (or its rotating band) over an appreciable length of projectile travel, thereby reducing the propellant pressure required for initial movement of the projectile.

(3) For recoilless rifles, the rotating bands of the projectiles are preengraved (grooved in manufacture) to fit the rifling of the bore in order to minimize the propellant force required to start the projectile. The rotating band is inserted into the rifling in the loading operation. Hence, the forcing cone is replaced by an abrupt taper or shoulder at the origin of rifling, to facilitate the manual alignment and insertion. The taper may be preceded by an aligning cylinder, which, in turn, may be preceded by a guiding taper.

4-4.2.2 Bullet Seat

This is a cylindical section immediately back of the forcing cone in small arms weapons, serving to support the bullet centrally at the entrance to the forcing cone.

4-4.2.3 Band Cylinder

This cylindrical section, a feature of some separate loading cannon, supports the rear of the projectile rotating band in central position while the

front edge of the band is pushed into the forcing cone.

4-4.2.4 Case Clearance Shoulder

This feature, appearing in some small arms, comprises an increase in diameter immediately back of the bullet seat to clear the mouth of a cartridge case crimped onto the bullet as the mouth expands to release the bullet. For some noncrimped cartridges, the shoulder forms a seat for the cartridge mouth, and stops the case at the correct depth of insertion when the cartridge is chambered.

4-4.2.5 Band Rear Slope

This is a tapered section used in separate loading cannon, immediately back of the band cylinder. It serves to guide the rotating band of the projectile being inserted to the central position required for entry into the band cylinder.

4-4.2.6 Centering Slope

The centering slope is a tapered section immediately to the rear of the band rear slope (artillery) or case clearance shoulder (small arms). It serves to guide the projectile, cartridge case, or cartridge being inserted toward concentricity with the bore. In guns using conventional cartridge cases, the taper is slight, and the section, closely encircling the neck of the case, provides the surface against which the mouth of the case is expanded by propellant pressure to seal against rearward escape of gases.

4-4.2.7 Chamber Front Slope

This tapered section accomplishes the reduction from the main cavity of the chamber to a suitable size for the centering slope. For some small arms cartridges, this slope forms a seat for the shoulder of the case, and so stops the cartridge at the proper chambered position.

CHAPTER 5

INTER-RELATION WITH PROPELLANTS

5-1 General Considerations

The motion of the projectile at departure from the gun muzzle is the net result of the forces applied to the projectile by the propellant, the inertia of the projectile, and mechanical interaction between the gun and the projectile as the latter passes through the bore. The summation of the forces applied by the propellant is dependent on (1) the quantity of gases produced; (2) the rate and amount of heat evolution; (3) the volume and rate of change of the space in which the gases are confined while exerting pressure on the projectile; and (4) the cross sectional area of projectile on which the gases apply accelerating pressure. From the combination of propellant properties and gun geometry involved, it is apparent that the problems in gun and ammunition design are mutually dependent, one upon the other.

Generally, for a required weight of projectile, a number of combinations of gun geometry and propellant charge may be found to satisfy the muzzle velocity requirements; then a preferred combination may be selected on the basis of appropriate considerations of weight, size, producibility, reliability, operability, material availability, cost, and such other factors as may be pertinent in the individual case.

Various properties and characteristics of propellants and considerations of gun-propellant relationships that affect the performance obtained from the combination of gun and propellant are presented briefly below:

5-2 Propellant Composition and Characteristics

5-2.1 Composition

The formulation and design of propellant charges are covered in other handbooks of the Series. In this handbook discussion is therefore limited to such considerations as may serve to clarify the relationship of gun and propellant designs.

Propellants for guns are classed as low explosives, i.e., explosives which, when used under the intended conditions, burn rather than detonate. A detonation produces a destructive shock effect and characterizes high explosives. Propellant charges may contain high explosives for increased power, but the properties of the final mixture must permit combustion of the mixture without subjecting the gun and projectile to the shattering effect of detonation.

Quite a number of propellant compositions have been standardized for use in Army guns. The propellants currently most used in Army guns include: single-base propellants, consisting principally of nitrocellulose; double-base propellants, basically nitrocellulose and nitroglycerin; and triple-base propellants, basically nitrocellulose, nitroglycerin and nitroguanidine. Standard compositions contain minor quantities of other ingredients for desired effects on various characteristics, including chemical stability, hygroscopicity, heat of explosion, rate of combustion, muzzle flash, erosion, smoke production, residue, electrical conductivity, moldability, strength of grain structure and facility of manufacture.

5-2.2 Total Energy

The total energy developed through combustion of a propellant in a gun is expended as follows:

(1) In expansion of the produced gases, to: (a) accelerate the projectile to exit velocity; (b) accelerate the gun (and other recoiling parts) to the velocity of recoil; (c) translate the propellant gases (and any residue); (d) perform the work of

projectile engraving and overcoming friction of projectile travel in the bore; and (e) overcome friction and other resistances to movement of the gun in recoil.

(2) In heat lost by: (a) raising the temperature of the gun, projectile and case (if used); and (b) discharge of hot propellant gases (and any residue) on exit of the projectile from the muzzle.

Consideration of the expenditures of energy indicated above, with the factors given in paragraph 6-1.1 affecting the energy spent on the projectile, emphasizes that the propellant characteristics and the dimensions of the gun chamber and bore, in combination, determine: (a) the kinetic energy imparted to the projectile; (b) the maximum temperature and pressure developed; (c) the exit temperature of the propellant gases; and (d) the total energy that must be evolved to obtain the required projectile motion. Hence, for optimum overall results, it is imperative that gun and propellant charge designs be fully coordinated.

5-2.3 Burning Rate and Pressure

When combustion takes place in a closed space, as in a gun, the combustion rate increases rapidly as the temperature and pressure of the confined gases rise. For effective designing of guns to obtain prescribed performance, weight and size characteristics, the rate of pressure rise and the maximum pressure must be restricted to appropriate limits. The propellant designer controls these effects by: selection of basic propellant constituents; addition of combustion retardants; selection of size and shape of propellant grains; and establishment of the chamber volume to be provided in designing the gun.

5-2.4 Stability

Effective service performance of the gun-propellant combination requires that the propellant action on firing shall not vary appreciably as a result of storage between manufacture and firing. Hence, chemical stability must be considered a major objective in the design of a propellant.

The nitrocellulose compounds used as basic ingredients of currently used propellants have less inherent stability than is desirable, but materials having their desirable properties plus greater stability are not adequately available. The stability of nitrocellulose is made adequate by addition of various other materials, as coatings or dispersed ingredients. The stability requirement necessarily affects, to some degree, the volume of the chamber. Most of the additions commonly used for stability are also helpful for other purposes, such as reduction of flame temperature, erosion and flash, or simplification of manufacture.

5-2.5 Mechanical Properties

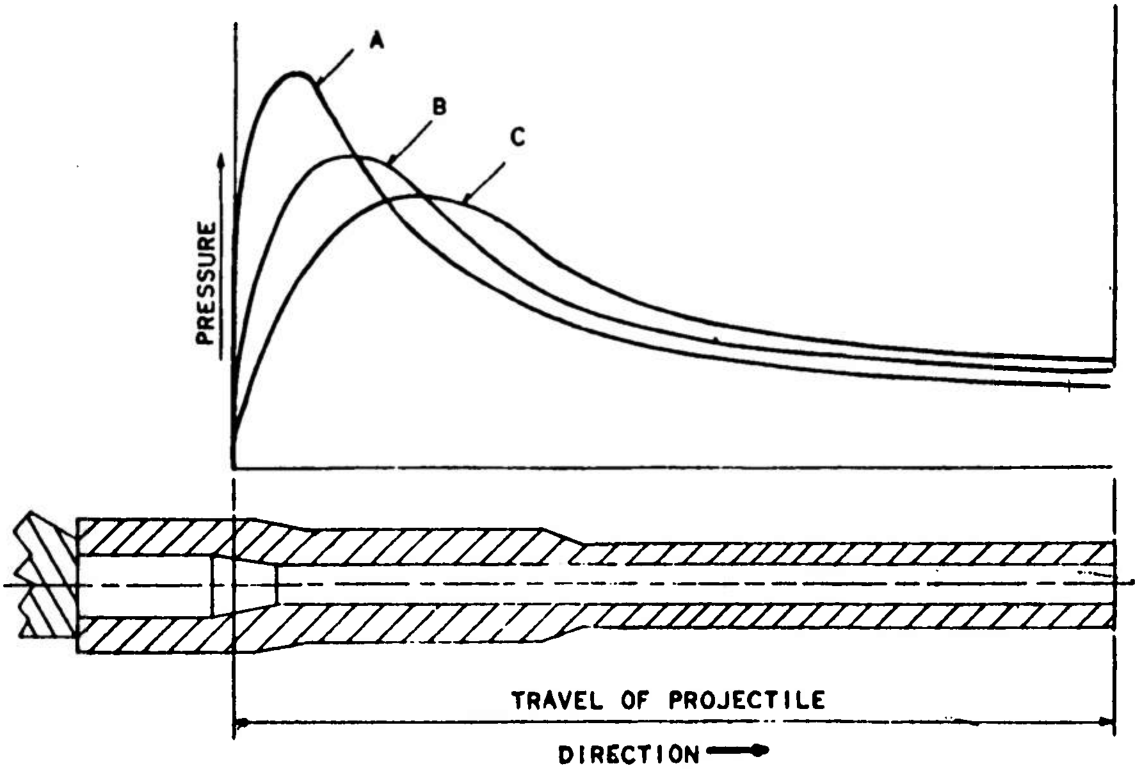
The time required to burn a charge of propellant depends, to a significant degree, on the size and shape of the propellant grains. Hence, the grains should not only be strong and tough enough to endure the loads and impacts incurred in transportation and handling before firing, but should withstand the pressures, motions and impacts developed in the chamber and tube without shattering before burning has been virtually completed.

5-2.6 Feasibility of Manufacture

The propellant designer's choice of materials is limited by the necessity for production of large quantities of propellants during national emergencies. The manufacturing processes should be as simple and reliable as possible, and capable of application to large quantity production without compromise in quality and uniformity of product. All operations should be as nearly free from hazard as possible. As far as practicable, products and manufacturing processes should be similar to those normally used in industry, so that production may be more readily expanded where necessary.

5-2.7 Costs

The cost of a propellant should be the lowest consistent with provision of the required behavior characteristics. A relatively high cost may be caused by limited supply of basic material or by complicated and costly processes of manufacture. However, when comparing propellant costs, the designer should consider costs per unit of usable energy rather than per unit of weight. Further, differences in temperature, pressure and expansion space required for best use of various compositions may entail such differences in the weight and cost of the required gun structure as to substantially affect the choice of propellant on an overall cost basis.



CONDITIONS:

A - FAST-BURNING CHARGE

B - BURNING RATE LOWER THAN A - PROGRESSIVE GRAIN FORM

C - BURNING RATE LOWER THAN B - PROGRESSIVE GRAIN FORM

AREA UNDER CURVES: A = B = C FOR EQUAL MUZZLE VELOCITIES

Figure 5-1. Pressure-Travel Curves, Indicating Shape Variations Resulting from Differing Propellant Granulations

5-3 Granulation

5-3.1 Purpose

The purpose of establishing a definite size and shape of granulation is to so control the rate of combustion (gas evolvement) that the requisite energy will be applied to the projectile without exceeding permissible pressure (and temperature) at any stage of the projectile's travel through the barrel.

5-3.2 Effect of Grain Form

Grain form is used to influence the quantity rate at which the propellant burns. Since combustion takes place only at the grain surface, the amount of propellant burned per unit of time, at a given linear rate, is directly proportional to the surface area of the burning grains.

The surface area of grains of solid section (rods or strips) decreases as burning progresses, thus exerting a decelerating influence on the quantity rate of combustion. Propellants of such grain form are termed *degressive.*

To effect other than degressive burning, perforated grains are employed. Cylindrical tubular grains have one axial perforation (typical form for U. S. small arms) maintain nearly the same area of surface until practically consumed, since the inner periphery increases as the outer periphery decreases. A propellant that maintains a uniform quantity rate of burning is termed *neutral.*

An increasing rate of burning may be effected by using multiple longitudinal perforations through a grain with cylindrical or fluted exterior. (Typical U. S. cannon propellants have a cylindrical grain with seven perforations, one axial and six equally spaced about the center, at mid-wall.) With more than one perforation the interior surface increases more rapidly than the outer surface reduces, so that the quantity rate of combustion increases as burning progresses. A propellant with grains formed so as to effect an accelerating burning rate is termed *progressive.*

If a degressive grain is used, the maximum rate of combustion will be reached quickly after completion of ignition, and a decreasing rate will follow. With a progressive grain, the maximum rate of combustion occurs somewhat later, when the projectile is farther forward and advancing more rapidly. Graphically, the effect is that the declining portion of the pressure-travel curve is less steep for progressive than for degressive propellants (see Figure 5-1). If charges of the two types of granulations are to impart the same muzzle velocity to the projectile, the areas under the respective pressure-travel curves must be equal. If the lengths of travel are also equal, the pressure curve of the progressive propellant, having a more gradual decline, will have a lower maximum. However, the slower reduction of pressure (and temperature) exhibited by progressive propellants results in slightly higher gas pressure (and temperature) at exit from the muzzle. This signifies a lower efficiency, i.e., a smaller portion of the energy generated by the propellant is transmitted to the projectile. Hence, for the same muzzle velocity, the quantity of propellant required is somewhat larger for progressive than for degressive propellants. An alternative to increasing the quantity of propellant is to increase the length of the bore, and so utilize a greater length of the declining pressure curve. In general, the effect of shifting from degressive to progressive granulation is to reduce structural strength requirements in the chamber region and increase strength requirements near the muzzle. The resulting alteration of the gun temperature curve corresponds to that of the pressure curve.

5-3.3 Effect of Web Thickness

The web thickness is a most important factor in the control of propellant combustion to obtain a desired shape of pressure-travel curve. Web thickness is defined as the least thickness of propellant material between opposite surfaces on which burning occurs. The geometric shape of the grain affects comparative rates of burning from ignition to completion (all burnt), while the web thickness affects the total time required to completely consume the grain and, hence, the time required to completely burn the propellant charge. A web too thin will permit completion of combustion before the projectile can be moved a sufficient distance forward in the bore, with resulting excessive pressure and temperature. A web too thick will delay the development of the peak of pressure until the projectile is too far forward, so that the maximum pressure is undesirably low, subsequent expansion is therefore less complete before exit, and gas pressure and temperature remain undesirably high at discharge from the muzzle.

5-4 Form of Charge

The propellant charge is subjected to several variations in form for adaptation to the type of gun and the performance characteristic required (see also paragraph 3-3 and subparagraphs thereunder). The following principal forms are included.

5-4-1 Cased Charges

These charges are contained in a cartridge case, including a primer extending forward from the rear end of the case sufficiently to obtain satisfactory ignition. An ignition charge may be included to aid in speeding ignition of all portions of the propellant. For closed-breech gun the case contour closely fits the gun chamber and the case provides obturation against rearward escape of propellant gases. Variations include the following:

(1) For fixed ammunition, in which the case is firmly attached to the projectile, the charge is enclosed without provision for subsequent disassembly.

(2) For semifixed ammunition, in which the case is loosely fitted to the rear of the projectile, the propellant is bagged in portions or otherwise separated into a basic charge and increments, the latter removable to adjust the propellant charge for zone firing.

(3) For separated ammunition, in which the case and projectile are separate units, separately handled until chambered in the gun or inserted into a mechanical loader-rammer, the full charge of propellant is securely sealed by a plug in the forward end of the case. No provision for zone firing is made.

(4) For open-breech guns (recoilless types), in which rearward discharge of a portion of the propellant gases produces recoil-neutralizing forces, a path must be provided for gas flow to the vents at the rear of the chamber. Present practice includes two methods, indicated below:

(a) The cartridge case is of smaller diameter than the gun chamber, except at the forward end, where the case is confined in the transition from chamber to rifled bore, and the projectile rotating band is fitted into the rifling of the bore. The metal case walls are perforated to permit escape of gas into the annular space between case and chamber wall and thence to the orifices at the rear of the chamber. The perforated portion of the metal case is sealed by an unperforated combustible liner until the liner is destroyed by firing the round.

(b) The cartridge case is not perforated, and fits the contours of the gun chamber. The rear end wall (base) of the case, instead of all-metal construction, incorporates a disk of a composition that disintegrates under the heat and pressure of the propellant gases, and so permits rearward escape through a central orifice. A further variation combined with this design of case is the formation of the propellant charge by stacking a large number of thin washer-like flat disks of propellant behind the projectile on the axial boom that carries the projectile stabilizing fins. Each disk has "dimples" embossed on one face to space the disks and expose both surfaces for ignition and combustion. The outside diameters of the disks are substantially less than the inside of the base and are progressively smaller toward the rear, to reduce obstruction of gas flow to the rear orifice.

5-4.2 Noncased Charges

These are contained in one or more combustible bags instead of a cartridge case. Guns utilizing these charges must provide for obturation against rearward escape of gases by features built into the gun breech (see paragraph 3-3.4). Variations include the following:

(1) Complete propellant charge in one bag. This arrangement may be used where the resulting size and shape is suitable for handling and loading. One or more elements of ignited material (usually black powder), formed as end pads or as a central core, are fixed within the propellant bag to augment the primer flame in effecting thorough ignition of the entire mass of propellant. The propellant bag (sometimes termed cartridge bag) constitutes one unit of separate loading ammunition, in which the projectile, propellant and primer are separately inserted into the gun.

(2) Propellant charge in two or more bags.

(a) This arrangement is used in separate loading ammunition either to divide the propellant into portions more easily handled in gun loading, or to provide a basic charge and increments for zone firing. An ignition charge may be included in the basic charge only, or in the increment

charges also, as may be necessary for satisfactory ignition.

(b) Separately bagged (or wrapped) basic charge and increments are also utilized as components of semifixed ammunition for zone firing of muzzle-loading mortars. In this use the separate portions of the complete charge are attached to the fins or fin shaft of the projectile, with the increments readily removable in the field to reduce the range from the maximum to the zone desired. A primer cartridge is carried in the rear of the fin shaft of the projectile.

(3) Grain arrangement. Generally, whether cased or bagged, propellant charges composed of the commonly used shapes of grain are assembled with the grains in random positions. However, where large rod-shaped grains are used in a package of large length-to-diameter ratio, improvement in compactness, rigidity and uniformity may be obtained by orderly arrangement of grains, end to end, with axes parallel to the axis of the container. A charge thus arranged is termed a stacked charge.

5-5 Ignition Systems

5-5.1 General

The release of the propellant's high energy in a very short time interval, with the necessary round-to-round uniformity, requires that the propellant be ignited by the quickest possible propagation of high-temperature gas to the largest possible fraction of the total surface of the propellant, with the least round-to-round variation that can be practically attained. (The ideal performance would be instantaneous ignition of the total surface of the propellant.) The effectiveness of the means of ignition, therefore, constitutes an important factor in the effectiveness of propellant performance. Some effects of inadequate ignition are indicated briefly below.

5-5.2 Relation Between Ignition and Muzzle Velocity

The uniformity of the projectile muzzle velocity effected by the propellant may be represented by uniformity of the area under the pressure-travel curve (Figure 5-1). If the elapsed time between the beginning and completion of ignition of all surfaces of the propellant varies from round to round, the early rate of burning and the total time to complete burning of the propellant will vary correspondingly, with resulting variation in the shape of the representative pressure-travel curve and in the muzzle velocity of the projectile.

5-5.3 Pressure Waves

If an insufficient fraction of the propellant is ignited initially, the difference in progress of combustion in various parts of the chamber tends to produce severe surging of the produced gases and irregular rise of pressure. The resulting pressure waves may cause unpredictable variations in the height and location of the peak of the pressure-travel curve, with resultant variations in muzzle velocity. There is also the possibility that the pressure peak may occur at such location as to subject a portion of the tube to pressure higher than is permissible at that section.

5-5.4 Primers and Igniters

The primer, alone or supplemented by one or more ignition charges, is the means by which the burning of the propelling charge is initiated. The primer contains an explosive mixture designed to be highly sensitive to impact, friction, or other shock, mechanical or electrical, in accordance with the means of firing provided by the gun. On activation by the firing mechanism, the primer projects a quick, hot flame against the propellant (or a supplementary igniter charge) contained in the more forward portion of the case. For the relatively small quantities of propellant contained in small arms cartridges, the primer ignites the propellant directly; for the larger quantities of propellant (and, generally, slower burning granulations) contained in cased artillery ammunition, the primer ignites a quantity of quick-burning black powder (igniter) so placed as to distribute an igniting flame to all portions of the propellant in the least possible interval of time. Elements of the igniter charge may extend to the forward end of the propellant charge. For large caliber guns using bagged propellant (without cartridge case) a relatively small primer is used, to project a jet of flame through a passage bored on the axis of the breechblock into the gun chamber, to ignite additional igniter units accompanying the propellant. The additional igniter charges are generally contained in, or attached to, each bag or increment of propellant, to further the rapid propagation of the igniting flame.

5-5.4.1 Voids

A device to aid the igniter charge or charges in effecting rapidity and uniformity of propellant ignition consists in the provision of voids within or around the propellant charge in the cartridge case or gun chamber. The unobstructed space permits the igniting flame to spread more freely to all portions of the propellant charge.

5-5.4.2 Ignition As a Factor in Design

The necessity for uniformity of ignition for uniform round-to-round propellant action compels consideration of ignition requirements as well as propellant space requirements in coordination of the design of the gun chamber with the propellant charge design. The determination of ammunition type having been made (i.e., fixed, semifixed, separated, or separate loading), the ammunition designer assumes the task of designing suitable propellant and ignition elements, and specifying the necessary chamber volume. For optimum results, the gun designer must cooperate by providing, within the limits imposed by other gun design requirements, a chamber of adequate volume and sufficiently low length-to-diameter ratio to enable a satisfactory solution of the ignition problem.

5-6 Smoke and Flash

5-6.1 Causes

Combustion of the propellant does not progress to completion in the gun tube or barrel. The available oxygen in the propellant is insufficient to complete the combustion reaction with all the remaining elements. For example, the major portion of the carbon may be converted to carbon monoxide, but not to carbon dioxide.

Depending on the quantity and characteristics of the propellant, the geometry of the gun tube, and size and weight of the projectile, various effects may be produced as the propellant gases emerge from the muzzle:

(1) If the initial combustion persists at emergence of the propellant, flash will result.

(2) If gases are not cooled below incandescence before exit, flash will result.

(3) If the products of incomplete combustion (notably hydrogen and carbon monoxide) are not below ignition temperature at emergence, contact with atmospheric oxygen will effect a renewal of combustion beyond the gun muzzle. This action produces what is termed secondary flash, of greater brillance than that indicated in (2) above.

(4) If unburned solid particles (notably carbon) below ignition temperature are ejected with the propellant gases, smoke will be produced. Particles other than carbon may contribute to visible smoke or vapor, through visibility of the particles, or by reaction with the atmosphere to produce condensation of water vapor. Materials added to the propellant for combustion or erosion control and metal particles abraded from the gun bore or projectile are considered possible causes of the reaction.

5-6.2 Disadvantages

Both smoke and flash are objectionable in that they reveal to the enemy the location of the weapon and operating personnel. Further, smoke may obscure the operators' view of the target area immediately after firing and so reduce the effective use of the weapon.

5-6.3 Correlation With Grain, Form, Charge and Tube Design

From the discussion in paragraph 5-6.1 it follows that the production of smoke or flash is affected by the form and dimensions of the propellant grains. Grains of degressive form produce their peak of temperature and pressure relatively quickly and, for a given energy yield within the gun, are reduced to relatively lower temperature and pressure before exit from the muzzle. This action presents a reduced tendency to flash, as compared to neutral and progressive forms (perforated types), which produce a lower and later peak of temperature and pressure, but show higher temperature and pressure at the muzzle for a given energy yield within the gun.

The composition of the propellant charge will affect the production of flash or smoke through its effects on: total heat evolved; rate of combustion; temperature of flame produced; the proportion of nonburnable gases evolved; the quantity of nonburning solids (included for control of combustion rate, temperature, erosion, stability, or other purposes) and oxygen balance. With the same gun interior, same projectile and same maximum pressure limit, increases in muzzle velocity necessitate persistence of near-maximum pressure and temperature into sections nearer the gun muzzle. This

condition results in higher gas temperature at exit, with attendant increase in flash. The effect of the tube design on the production of smoke and flash becomes obvious from the discussion of the causes in paragraph 5-6.1 The tube and propellant charge, with some contribution by the projectile, are jointly responsible for the conditions represented by the contour of the pressure-travel curve, including the composition, condition, and state of the propellant charge material at exit from the gun muzzle. These attributes of the discharged material, in turn, substantially determine the occurrence or absence of smoke and both primary and secondary flash.

5-6.4 Elimination of Flash and Smoke

5-6.4.1 Flash

Flash may be most effectively reduced by such combination of barrel, projectile and propellant designs as will cause the combustion of the propellant to be completed while the projectile is still near the breech, so that subsequent expansion will sufficiently cool the propellant gases before exit from the muzzle. While this is feasible in some small arms, it is unsuitable for many weapons because of the opposing demand for obtaining high projectile velocities from guns of least practical overall size and weight. Consequently, where needed, other methods of minimizing flash are used, with varying degrees of effectiveness.

Chemical methods introduce additional material into the propellant charge. One approach adds material to evolve quantities of nitrogen or other nonexplosive or partially combustible gases to absorb heat and so lower the exit temperature of the propellant gas mixture to a point below the ignition temperature of the combustible gases contained. The resulting dilution of combustible gases may further reduce the likelihood of occurrence of secondary flash. The temperature reduction effected by this method may entail some loss of energy. Another approach is the addition of certain salts which have been found effective in preventing re-ignition of hydrogen and carbon monoxide in the ejected propellant gas. This method, while suppressing flash, generally produces smoke.

Mechanical means of flash reduction include muzzle attachments designated as flash hiders or flash suppressors (Figures 5-2 and 5-3). The flash hider consists of a conical tube with its small end

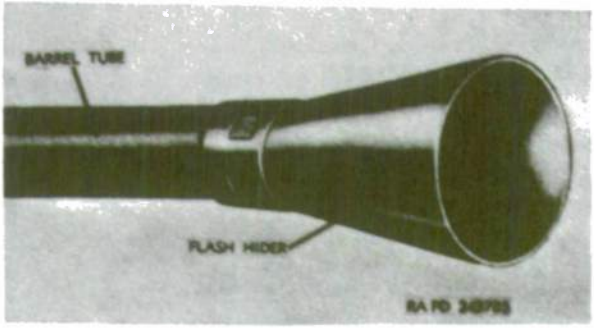


Figure 5-2. Flash Hider

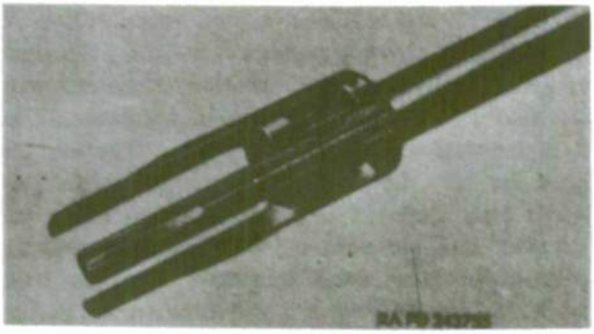


Figure 5-3. Flash Suppressor

attached to the muzzle of the barrel, and serves to conceal the emerging flash from sideward view, but is ineffective against observation from positions well forward of the gun. The flash suppressor comprises a muzzle attachment providing several forward-projecting prongs extending from a collar on the gun muzzle. This device eliminates or reduces the flash resulting from a secondary burning of the propellant gases at the muzzle. The reduction is due to the cooling action on the emerging gases.

5-6.4.2 Smoke

Means of minimizing the production of visible smoke are the subject of continual investigation. One approach is aimed at avoidance or reduction of smoke-producing compounds in the propellant; another has the objective of reducing the visible products of incomplete combustion by improving the co-ordination of design of gun and propellant, so that desired ballistic performance can be achieved with (a) propellant charge composition and combustion processes that will leave a practical minimum of smoke-producing elements or compounds in the discharged gases; and (b) ejection

of the gases, vapors and particles resulting from combustion and projectile passage in a condition as unfavorable as possible to undesired atmospheric reaction.

5-7 Fitting the Propellant and the Gun

5-7.1 General Considerations

The interdependence of gun design and propellant charge design can hardly be over-emphasized. Within limits, the design of either may be adjusted to accommodate the characteristics of the other, so a number of coordinated combinations may be found to satisfy a given projectile velocity requirement. The range of possible combinations, however, does not present an area for uncoordinated choice by either gun or propellant designer. Rather, it provides a measure of latitude for joint effort to combine, with the required velocity, other characteristics (as light weight, short barrel, facility of ammunition handling, for example) to the extent found practicable and desirable in the intended use of the weapon.

5-7.2 General Procedure

The initial requirements for a new design of gun usually include the desired caliber, type and weight of projectile, muzzle velocity or range of firing, and overall limitations on gun length and weight. Since the velocity of the projectile is imparted by the pressure of the propellant while confined in the gun chamber and bore behind the accelerating projectile, the initial step in the design of the gun is the calculation, by the ammunition designer, of combinations of chamber volume, bore length and propellant charge that will impart the required velocity to the projectile without exceeding temperatures and pressures suitable for gun design. In view of the stated weight, dimensional or other limitations or desired characteristics, the apparently optimum combination is selected and the pertinent data, including the pressure-travel curve (see Figure 5-1) and recommended chamber dimensions, are transmitted to the gun designer. The latter then designs the gun in accordance with the data. If the gun designer desires any changes in the data to improve the mechanical design, the proposals are subject to agreement by the ammunition designer before adoption. On concurrence in the tentative design, one or more guns of this design are built, and propellant charges are prepared with such modifications or refinements as are deemed necessary or desirable by the ammunition designer. Test firings are then conducted to determine whether the desired performance and other characteristics have been attained. If the firing test results indicate the desirability of further modifications in the gun or propellant charge, or both, the indicated changes are coordinated and accomplished, and the results checked by further test firings. The modification and test procedures are repeated until a satisfactory combination is obtained.

5-7.3 Estimation of Weight and Granulation of the Charge

The details of methods and procedures of designing a propellant charge are covered in other handbooks of the Series. The following discussion indicates only the basic elements and procedures. The weight of propellant charge must be such as to provide the energy to (1) accelerate the proposed projectile to the desired muzzle velocity (translations and rotational); and (2) supply all energy losses incurred in the firing of the round, with the charge burning under confinement by the gun and advancing projectile, and the resulting gases and residue discharging to the atmosphere as the projectile leaves the muzzle. The losses include the following:

- Energy remaining in the gases ejected from the gun;
- Energy expended in heating the gun and projectile;
- Energy expended in moving the products of combustion and unburned remainder forward behind the projectile;
- Energy expended in separating the projectile from a cartridge case (bullet pull), in engraving of the projectile or rotating band (in rifled bores), and in overcoming friction of projectile passage through the bore; and
- Energy expended in effecting recoil of the gun.

As indicated in paragraph 5-7.1, the characteristics of the gun and propellant charge are interdependent in imparting the desired motion to the projectile. The interdependence of the various factors may be expressed mathematically by a series of equations, but simultaneous solution of the equations become extremely complicated and la-

borious, unless simplified by various assumptions that have been found to be reasonably in harmony with experimental results. In the development of a new gun, the simplified equations are used in a trial-and-error procedure, with assumed quantity, composition, and granulation of propellant, and several assumed chamber volume-bore length-combinations, to obtain an approximation of the total expansion volume necessary to effect required velocity of the known projectile, without exceeding a maximum pressure acceptable for gun or ammunition design. If a maximum permissible gun length is specified, a corresponding bore length may be included in the original calculations, as such a restriction will impose a corresponding minimum volume on the chamber.

When trial calculations indicate that the assumed chamber and weight of charge will produce a fair approximation of required velocity with permissible pressures, several more calculations are made, using the same chamber volume, but varying the weight of charge and "quickness" (burning rate/web thickness) of the assumed propellant, to find the optimum combination for maximum velocity at the desired pressure limit. Repeating this procedure with several variations in chamber size will indicate the most desirable combination of chamber size, weight of propellant charge and propellant granulation to meet the specified requirements with the least possible incurrence of undesirable conditions or characteristics.

The number of trial calculations necessary to approach a satisfactory final solution is reduced by the use of tables compiled from the results of numerous approximate calculations, showing relations between velocity, loading density, gun dimensions, and pressure.

5-7.4 Correlation With Chamber Design

The calculations referred to in paragraph 5-7.3 enable the interior ballistician to determine the optimum chamber volume for a gun that is to satisfy a given set of requirements. The shape of the chamber to provide the required volume then becomes a matter for coordination between the gun designer and the ammunition designer, and the determination of the most satisfactory compromise where opposing preferences occur.

In the gun designer's interest, principal considerations include the following:

The chamber diameter should be kept as small as possible, to reduce the size and weight of gun breech necessary to withstand the propellant pressure.

The chamber length should not be such as to require a cartridge case or propellant bags of length unwieldy to handle, or necessitate undue length and clearances for mechanical loading or ramming devices.

In the ammunition designer's interest, considerations include the following:

Excessive length-to-diameter ratios should be avoided to minimize ignition difficulties, handling and storage problems, and difficulties of manufacture of cartridge cases, if used.

Where metallic cartridge cases are used, excessive taper of main cavity should be avoided to reduce problems of manufacture of cases. Main cavity diameter and taper, and transition and mouth proportions, must be suitable for effecting proper obturation on firing and subsequent elastic recover of case to permit satisfactory extraction.

Where obturation is provided by a cartridge case, the contour of the chamber, which must closely encircle the case, is principally determined by considerations of desirable case contour and length-to-diameter ratio. However, to avoid unnecessary gun weight, all possible consideration is given to keeping the ratio of chamber diameter to projectile diameter at a reasonably low value. Modifications for advantage in gun design must be fully coordinated with the case designer and incorporated only on determination that a case to suit the proposed chamber will function satisfactorily and is practical to manufacture.

In recoilless weapons, the chamber and closure must combine an accurately determined degree of propellant confinement with a precisely sized and proportioned nozzle outlet, in order to produce not only the required projectile velocity but effective recoil-neutralizing forces. It is, therefore, of prime importance that the chamber and nozzle interior size and shape be as specified or approved by the interior ballistician.

CHAPTER 6

GUN DESIGN PROBLEMS

6-1 Similarity and Variety of Design

Chapters 2 and 3 indicate substantial differences between guns for Army purposes, in size, type of construction and mechanism, and method of operation. The extent of size and weight differences is illustrated by the following tabulation of characteristics of three guns of current design.

Weapon	*Length*	*Bore Diameter*	*Weight*	*Weight of Projectile*
Pistol (semiautomatic)	8⅝ in	0.45 in	2½ lb	231 grains
Carbine	2 ft 11½ in	0.30 in	5½ lb	110 grains
Heavy Cannon (280mm)	45 ft	11.00 in	21 tons	600 lb

Variations in structure and mechanism, aside from mere size and weight, stem from differences in type of projectile to be fired, length and height of trajectory, required rate of fire, and type of mount.

The indicated differences involve no departure from the basic definition of a gun given in Chapter 2, but emphasize the wide range of designs resulting from variations in the factors of the design problem. Each weapon presents the combined solutions of a number of problems posed by performance, operation, logistics, and psychological considerations applying to a gun intended for a specific use.

6-2 Problem Elements

Several of the numerous factors affecting the solution of the design problem are identified below, with indications of their significance in effecting a solution. The discussion does not necessarily include all possible factors, but introduces basic considerations essential to military gun design.

6-2.1 Energy Imparted to Projectile

Since the bore and chamber of the gun constitute the confined space in which the propellant expands to drive the projectile through the tube and expel it from the muzzle, the form, dimensions, and necessary strength of the tube and chamber structure are primarily determined by the shape and dimensions of the projectile and the energy required to propel it to the target in the desired manner. The basic approach to design is summarized as follows:

(1) To the known requirements for projectile flight (such as distance, time of flight to target, velocity at target, type of trajectory) application can be made of the calculated effects of gravitational and air resistance forces during flight to deduce the required initial velocity of the projectile (muzzle velocity).

(2) From considerations of trajectory, velocity, air forces, and projectile characteristics, the rotational velocity necessary for the desired degree of projectile stability in flight can be determined. The combination of linear and rotational velocities will yield the appropriate angle of rifling.

(3) Considerations of bore (projectile) diameter, weight of projectile, and anticipated energy losses in the gun and propellant enable determination of a combination of chamber size, bore length, and propellant charge that will effect the necessary pressures on the projectile, during its passage

through the bore, to accelerate it to the required muzzle velocity. Calculated curves of propellant pressure (ordinates) versus projectile travel in the bore (abcissa) are constructed for tentative combinations, and these provide useful means of selection of the optimum combination. The area under the curve, from beginning of travel through the length of bore, represents the work done in accelerating the projectile; while the ordinates provide bases for strength requirements at all sections of the tube and for pressure-resisting parts of the breech closure (see Fig. 5-1).

6-2.2 Accuracy

While the external air forces affecting accuracy of projectile flight to the target cannot be completely neutralized by forces applied to the projectile by the gun, certain features or details of gun design may be employed to reduce or control in some measure the effects of unbalanced air forces.

6-2.2.1 Yaw

If a minimum of variability of flight is to be achieved with a projectile having a length exceeding its diameter, yaw must be minimized. That is, at all times during flight, the longitudinal axis of the projectile must be as nearly coincident as possible with the line of flight, so that, in still air, air resistance forces will be distributed as evenly as possible about the circumference of the projectile. However, even assuming perfect launching, air movement (wind) would effect an unbalance, tending to deflect the projectile from its theoretical path. If the resultant of the unbalanced air forces is ahead of the center of gravity of the projectile, the turning movement may not only increase the yaw, but tend to induce tumbling. To combat these tendencies, the projectile may be provided with fins at the rear to produce a correcting air force moment; or the stability of the projectile may be improved by imparting a spin about the longitudinal axis by means of rifling in the bore of the gun.

If the rifling method of stabilization is used, unnecessarily rapid spin is to be avoided, as excessive stability will cause the axis of the projectile to persist in upward inclination as the trajectory curves downward, thus effecting excessive yaw in the latter portion of the trajectory. Aside from effects on accuracy, a wide angle between the projectile axis and the line of travel may cause failure of such artillery projectiles as depend, for effectiveness, on detonation by nose impact or on penetration of armor or other structural material. To reduce the spin necessary for stability in the earlier portion of the trajectory, the projectile should be discharged from the gun with as little yaw as practicable. To this end, the projectile and bore designs should be so coordinated that: on insertion of the projectile into the rear of the bore, the longitudinal axis is aligned as accurately as possible with the centerline of the bore; sealing of the propellant gases is maintained as the projectile moves through the bore; and contours of the rear of the projectile and gun muzzle (including attachments) are not such as to cause unbalanced gas blast pressures on the rear end of the projectile on emergence from the bore.

6-2.2.2 Whip

Some cannon designed with relatively thin-walled tubes composed of relatively high strength steels have shown marked elastic deflection normal to the longitudinal axis (whip) on firing. Insufficient study has been made to determine what relation exists between tube rigidity and firing accuracy. Pending accumulation of experimental data sufficient to isolate the influence of whip from other sources of inaccuracy, the effect of whip cannot be rationally evaluated.

6-2.3 Erosion

The useful life of a gun depends largely on the ability of the chamber and bore surfaces to resist erosion and abrasion by the hot propellant gases, projectile, and unburned particles of propellant. The deterioration of these surfaces reduces the velocity and accuracy by increasing the effective chamber size, shortening the bore, increasing leakage of gases past the projectile, destruction of rifling, and increasing clearances to aggravate tendencies toward balloting and initial yaw. A short gun life obviously increases the cost of an adequate supply of replacement weapons, including all logistic problems of storage, transportation, distribution, and quick availability in emergency.

Early failure by erosion may be combatted by: use of heat abrasion resistant material for the parts involved, or use of a liner or plating of such

material; by limiting the generated pressures and temperatures to the extent that size, weight, and performance requirements will permit; and by use of such means as are practicable for minimizing the heat absorbed by the interior surfaces of the tube and for increasing the rate at which the absorbed heat can be removed from the critical inner layers.

6-2.4 Firing Rate

In the brief period of burning of the propellant and ejection of the projectile, the high temperature of the gases causes the transmission of heat into the metal at the bore surface more rapidly than it can be transmitted into the intermediate and outer metal of the tube. The metal at the inner surface is consequently heated to a temperature so high that minute particles of softened metal may be eroded and blown out of the bore by the propellant. If firing is repeated before the surface metal has cooled sufficiently to regain normal strength and wear resistance, the weakened metal will be subject to wear by the second projectile, plus firing stresses, and to an additional increase in temperature. Repetition of the cycle at short intervals can result in rapid deterioration of the bore surfaces. The rate of fire is thus an important determinant of the service life of a gun, and a rapid rate should be planned only with due regard for the penalty in reduction of number of effective rounds that may be fired before the tube requires replacement. Where rapid fire is an accepted requirement, the methods of combatting erosion indicated in paragraph 6-2.3 should be carefully considered.

Since the effectiveness of small caliber weapons may depend on the firing of a large number of projectiles in a short time, and since relatively small, light projectiles are more readily handled either manually or by rapid automatic mechanisms, the rate of fire is a matter of greater concern in small arms and small caliber automatic cannon than in the larger caliber weapons. Moreover, in the relatively thin-walled barrels of small bore guns, there is less heat-absorbing metal per unit of bore surface, so a given thickness of excessively heated metal about the bore effects a greater proportionate loss in stress capacity of the small-bore type of barrel than in those of larger caliber. From these considerations, among others, the allowance for thermal effects included in determining barrel thickness by small arms procedure is greater than that used in cannon procedure.

6-2.5 Weight

The weight and center of gravity of a gun must be considered in connection with the manner of transport and use. In shoulder- or hand-supported guns, weight and its location are prime factors in governing the amount of energy to be absorbed by the firer, and the amount and direction of deflection of the gun from the line of sight on firing. Other factors being equal, velocity of recoil and amount of "jump" decrease with increasing weight and closer alignment of bore axis, center of gravity and center of support. However, greater weight decreases ease of carrying and handling, and some degree of nonalignment of bore and support simplifies practical solution of the sighting problem. The most advantageous compromise between opposing considerations should be sought in each case.

Similarly, in cannon and other mounted guns, stability in firing is favorably affected by increased weight and by reduction of moment arms between bore axes, centers of gravity, and supporting and recoil-resisting forces. However, where mobility is a desired characteristic, minimum practical weight of the complete weapon is desirable, and the designs of the gun and mount or carriage should be coordinated to obtain the optimum overall solution for the intended use. When the mount or carriage includes a recoil mechanism (to reduce the firing forces applied to ground or supporting structure), the weight and location of center of gravity affect: (a) the length of recoil and resisting forces required; (b) the energy needed for counterrecoil movement of the recoiling parts; and (c) the supporting forces necessary for stability throughout the recoil and counterrecoil movements at all contemplated angles of gun elevation. Since the weight characteristics are essential factors in design of the carriage or mount, the carriage designer is submitted a tentative design of gun tube and parts carried thereon, with pertinent weight data, for coordination prior to completion of details. In formulating the tentative design, considerations of weight and its distribution will normally yield precedence to those of strength, performance, operation, etc.; within the latitude permitted by other factors, the center of gravity should generally lie on or near the axis of the bore

and as far rearward as is feasible. However, weight not otherwise needed should not be incorporated for the purposes of increasing inertia or shifting the center of gravity, unless coordination with carriage design indicates such addition to be advantageous.

6-2.6 Safety

Safety in guns is of two-fold importance. Obviously, guns properly designed for safety in operation are more dependable in performance, so that a smaller number are necessary to insure accomplishment of a given mission. But in addition, the safely-operable weapon not only reduces the likelihood of injury to its operators, but engenders confidence and morale favorable to efficient operation. Specific points to be considered follow:

(1) Provision of a method of loading that permits rapid operation with minimum physical effort and minimum possibility of injury in the procedure.

(2) Adequate locking or interlocking devices to prevent unintentional firing of the weapon, or to prevent any violation of proper sequence of the operating cycle in such manner as to cause damage to the equipment or endanger personnel. These devices may be mechanical or electrical, as best suited to the means of weapon operation.

Examples include: "safety" levers or slides that block operation of firing mechanisms unless moved to firing position; mechanical interlocks that prevent mechanical ramming unless the breech is fully open, or that prevent the firing mechanism from functioning unless the breech is closed and locked; and electrical firing circuits that remain open and inoperative until closed by completion of breech locking. Thorough control of the firing mechanism is particularly important, to prevent possibility of igniting the propellant before it is adequately confined in the chamber, or while being removed after a misfire, or on termination of firing. Automatic breech opening devices should also remain inoperative while an unfired propellant charge remains in the chamber, so that, should a hangfire occur, the delayed explosion may be normally confined rather than be free to blast through the opened breech.

(3) Adequate tube strength to prevent failures from pressures generated by propellants. This requires not only adequate design for a new gun to withstand all stresses generated by firing ammunition that develops the design pressures, but provision of sufficient factor of safety to cover unavoidable variations. These include: variations in ammunition, from manufacturing tolerances or from changes in properties occurring in periods of storage; unavoidable variations in tube properties, arising in manufacture; and deterioration of the tube from combined effects of heat, erosion, chemical effects, and progressive failure starting at minor cracks, inclusions, or other types of stress raisers.

Avoidance of rupture of a tube in service is of major importance, since such a failure involves serious danger to the operators and to nearby equipment; and it completely disables the weapon in a manner not correctable in the field, unless the weapon has been specifically designed for field tube replacement.

(4) Minor mechanical failures. A high degree of reliability of operation of all mechanical parts is of prime importance in guns intended for use against enemy personnel. Failure of a minor component can make the weapon inoperative in circumstances where neither time nor replacement parts are available to remedy the deficiency, and the defection can jeopardize not only the operating individual or group, but others involved in the same action.

6-2.7 Obturation

With few exceptions, satisfactory performance and service life of guns are dependent on effective sealing of the breech against rearward escape of propellant gases.

In guns using cartridge cases, a seal is effected by pressure-expansion of the case against the closely-fitting containing chamber surface, while the bolt or breechblock of the gun blocks the closed rear end of the case against rearward ejection. Contour, finish, and clearance of the chamber must be such that the case, when propellant pressure decays, can be withdrawn rearward without excessive effort.

In guns not employing a cartridge case, another form of seal must be provided between the closing member (breechblock) and the tube. The sealing member must be capable of rapid sealing and unsealing as pressure is applied and released; retain its elastic properties under high rates of loading

and in extremes of field temperatures; withstand high temperatures and pressures; and should have high degrees of durability and freedom from deterioration in storage. A design completely fulfilling all these requirements to the desired degree has not been produced to date, and better materials and improved devices are being continually sought.

6-2.8 Blast and Flash

Since it is impractical to obtain complete combustion of the propellant within the gun, or to approach complete use of the pressure generated, the propellant gases emerge from the muzzle with high velocity and at fairly high temperature. If appreciable combustion persists as the propellant emerges from the muzzle, flash will be evident; and if the temperature is sufficiently high the flash may be augmented by further combustion of gases by combination with atmospheric oxygen

6-2.8.1 Blast

Excessive blast can cause distress and reduced efficiency of the operators, and may have unfavorable effects on adjacent personnel and equipment. Obscuration of the vision by violent projection of combustion products into the atmosphere, and by dust raised by air disturbance, may prevent effective aiming of successive shots, as well as indicate position to the enemy. Current means of reducing these effects consist of muzzle attachments of various designs, called blast deflectors, that serve to divert considerable portions of the blast to right and left, reducing the upward and downward air disturbance (see Figure 6-1).

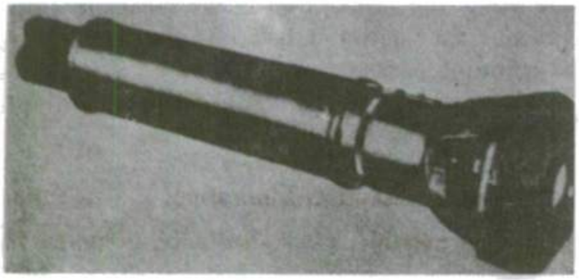


Figure 6-1. Combination Blast Deflector and Muzzle Brake, With Evacuator Chamber

6-2.8.2 Flash

Visible flash also serves to betray position to opposing forces, and produces a blinding effect unfavorable to a rapid succession of aimed shots. Flash may be combatted by muzzle attachments of either the "flash hider" type (Figure 5-2) or the "flash suppressor" type (Figure 5-3) or an attachment combining these two types may be used. The two types are described in Chapter 5.

6-2.8.3 Muzzle Brakes

Where both blast deflection and reduction of recoil energy are desired, both effects may be obtained by use of a muzzle attachment designed to turn and deflect a large portion of the muzzle blast sideward and rearward (Figure 6-1). The blast-deflecting vanes, in such case, are designed to receive as much forward pressure as is practicable from the gases, and this pressure becomes effective in reducing the net recoil impulse imparted to the gun by the propellant gases.

6-2.9 Bore Evacuation

In some cannon installations, notably tank and other vehicular mounts, it is necessary to prevent rapid contamination of air in the firing compartment by propellant gases emerging rearward from the bore when the breech is opened. Some large caliber weapons using separated ammunition have been equipped with a compressed air system arranged for discharge of air through the bore to sweep out residual gases before opening the breech. Need for a simpler and less space-consuming system for vehicle installations prompted development of the currently used "evacuator" (Figures 6-1 and 6-2). This system utilizes a cylindrical jacket fitted around the gun tube near the muzzle so as to form an annular chamber outside the tube, and a series of small drilled holes through the tube wall for restricted flow of gas between the gun bore and the annular chamber.

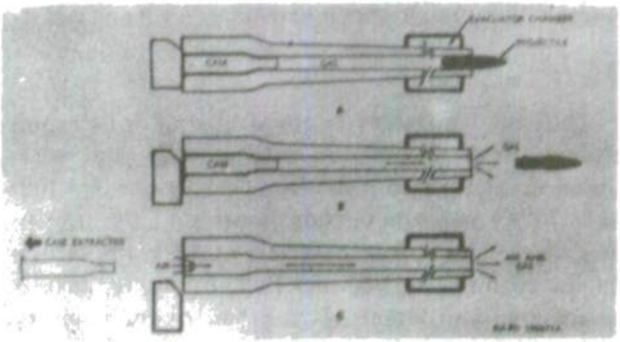


Figure 6-2. Schematic Diagram of Bore Evacuator Operation

When the projectile passes the holes, a portion of the propellant gas passes into the chamber creating a considerable pressure. When the projectile leaves the muzzle the major portion of the propellant gases follow, and pressure in the bore drops below that in the evacuator chamber. The gas content of the chamber then discharges through the drilled passages into the bore and thence out the muzzle, the passages being inclined inward toward the muzzle to obtain a jet action. Meanwhile the breech starts to open, and the jet discharge at the muzzle induces a flow of air into the breech and forward through the bore. Size and location of the evacuator chamber and passages must be carefully determined to obtain effective flow in proper timing with breech opening action.

6-2.10 Space Limitations

The desirability of minimum practical bulk in all guns assumes major importance in weapons intended for mobile mounts, and particularly for installation in tanks, aircraft, or other vehicles where internal space is limited by the necessity for presenting the smallest possible overall silhouette and maintaining a high degree of mobility. An increase in size of the gun or of the space necessary for its operation is reflected in increased area, hence increased weight, of armored enclosure. This in turn requires a larger and heavier vehicle for support, and greater power to provide desired mobility. Hence, a relatively moderate reduction in space requirements for the gun may effect a significant saving in the overall weight of the complete weapon, decrease its vulnerability, and so reduce both the cost per complete weapon unit and the number of units required to maintain a given degree of military effectiveness.

6-2.11 Temperature

The wide ranges of temperatures at which guns are required to function satisfactorily and withstand storage without damage (extreme range 150° to −70°F) necessitate consideration of the properties of the structural materials at all temperatures in the required range. Further, for tubes, barrels, chambers, and other parts that directly or indirectly absorb heat from the propellant, the effects of temperatures attained from this cause must be taken into account. The importance of this operating temperature rise increases with the rate of firing, as the cooling interval between shots decreases correspondingly. Temperature rise generally increases also as bore diameter decreases, as the latter is normally accompanied by decrease in tube thickness and consequent decrease in the quantity of metal absorbing and dissipating heat from each unit of bore area. Hence, temperature rise becomes a major consideration in the design of automatic rifles and machine guns in the small arms category, and of automatic and semiautomatic cannon in the lower range of bore diameter.

In addition to the effects of temperature on the mechanical properties of materials, the differences in coefficients of expansion with temperature require consideration when unlike materials are used for contiguous or closely clearing parts. Care must be exercised to avoid the possibility that differential expansion or contraction within the design temperature range may cause looseness, or excessive stresses, misalignment, binding or interference of parts, or other conditions preventing satisfactory functioning or endurance.

6-2.12 Manufacturing Limitations

To insure full effectiveness of a particular gun design, the relative number to be produced should be considered in connection with the manufacturing operations necessary to produce it, and available facilities for performing the operations. Requirements for operations requiring special types of production equipment, unusual techniques, and difficult degrees of accuracy should be minimized, particularly for large production items, in order to broaden the field of industrial plants capable of production of parts or complete items without incurring excessive waste of man-hours and material through rejections of defective items.

6-2.13 Strategic Material Limitations

So far as possible, guns should be designed for construction with materials that will be available in sufficient supply under war conditions. Where practical, designs should be suitable, or readily modifiable, for effective use of alternative or substitute materials of better availability, when such procedure becomes necessary to improve the balance of national supply and demand for materials or production facilities.

6-2.14 Logistic Requirements

The need for rapid mobility in modern tactics, and the high demands on national supply and transportation resources make it highly desirable to avoid unnecessary bulk and weight. Hence, the military requirements for proposed weapons normally include not only the desired performance characteristics, but limitations on weight and overall dimensions. These are particularly important where transportability by air is required. The need for minimizing demands on transportation, production, and storage facilities also emphasizes the importance of designing for high dependability and long service life, in order to minimize the need for replacement items and parts.

6-2.15 Maintenance Requirements

For high and continued effectiveness of the gun in field use, it is important that the operation, maintenance, and servicing be as simple as possible, and not require highly skilled personnel, nor laborious and time-consuming procedures. Standard tools and equipment should be utilized as far as is practicable, and any special equipment necessary should be as simple and compact as adequacy permits. Maintenance considerations are given more fully in Reference 13.

6-3 Balanced Solution

Obviously, some of the factors and characteristics indicated above are in opposition to others, and achievement of one characteristic in the desired degree may require the sacrifice, in some degree, of other desired characteristics. For example, higher velocities (or shorter times of flight), desirable for antiaircraft and antitank guns, involve higher pressures and temperatures that not only necessitate stronger and heavier structures, but increase bore erosion to reduce the useful life of the weapon. Design of a gun requires adjustment between opposing factors. Each new weapon should present a combination of satisfactory or acceptable solutions of a number of problems in the mandatory or preferential areas, achieved with the least possible incurrence of undesirable conditions in the opposing areas. The balance effected obviously will depend on the relative importance assigned to the various factors in the design project, in accordance with the purpose and conditions of use of the weapon.

6-4 Reasons for New Weapons

In military operations, as in production of commodities for peaceful consumption, the effectiveness of manpower depends to a large extent on the mechanical aids used to increase, concentrate and apply that power. Hence, it is essential, for effectiveness of the national defense, that new designs be continually developed for improvement in both weapon effectiveness and the relation between effectiveness and overall cost in man-hours of labor. Factors prompting new weapon design include the following:

(1) The using services require a weapon having a new combination of characteristics to implement new concepts or developments in tactical operations.

(2) New developments in projectiles or in propellants require new or modified gun designs for proper utilization.

(3) Appropriate improvements in attainable solutions in one or more of the problem areas indicated in paragraphs 6-2 through 6-2.15. These improvements may be realized from:

(a) Extension of knowledge resulting from research and development programs. Fields of possible gain include: new materials, alloys, or mixtures having favorable characteristics or behavior; new developments in shaping processes, or in treatments of conventional materials to improve their behavior under conditions of gun usage; more accurate methods of evaluating the stresses and destructive factors produced in gun operation, and of reducing or counteracting their effects; and new or improved methods of detection of latent material defects, that may enable reduction in design safety factors without increase in the risk of failure of materiel accepted for service.

(b) Ingenuity of designers. Designers may evolve new arrangements, mechanisms, or component details that present improvement in ease, speed, or safety of operation, effectiveness of reliability of function, length of service life, elimination of excess weight, or economy of production or maintenance.

(c) New manufacturing processes. New procedures or processes in the production of semi-

manufactured materials (such as forgings, castings, extrusions), may make feasible a redesign for more efficient use of the improved material. New or improved methods of forming, shaping, or fabrication (casting, welding, machining, extrusion, etc.) to required contours and dimensions may enable a new design to reduce the number of parts or operations, or effect other savings in production costs.

GLOSSARY

ammunition. General term denoting all items expended in firing a gun, excluding the gun itself, but including the complete projectile, propellant, primer, case, and other components contributing to the firing operation and completing their service life by functioning only once.

automatic. As applied to firearms: Having an action that is initiated by manual operation to fire the first round, and thereafter continues to reload, fire and eject (cases), under power derived from the ammunition, until the supply of ammunition to the gun mechanism is interrupted or operation is stopped by a mechanical control.

barrel. The major unit (tube) of a gun, the bore of which guides the projectile during its acceleration to exit velocity. The term is preferred for use in reference to small arms. In most current designs, the barrel also contains the cartridge chamber (revolver types are a notable exception). *See:* **tube.**

bolt. A type of breechblock, principally used in small arms, characterized by elongation in the direction of the barrel axis and opening and closing travel parallel to the barrel axis.

bore. In reference to guns, the passage within the gun tube or barrel through which the projectile is driven by the propellant. The term is applied to both the space and the bounding interior surface of the tube.

breech. The rear part of the bore of a gun, especially the opening that permits the projectile to be inserted at the rear of the bore.

breechblock. The component that is moved to and from the rear opening of the gun chamber, to block the opening for firing and to expose the opening for case extraction and reloading.

breech mechanism. The combination of mechanical devices that accomplishes the opening and closing of the breech and the firing of the round. Incidental functions included, as required, are insertion of the cartridge, extraction and ejection of the case, obturation, and necessary safety interlocks.

breech recess. Cavity within the breech ring of a cannon, at the rear of the tube, designed to properly confine the breechblock at closed position and permit the necessary breechblock opening and closing movements.

breech ring. Structural member screwed or shrunk onto the breech end of a cannon tube, to house the breechblock and support other parts of the breech mechanism. It may provide lugs for connection to a recoil mechanism.

bullet. A small projectile. Use of the term is generally limited to small arms projectiles.

caliber. The magnitude of the diameter of the bore of a gun tube or barrel, or (nominally) the diameter of a projectile. The term does not denote chamber diameter and excludes depth of any rifling grooves. It is frequently employed as a unit for gun length; that is, the gun length in calibers expresses the ratio of gun length to bore diameter. To clarify proportions, the chamber diameter and length are also sometimes expressed in calibers.

cannon. *1.* A gun having a bore larger than the limit assigned to small arms, and supported by a mechanical structure in firing. *2.* The "shooting" part of a gun as in *1.*, including tube (or barrel), breech opening and closing mechanism, firing parts and muzzle attachments.

carbine. A small arms gun, hand-supported and shoulder-fired, resembling a rifle, but of shorter barrel, lighter weight, and lower power.

cartridge. A round of ammunition in which the primer and propellant components are contained in a case affixed to the projectile, the assembly being stored, shipped, handled and loaded into the weapon as a unit; a round of fixed ammunition.

cartridge case. The container for the primer and propellant of a cartridge, or of the cased portion of semifixed or separated ammunition.

chamber. That portion of the interior of a gun in which the propelling charge is placed.

choke bore. A gun bore diminished in diameter near the muzzle to reduce the lateral spread of pellets. A characteristic of some shotguns.

density of loading. The weight of propelling charge per unit of volume of chamber with the projectile seated in firing position. It is commonly expressed in grams per cubic centimeter.

firing mechanism. In guns, the mechanism whose action effects the ignition of the primer that ignites the propellant.

fixed ammunition. Ammunition in which the primer and propellant are contained in a cartridge case firmly attached to the projectile, forming a round to be handled and loaded as a unit; a cartridge.

forcing cone. A slightly conical passage from the chamber to the bore, into which the projectile is firmly pressed or rammed in loading to prevent escape of propellant gas past the projectile before the increasing gas pressure drives the projectile fully into the bore.

gun (General). A projectile-throwing device comprising a guiding tube through which a projectile is propelled toward a target by force, with an incorporate or connected reaction chamber in which the chemical energy of a propellant is rapidly converted into hot gases which expand to propel the projectile at a high velocity.

gun (Specific). A complete weapon of cannon caliber, with mount and all equipment, designed for high velocity, relatively long range and flat trajectory.

howitzer. In Army supply usage, a complete weapon of cannon-size bore, with mount and all equipment, designed for medium velocity and medium curvature of trajectory of projectile to target.

liner. An inner tubular member inserted in a gun tube or barrel to improve resistance to corrosion, erosion, heat effects and abrasion, or to provide a practical means of replacing an unserviceable bore surface. Any contribution to structural strength of tube or barrel is considered incidental. A liner may include the entire length of the bore or any portion of bore length.

machine gun. A gun of small arm bore diameter, capable of automatically reloading and firing rapidly a series of shots of indefinite number, extracting the rounds from a belt of no arbitrary limit of length. May be mechanically supported for firing.

mortar. A complete weapon of cannon-size bore, with mount and all equipment, designed for low velocity projectile and highly arched trajectory to target.

muzzle. The forward end of a gun tube or barrel.

pistol. A short-barreled gun designed to be held and fired by one hand. Capacity may be one or more rounds per loading, and operation may be manual, semiautomatic or automatic.

primer. A relatively small and sensitive explosive assembly employed to ignite the propellant charge in a gun. The primer may be designed for actuation by one or more methods, including percussion, electric current, friction, etc.

projectile. A body propelled by a gun toward the object or area on which impact is desired.

propellant. A low explosive substance or mixture whose combustion produces the hot gases that propel the projectile through the gun bore.

range. The distance to which a gun can, or does, propel its projectile; also the distance from a gun to its target.

receiver. A principal structural unit of a firearm, particularly of small arms, which supports the breech end of the barrel, houses the breech opening and firing mechanism, and serves for attachment of stock, handle, or other support feature.

recoilless gun. A gun, with mount and all equipment, designed for practical neutralization of weapon recoil by forward thrust on the gun produced by rearward discharge of a portion of the propellant gas.

rifle. A gun of relatively long barrel having a rifled bore. The term is most commonly applied to hand-supported, shoulder-fired small arms weapons characterized by high velocity and accuracy, but in some instances is used to designate a cannon with a rifled bore.

rifling. The helical grooves cut in a gun bore to

impart rotation to the projectile about its longitudinal axis as the projectile is impelled through the bore.

rotating band. A band of soft metal about the circumference of a projectile, which, on being forced into the bore, is deformed to fit the rifling, and so (1) seals against the escape of propellant gas past the projectile, and (2) follows the twist of the rifling to impart spin to the projectile as it moves forward through the bore.

round. All ammunition components needed to fire a gun once (also termed a *complete round*).

semiautomatic. As applied to guns, the term commonly indicates that operations of case ejection, reloading and cocking are automatic, but each round is fired only by an individual manual operation of the trigger or equivalent releasing device. Also used to indicate a mechanism in which some portion of the complete cycle of operations is automatic and the remaining operations are actuated manually or by other external power.

semifixed ammunition. Ammunition in which the cartridge case and projectile are joined for handling and loading as a single unit, but separable for adjustment of propelling charge.

separate loading ammunition. Ammunition in which the projectile, propellant, and primer are separate components of a round and are separately loaded into a gun.

separated ammunition. Ammunition in which the primer and propellant are contained in a cartridge case not attached to the projectile.

small arms. In application to guns, those having a bore (projectile) diameter not larger than an arbitrarily assigned limit (currently 30 millimeters).

squeeze bore. A gun bore tapered to progressively reduce the diameter of a single projectile as it advances toward the muzzle.

trajectory. The path traversed by a projectile after its departure from the gun muzzle.

tube. The major unit of a gun, the bore of which guides the projectile during its acceleration to exit velocity. The term is preferred for use in reference to cannon. In the commoner cannon types the tube also contains the chamber. *See:* **barrel.**

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* See inside back cover for information on handbook designation.

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