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Naval Ordnance and Gunnery

NAVPERS 16116

PREPARED FOR TRAINING IN NAVAL ORDNANCE AND GUNNERY

Bureau of Naval Personnel
Training Division
May, 1944

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PREFACE

Improvements in naval ordnance and fire-control methods have been so numerous and comprehensive since the opening of hostilities that the need for a new instruction manual became apparent to officers teaching ordnance and gunnery at Naval Reserve Midshipmen's Schools. Officers in charge of the Standards and Curriculum Section, Training Division, Bureau of Personnel, likewise recognized the need for a manual which would represent the standardized curriculum of these schools. Accordingly, in June, 1943, the preparation of "Naval Ordnance and Gunnery" was authorized, and authors were selected to prepare the manuscript.

The first part of the following manual deals largely with naval weapons, and is intended to provide the student with a basic conception of gun design and construction. Emphasis is given to the specific guns that graduates of Naval Reserve Midshipmen's Schools are most likely to encounter upon joining the Fleet. The second part of the manual is concerned with fire control, including the surface and antiaircraft problems. In this case the emphasis is upon director control principles and the particular systems in common use.

The original manuscript was prepared by the following authors: Lieut. Comdr. Orval H. Polk, U.S.N.R. of U.S.N.R.M.S., Columbia University; Lieut. Ernest H. Dunlap Jr., U.S.N. of U.S.N.R.M.S., Notre Dame University; and Lieut. Frank L. Seyl, U.S.N.R. of U.S.N.R.M.S., Northwestern University. Advantage is taken of this opportunity to acknowledge the fine work of these capable and enthusiastic officers.

The manual was edited by Lieut. Fred L. Fitzpatrick, U.S.N.R., and Lieut. (j.g.) H. E. Shaw, U.S.N.R., Standards and Curriculum Section, Training Division, Bureau of Naval Personnel.

The authors worked at the U. S. Naval Academy. Captain Duncan H. Curry, U.S.N., Head of the Department of Ordnance and Gunnery, made the facilities of his organization freely available. Comdr. H. F. Agnew, U.S.N., was particularly generous in supplying aid and encouragement. Various portions of the manuscript were reviewed and criticised by Comdr. F. V. H. Hilles, U.S.N., and Lieut. Comdr. E. W. Foster, U.S.N. (Ret.).

Acknowledgment is also due to Captain M. R. Kelley, U.S.N., of the Bureau of Ordnance, and to Comdr. Alvin C. Eurich, U.S.N.R., and Comdr. Carlton R. Adams, U.S.N., successively Officers-in-Charge, Standards and Curriculum Section, Training Division, Bureau of Naval Personnel, whose support of the project made the completion of this manual possible.

Recognition of various subject material sources is also in order. Much of the material has come more or less directly from publications of the Bureau of Ordnance. In addition, publications of the General Motors Corporation have been drawn upon in the case of the 20 mm. and caliber .50 guns. Considerable use was made of ordnance department notes compiled at the U. S. Naval Academy and the various Midshipmen's Schools. Illustrations were prepared at the U. S. Naval Training Aids Development Center, New York City, under the immediate supervision of Lieut. (j.g.) Eugene Wasserman, and Lieut. (j.g.) J. S. Virostek.

Suggestions for improvement of the manual are invited. Some of the copies have been bound in loose-leaf form to facilitate revisions that may be made necessary by changes in equipment and design. Although the manual was prepared primarily for use at Naval Reserve Midshipmen's Schools, and represents the ordnance and gunnery curriculum of these institutions, its form permits easy addition or elimination of subject material so as to widen its scope of usefulness.

EDWIN L. BRASHEARS,
Lieutenant Commander, U.S.N.R.

May, 1944.

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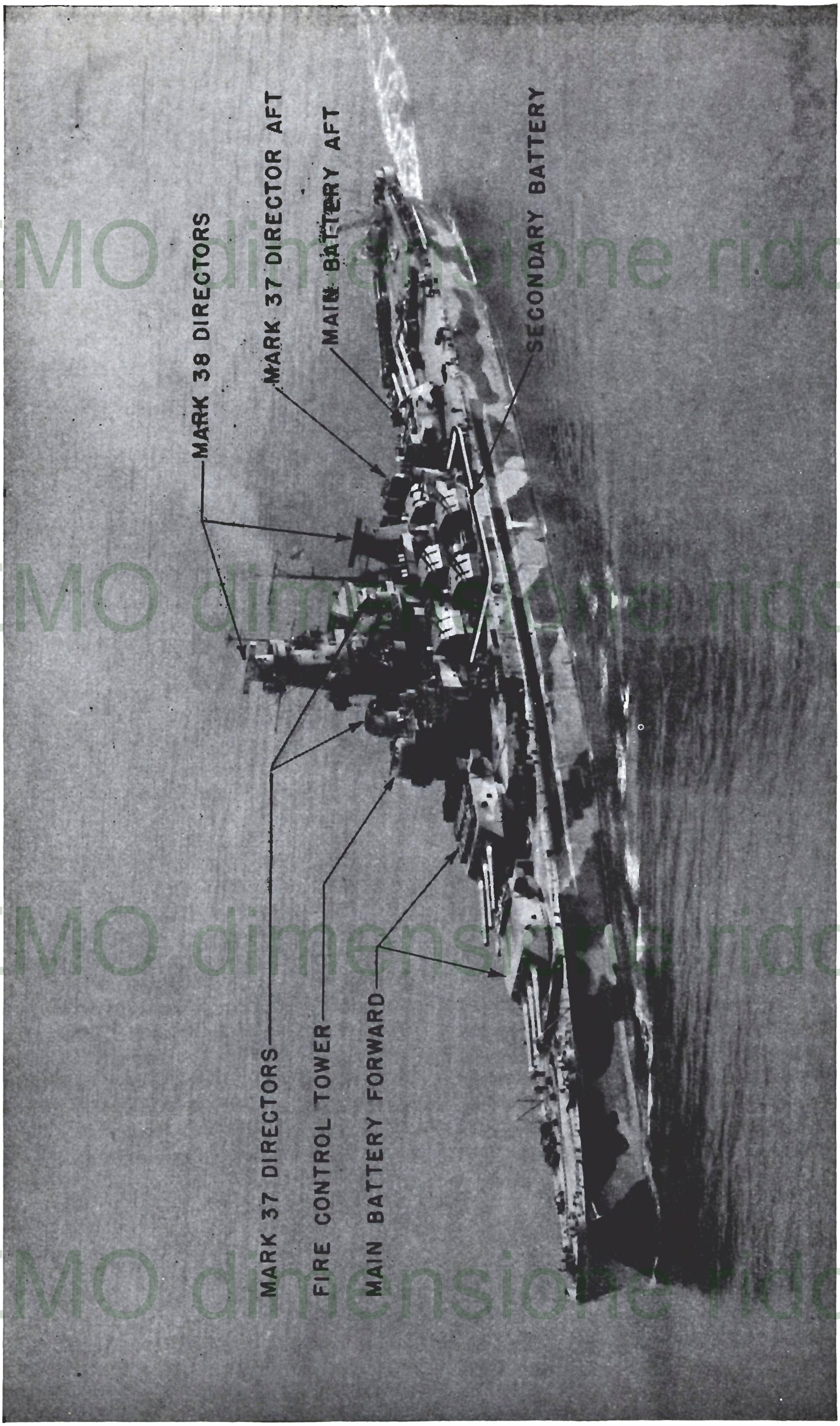


Figure 1-1. Arrangement of guns on a battleship.

CHAPTER 1

INTRODUCTION TO WEAPONS

1–1. Function of the gunnery department. The effectiveness of a navy must ultimately be gauged by its ability to damage and destroy the enemy. Success in such a venture depends upon various weapons, which aboard ship, are under supervision of the *gunnery department.* Officers and men in this department are primarily concerned with that care and use of armament which will enable the ship to deliver the most effective blows.

1–2. Ordnance. The term ordnance includes weapons and the control equipment used to operate them. The Bureau of Ordnance of the Navy Department supervises the manufacture, installation, upkeep and operation of all naval ordnance.

1–3. Gunnery. Weapons are tools of offense or defense, but are useless without proper application. Strictly speaking, *gunnery* is the art or science of using guns. As the term is employed in this discussion, however, it includes the handling of all armament. An understanding of the weapons and their capabilities is implied, as well as intimate knowledge of the methods and equipment used in controlling them.

1–4. Scope of text. Nearly every naval officer will have some association with guns, while a smaller number will work with torpedoes, mines and depth charges. This manual emphasizes guns and their control, because specialized training usually is provided for those who must have an intimate knowledge of other weapons. The chapters which follow, then, do not represent a book of reference, but rather an introduction to the broader aspects of ordnance and gunnery.

The descriptions of equipment presented therein are primarily designed to show functional operations. They are not intended for use by maintenance personnel, but are to acquaint officers with the operation and use of the equipment they may some day supervise. Discussions pertain strictly to U. S. Navy equipment, although in a few cases they also are applicable to items of Army ordnance.

1–5. Presentation of the subject. Any practical treatment of weapons and their control cannot be sharply divided into sections on ordnance and gunnery. It is practically impossible to study the structure of ordnance mechanisms without giving some thought to their functions; likewise, the successful study of gunnery is dependent upon thorough understanding of the guns and instruments concerned. In this book a compromise has been effected; the first part concentrates upon a study of weapons with minimum reference to control, the second part is largely concerned with fire control.

1–6. Study hints. It is suggested that the student read an assignment rapidly to obtain a general concept of the subject matter. It is better not to linger on a troublesome paragraph during the first reading, for frequently subsequent statements provide the necessary clarification. After the first reading, a thorough study of each article, a paragraph at a time, will usually produce the desired results. The student is warned, however, that ordnance and gunnery cannot be learned successfully by memorizing descriptions. The real key to success is understanding of functions, which in turn depends upon knowledge of the structures which make these functions possible.

Study of actual equipment is also a vital phase of the learning process. Insofar as possible, the inspection and operation of such equipment should be coordinated with study of appropriate sections of the manual.

1–7. Naval weapons. Among the weapons used in naval warfare are (1) guns, (2) torpedoes, (3) mines, (4) depth charges, (5) bombs and (6) chemicals.

Guns. Nearly all naval vessels and aircraft carry guns of some type. In time of war even merchant ships are so equipped, their weapons usually being manned by naval crews.

Developments in the manufacture of explosives and guns have greatly increased the destructive power and effective range of naval weapons. The 16-inch guns of some battleships can throw a projectile weighing more than a ton to distances of about 40,000 yards with reasonable accuracy. The general location of guns aboard typical ships is illustrated in figures 1-1 to 1-3.

Torpedoes. Torpedoes are the principal weapons of destroyers, submarines, torpedo planes, and PT boats. The modern version is a development from an early form in which an explosive on the end of a spar was placed against the hull of the target by a small boat or a submarine. Times have changed, however, and today a torpedo carries a very heavy charge of high explosive, and when properly launched, propels itself through the water at high speed and under accurate control to distances of 6 or 7 miles.

Mines. Mines are passive weapons which float in the water or rest on the bottom and explode when a target comes within range. They contain large charges of high explosive, and provide barricades against enemy entrance of harbors and other areas. Mine fields may also be planted so as to surprise the enemy in a place where his future presence may be anticipated, or they may be laid in the path of an enemy force causing it to maneuver to a disadvantage. These weapons are normally placed in position by mine layers, but they may also be planted by destroyers, cruisers, submarines, planes or partol craft.

Depth charges. Depth charges are weapons developed expressly for attacks against submarines. The name comes from the original form of depth charge, which was designed to explode at a definite depth in the water. The destructive effect of such a charge may be considerable even though the explosion occurs several yards from the target. Depth charges are carried by destroyers, patrol craft, destroyer escorts, and some cruisers.

Bombs. The several types of missiles (except torpedoes and mines) dropped from planes are usually classed as bombs. Since this text is designed for deck officers, they are not discussed in detail.

Chemicals. Various chemicals are available for attacks upon personnel, for hindering visibility, and for initiating fires. The specialized subject of *chemical warfare* deals with the use of these chemicals and the protective measures to be taken against them. Most phases of chemical warfare do not lend themselves readily to naval employment, although an obvious exception exists in the case of screening operations.

1–8. Ballistics. Ballistics is the science of projectile motion. Volumes have been written on the subject; only an introduction thereto is attempted here. The naval officer necessarily is interested in applying the results of the ballistician's work, just as he employs results obtained by mechanical and electrical engineers, physicists, and chemists.

The general subject of projectile motion may be divided into *interior* and *exterior ballistics.* Interior ballistics considers motion of the projectile within the bore of a gun. The gun designer must understand this subject so that he can build a gun which will expel the projectile at a specified muzzle velocity. Planning for such a result involves not only the interior shape of the gun, but also the type of powder, and many other factors over which the deck officer has no control. The primary interest of the naval officer in interior ballistics is the velocity with which the projectile leaves the bore.

The action of the projectile after it leaves the gun is a matter of exterior ballistics. The projectile is subjected to a number of influences which affect the path it will follow. The nature and magnitude of these influences are important to any officer in gunnery, but the actual analyses of the phenomena are problems for the ballisticians.

1–9. Fire control. The practical application of exterior ballistics, and the methods and devices used to control the guns (and other weapons) are included in the subject known as *fire control.* The latter part of the book deals with this subject in some detail, but a few items of fire-control equipment are briefly described here to provide the student with a more inclusive mental picture of the ordnance equipment found aboard most ships.

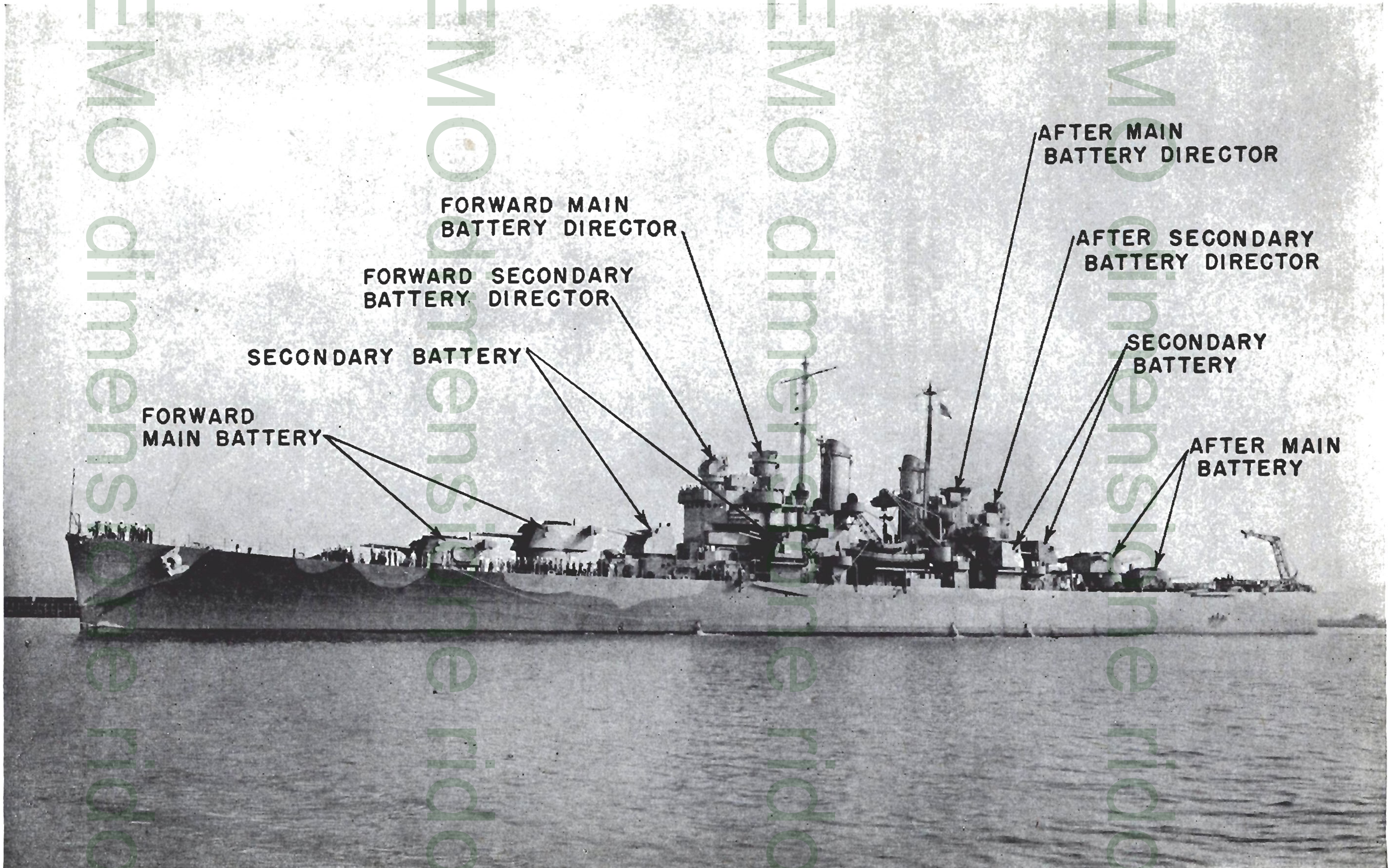


Figure 1–2. Arrangement of guns on a cruiser.

Range finders are optical instruments used to measure the distance to the target.

Directors are mechanical and electrical instruments which control guns from a distant location. This position is generally located at a higher level than the guns to provide greater visibility.

Range keepers and *computers* are mechanical and electrical instruments which automatically compute information needed to direct gunfire.

Visual indicators are electrical devices which receive certain standard orders and information from a remote control station. The transmitted information appears on dials at the receiving station.

Stable elements are gyroscopically controlled mechanisms which measure movement of the ship with respect to the true horizontal plane, and are employed to increase the accuracy of gunfire.

1–10. Identification of ordnance equipment. Each assembled unit of ordnance equipment is identified by a name, a *mark* number, often a *modification* number, and a *serial* number. This information is stamped either on the equipment itself or on an attached plate. Whenever a basic change in design is made a new mark number is assigned. Modification numbers are added when there has been a minor alteration of design. Individual units of identical design have the same name, mark, and modification numbers, but have different serial numbers.

An example will help to illustrate the use of this identification system: Range keeper, Mark 1, Mod. 0 is the first range keeper designed. Units built to this design are assigned serial numbers. Range keeper, Mark 1, Mod. 1, is similar to the Mark 1, Mod. 0, but has a slight modification. Each range keeper built to this design has a different serial number. From these facts it can be seen that range keeper, Mark 7, Mod. 5 is built according to the fifth modification of the seventh basic design.

In referring to a piece of ordnance, the information required for identification depends upon the circumstances. For example, if reference is made to functions only, the name, mark and modification will be sufficient. If, however, spare parts are requested from the Bureau of Ordnance, the serial number may also be necessary. This number, together with mark and modification numbers, identifies the specific unit involved, and enables the factory to refer to its manufacturing records for precise information.

To consider a further example, a gun mount has a mark and modification number. It also has an *assembly number*. All three of these items should be noted in requesting replacement parts. Within a given mark and modification there may be various assembly numbers, each representing the fact that some component parts differ from components listed under other assembly numbers.

The name of a gun includes its bore diameter. Thus, we find the designation: 5-inch gun, Mark 1, Mod. 2; or 3-inch gun, Mark 21, Mod. 1. There is a separate series of mark numbers for each caliber of gun.

1–11. Knowledge of matériel. Operation of some ordnance equipment calls for relatively detailed knowledge. Such details have been included in this manual but an effort has been made to present them in understandable fashion. An officer must be well acquainted with his equipment, as the following quotation from the *Bureau of Ordnance Manual* testifies:

> "One of the greatest detriments to progress is a tendency on the part of personnel to simply follow general directions and to investigate only where troubles have forced investigation. Results obtained will lead to misdirected effort and erroneous conclusions when the users of matériel fail to equip themselves with detailed and thorough knowledge of the mechanism with which they work. This can only be obtained by hard work, study of pamphlets, blueprints, and ordnance circular letters, etc., without tearing down the material. The starting point, therefore, on the part of officers is a thorough study and understanding of all details of the mechanisms assigned to their charge. Through them the necessary knowledge must reach the enlisted personnel. It is important that no attempt should be made to get results until this knowledge is first obtained."

1–12. Care of matériel. The Bureau of Ordnance issues complete instructions for proper maintenance of ordnance matériel. These instructions should always be consulted and followed in

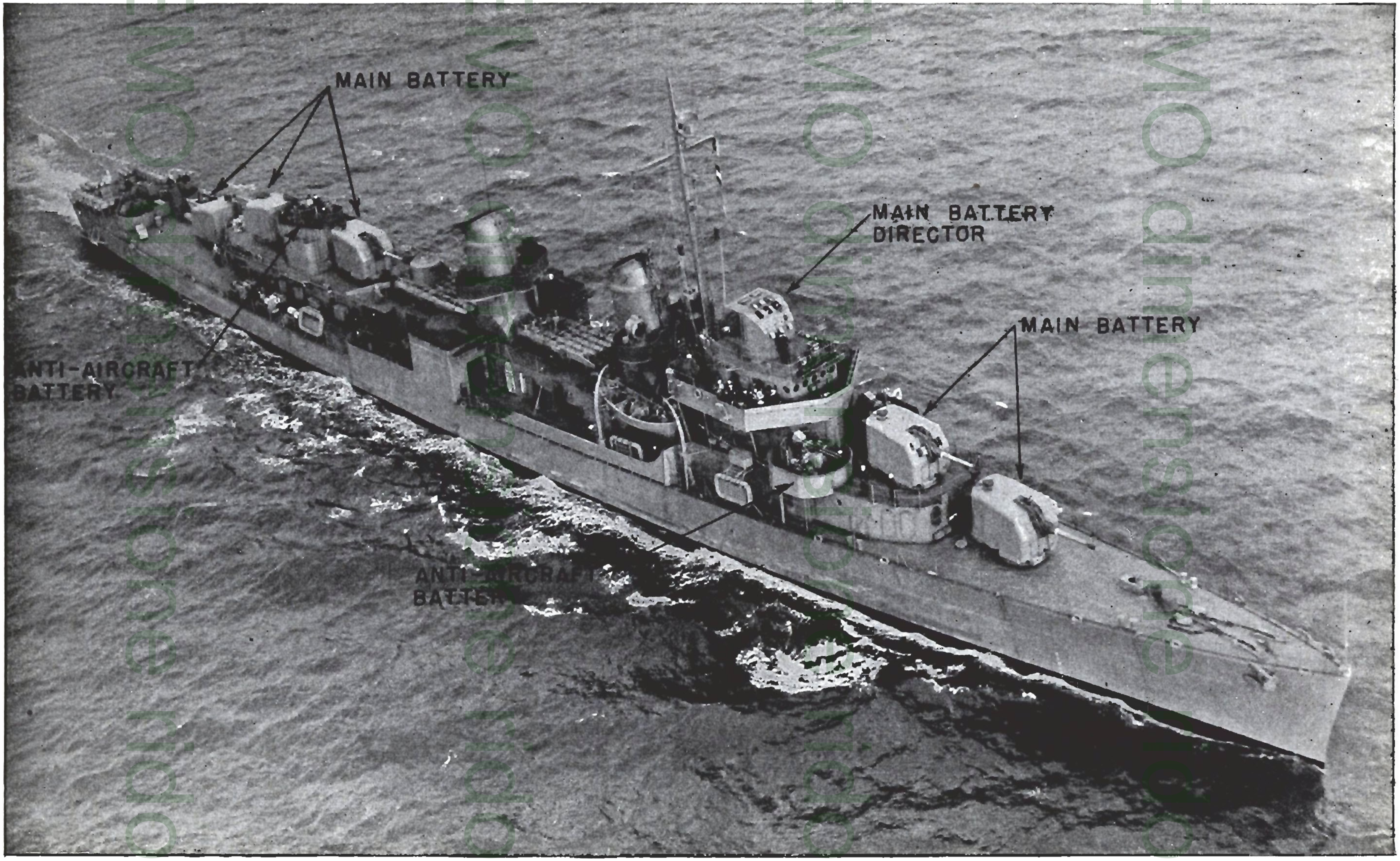


FIGURE 1–3. Arrangement of guns on a destroyer.

detail. Needless to say, they cannot be fully reviewed here, but a few general remarks are appropriate.

All ordnance matériel is carefully manufactured, usually to close tolerances. Any careless treatment is likely to damage seriously a valuable piece of equipment, disabling it when it may be needed most. In using any fine apparatus, it is wise to be governed by common sense. The equipment was built to function. If it does not, something is wrong, and physical forcing will inevitably cause trouble. Levers, knobs, buttons and switches should not be touched by a person who does not know what they will do. The *Bureau of Ordnance Manual* states: "The permanent damage done in a single day of experimentation by inexperienced personnel has frequently exceeded that which, with proper care, might be expected during the entire normal life of the material."

1–13. Safety precautions. Over a period of many years, various rules have been established to prevent casualty to personnel through carelessness. These rules are called *safety precautions,* and are part of *Navy Regulations* (Article 972). Additional precautions, set forth by the Bureau of Ordnance in various publications, have the full force of regulations. They have been built up through actual experience with ordnance during the early part of this century. Selected safety precautions are included at the ends of appropriate sections in this manual; this treatment, however, cannot be complete, and the officer must be familiar with BuOrd listings as well as Article 972. A few general items from this article are included here:

1–14. Safety precautions, selected from Article 972, Navy Regulations.

"1. As familiarity with any work, no matter how dangerous, is apt to lead to carelessness, all persons who may supervise or perform work in connection with the inspection, care, preparation, or handling of ammunition or explosives—

(1) Shall exercise the utmost care that all regulations and instructions are rigidly observed.

(2) Shall carefully supervise those under them and frequently warn them of the necessity of using the utmost precaution in the performance of their work. No relaxation of vigilance shall ever be permitted."

"2. In each part of the ship where ammunition is stored or handled or where gunnery appliances are operated, such safety orders as apply shall be posted in conspicuous places easy of access, and the personnel concerned shall be frequently and thoroughly instructed and drilled in them."

"3. Conditions not covered by these safety orders may arise which, in the opinion of the Commanding Officer, may render firing unsafe. Nothing in these safety orders shall be construed as authorizing firing under such conditions."

"4. The Commanding Officer shall at any time issue such additional safety orders as he may deem necessary, and a report thereof shall be made to his immediate superior and to the Bureau of Ordnance."

"5. When in doubt as to the exact meaning of any safety order, an interpretation should be requested from the Bureau of Ordnance."

"6. The Bureau of Ordnance shall be informed of any circumstances which conflict with these safety orders or which for any other reason require changes in or additions to them."

"7. Helpful suggestions and constructive criticism of these orders are invited. They should be made to the Bureau of Ordnance through official channels."

"8. Changes, modifications in, or additions to ordnance material, or other material used in connection therewith, shall not be made without explicit authority from the bureaus concerned."

"9. Safety devices provided shall always be used to prevent possibility of accident, and shall be kept in good order and operative at all times."

CHAPTER 2

EXPLOSIVES

A. EXPLOSIVE REACTIONS

2A1. Definitions. An *explosion* is a rapid and violent release of energy. An *explosive* is a substance which, when subjected to a suitable initiating impulse, undergoes a sudden chemical change characterized by the liberation of heat and the formation of products which are mainly gaseous. This reaction is accompanied by a rapid rise in pressure caused by heating of the gases.

2A2. Classification by reaction. A hard-and-fast classification of explosives is very difficult to formulate without introducing exceptions. One procedure is to classify explosives according to the *velocity* at which their chemical transformations occur. Thus *low explosives* are relatively slow-acting compared with *high explosives,* which react with extreme rapidity.

2A3. Low explosives. The reaction of a low explosive, such as a propellant, is a burning process. Low explosives usually are ignited by flame. Their reactions occur only on the exposed surfaces of the substance and progress through the mass as each layer is consumed. Smokeless powder is a good example.

2A4. High explosives. High explosives have a nearly instantaneous reaction which takes place throughout the entire substance. Some examples are TNT, fulminate of mercury, explosive D, and tetryl.

2A5. Characteristics of explosive reactions. An explosive reaction proceeds at high velocity, liberates heat, evolves gases, and develops high pressures.

Velocity. The chief characteristic which differentiates an explosive reaction from ordinary combustion, such as the burning of coal, is the high velocity of the explosive reaction. Velocity is a further basis for classification of high and low explosives. A low or propellent explosive reaction proceeds at a rate of about 5 inches per second, whereas a high or disruptive explosive reaction proceeds at a velocity approximating 5 miles per second.

Heat. An explosive reaction is always accompanied by the liberation of heat, which represents the energy of the explosive. This energy is a measure of the explosive's *potentiality* for doing work; for example, in propelling a projectile from a gun, or in causing a projectile to burst. This heat energy is not, however, a measure of an explosive's *capability* to perform such tasks. For example, coal yields about 4½ times as much heat energy per pound as does a propellent explosive. Nevertheless, coal cannot be used as a gunpowder because it does not release its energy with sufficient rapidity. Because of the high temperature at which an explosive reaction takes place, it is nearly always accompanied by flame.

Gases. The principal gaseous products of commonly-used explosives are carbon dioxide (CO_2), carbon monoxide (CO), nitrogen (N_2), nitrogen oxides ($NO_{(n)}$), hydrogen (H_2), methane (CH_4), hydrogen cyanide (HCN), and water (H_2O). Some of the gases are inflammable, or form explosive compounds with air. A secondary explosion of these compounds may occur within a gun as it is opened after firing. The initiation of this secondary explosion may come from the high temperature of the gas or from burning residue in the gun. The resulting blast of flame to the rear of the gun is called *flareback.*

Pressure. The high pressure accompanying an explosive reaction is caused by the heating of the gases. In general, maximum pressure of a low explosion is attained comparatively late in the reaction because of the low velocity at which it proceeds. Maximum pressure of a high explosive reaction, however, is attained almost instantly, and will be much greater than in the case of a low explosive reaction. Some high explosives are *brisant.* A brisant explosive develops maximum pressure so rapidly that the effect is to shatter material that is in contact or nearby.

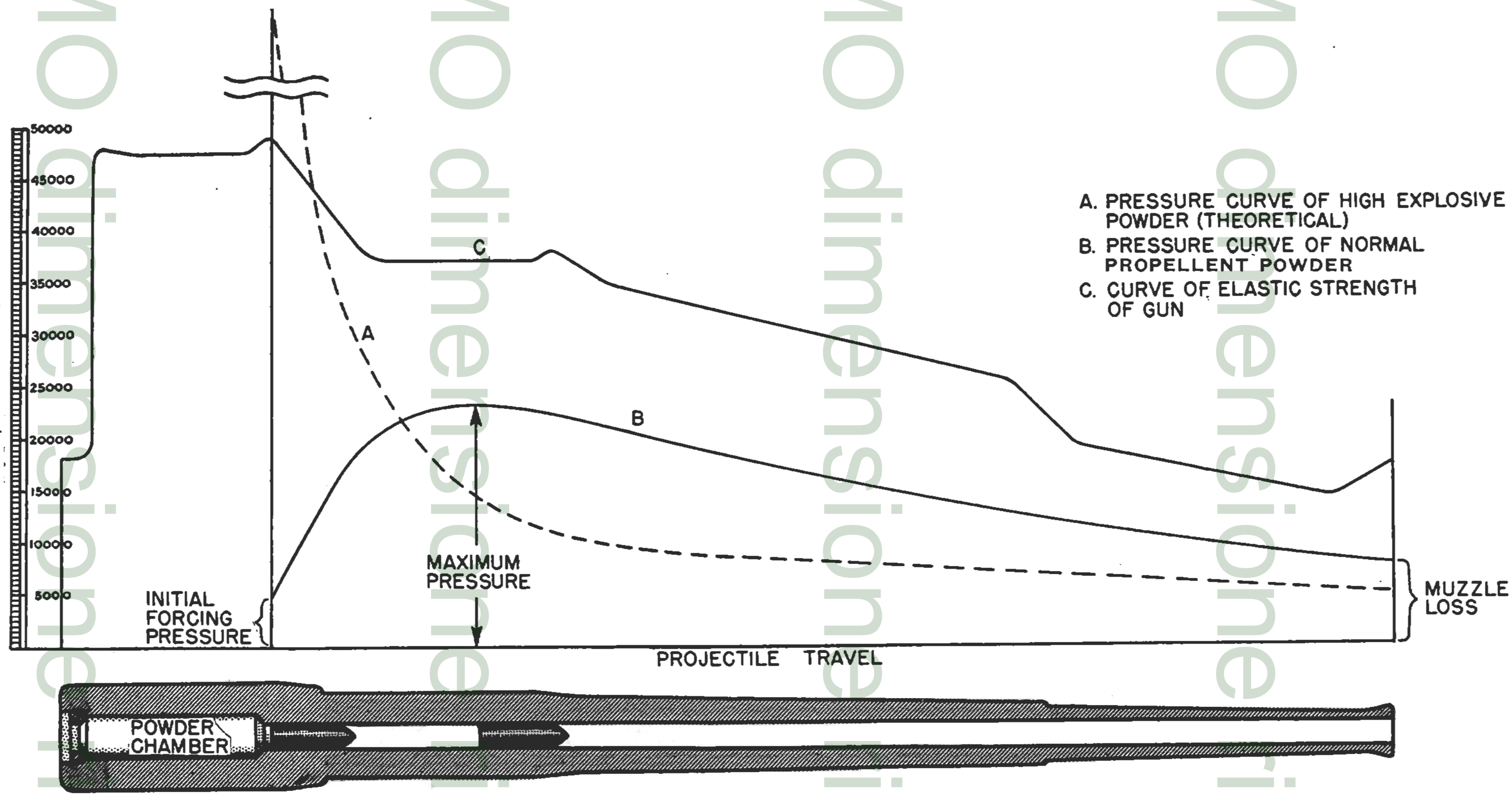


FIGURE 2B1. Gun pressure and strength curves.

2A6. Initiation. To initiate an explosive reaction one of the following causes must exist:

1. Heat, flame, or friction.
2. Percussion, or impact.
3. Detonation, or shock.
4. Influence.

The amount of energy necessary to initiate an explosive reaction is a measure of an explosive's sensitiveness. Thus, when little energy is required, the explosive may be characterized as "sensitive."

Heat, flame, or friction. The low or propellent explosives are commonly ignited by the application of some form of heat: particularly flame. Some high explosives react in a similar manner when sufficient heat is applied, but as a general rule such initiation does not produce the desired high-explosive effect.

Percussion, or impact. Initiation of an explosive reaction by direct impact, or blow, is simply initiation by heat that is derived from the energy of such impact. This method is commonly employed by various mechanisms in which a small amount of a sensitive explosive in a primer cap is struck.

Detonation, or shock. Most of the high or disruptive explosives, such as the main charges of mines and torpedoes, and the fillers of projectiles, require a sudden application of a very strong shock to initiate the explosive reaction. This shock, or detonation, may be obtained by firing a smaller charge of high explosive that is in contact with, or in close proximity to the main charge. This smaller charge may be readily exploded by heat, impact, or detonation.

Influence. Some explosions are said to be initiated by *influence,* which is similar to initiation by shock, except that the means of detonation (another explosive charge) does not have to be in close proximity to the main explosive mass. In this case the energy is transmitted through air or some other medium in the form of a *percussive wave.* When a percussive wave detonates another explosive mass, the result is called a *sympathetic explosion.*

The tremendous energy of a percussive wave in an underwater explosion is evidenced by the immediate upheaval of the water's surface just before the geyser-like disruption occurs when the gases of explosion rise.

B. SERVICE EXPLOSIVES AND THEIR USES

2B1. General. In the preceding section, explosive substances and their reactions were defined. Explosive substances were classified as high and low according to the velocity of their reactions. However, the distinction between the two is not sharply defined. Some low explosives, under proper conditions of fine granulation, confinement, and firing, may have characteristics approximating a high, or detonating, reaction. On the other hand, some high explosives, when unconfined, may simply burn if ignited by flame. Therefore, it is desirable to classify explosives according to their *service use* as follows:

1. Propellent and impulse explosives.
2. Primers and igniters.
3. Disrupting and bursting explosives.
4. Boosters.
5. Detonators.

The number of widely known explosive substances has become so large that it is possible to discuss only those in most common naval use. They are black powder, smokeless powder, TNT and the various mixtures in which it occurs, explosive D, tetryl, and fulminate of mercury.

2B2. Propellent and impulse explosives: characteristics. The primary function of a propellant is to provide pressure which, acting against the base of a projectile, will accelerate the projectile to the required velocity. This pressure must be so controlled that it will never exceed the strength of the gun.

The volume which is occupied by a gas containing a fixed amount of heat determines the pressure of the gas. The gases released by a propellent explosive fill the chamber and that part of the bore behind the projectile. Referring to figure 2B1, it is clear that the volume available for the gases increases as the projectile moves through the bore.

If, on explosion, the explosive is transformed instantaneously and completely to gases, the container of the gases will be the chamber alone, and the maximum pressure will occur before the projectile begins to move. The pressure will thereafter continuously decrease, for no more heat or gases will be liberated as the volume increases. The maximum pressure would have to be very high, as indicated by curve A, to produce the required muzzle velocity. Obviously, the breech end of the gun would have to be excessively heavy to withstand such an explosion.

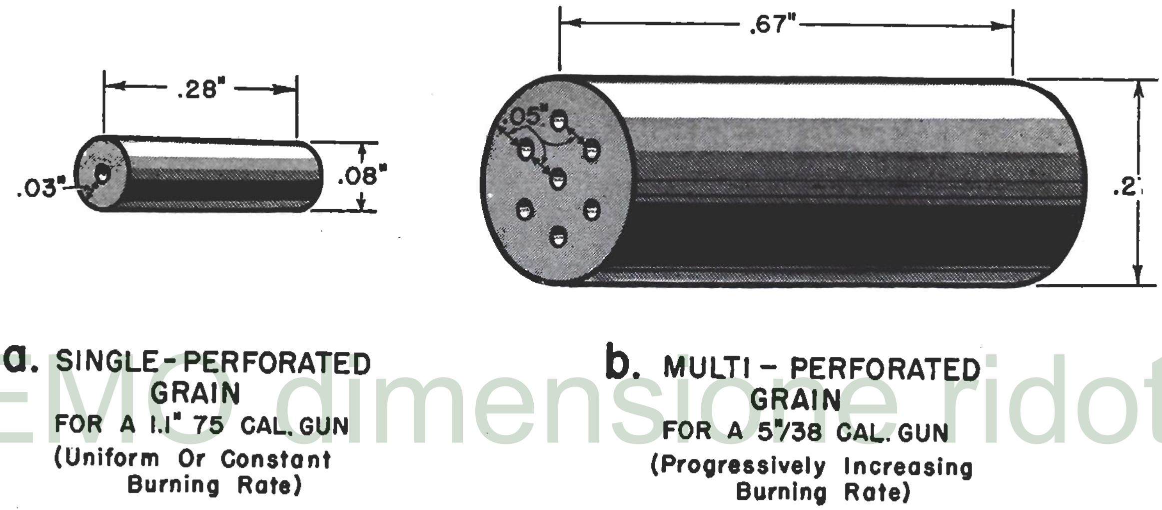


FIGURE 2B2. Typical smokeless-powder grains.

It is therefore desirable to control the evolution of gases so that the projectile begins to move before the charge has been entirely consumed. Then the space occupied by all of the gases will be greater, and the pressure will be lower than in the case of an equivalent charge having an instantaneous reaction. The pressure of the controlled reaction will follow a curve similar to B in figure 2B1. Consequently, the dimensions of the gun may be reduced as indicated by curve C, with a decided saving in weight.

Only a low or burning explosive can provide a reaction developing pressure at a rate suitable for the propulsion of a projectile from a gun. Since a low explosive is consumed layer after layer, the total burning area, and hence the rate of gas production, will depend on the amount of surface exposed. Actually, it is necessary to provide an *increasing* burning rate if pressure is to be sustained, since the volume available for the gases grows at an increasing rate as the projectile gains velocity.

Any solid powder grain presents a continuously decreasing burning surface. The burning area can, however, be controlled by perforating the grain, as shown in figure 2B2. The small holes, about 1/32-inch in diameter, present an interior burning surface. As burning progresses, the surface around each of these holes *increases* at the same rate as the outer cylindrical area *decreases*. The single-perforated grain maintains a constant area, except for the slight decrease in length as the explosion progresses. This type of grain is used in small guns, since manufacturing difficulties prevent the use of more perforations.

The seven-perforated grain is used in all U. S. naval guns 40 mm. and larger. Since the area surrounding *each* of the seven holes increases as fast as the outside area decreases (excluding the ends), the total burning area, and hence the rate of gas production, *increases* progressively until the holes meet. The burning rate decreases from then on. Seven holes provide the optimum burning rate for propellent powders. It is Navy practice to regulate the burning time of powders for different guns chiefly by varying the size of the grain. Other influencing factors are held within narrow limits.

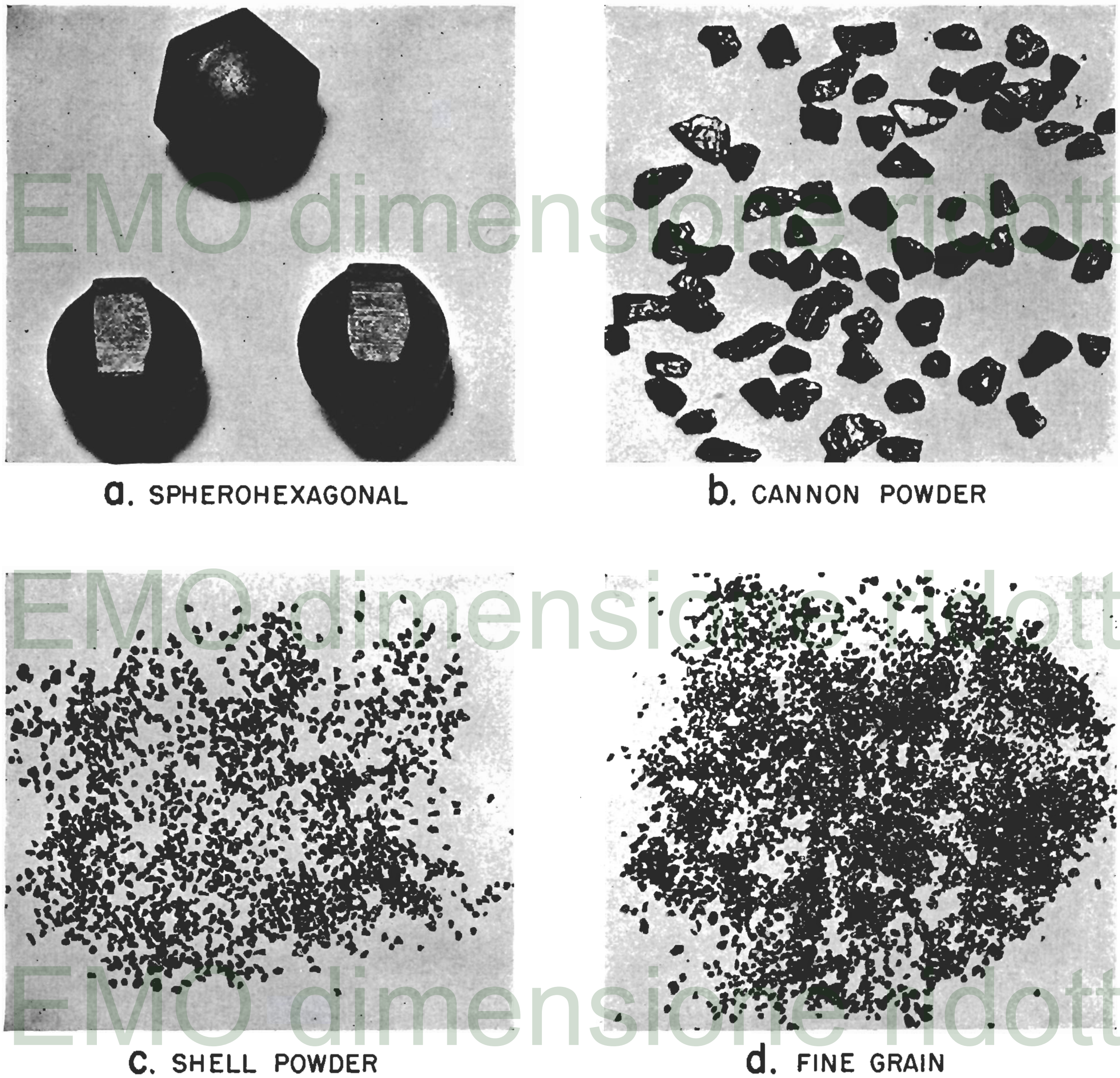


FIGURE 2B3. Black powder samples.

2B3. Black powder. Black powder is a low explosive, but some of its characteristics are like those of a high explosive. Its grain structure is such that its rapidity of burning produces a pressure curve more like A than B in figure 2B1. In the past many attempts have been made to control its behavior to make it acceptable as a propellent explosive. However, only in the case of certain small arms, depth-charge release gear, and torpedo tubes has black powder been found useful as a propellant. Nevertheless, black powder has a greater variety of service uses than any other explosive, such uses being varied, and of a special nature.

The usual composition of black powder is about 75% potassium nitrate, 15% charcoal, and 10% sulphur. The form of the powder depends upon the use for which it is intended. One variety consists of grains which have a somewhat glazed surface, and are free from dust; in another form, the product is a finely-granulated powder. In general, large grains make for a slower burning rate. The types of black powder used in the naval service, some of which are shown in figure 2B3, are arranged in order of decreasing size of grain as follows:

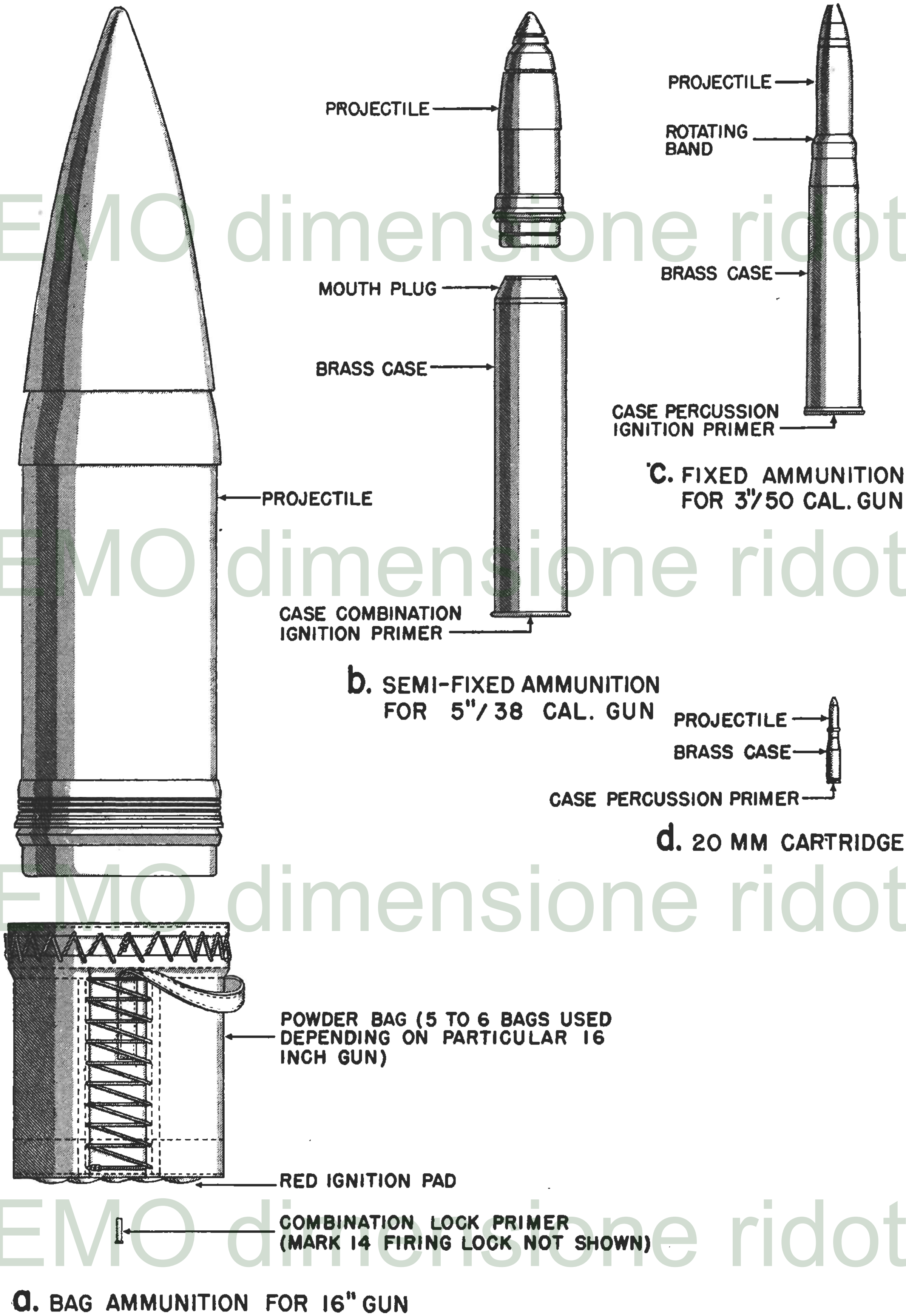


FIGURE 3A1. Typical gun ammunition.

"12. Service ammunition is supplied to ships for use in battle. It shall not be used for drill, for testing appliances, or for other similar purposes except upon the express authority of the Navy Department. It shall be regarded as a part of the vessel's outfit, shall be kept distinct from the ammunition used for gunnery exercises, and shall never be expended in gunnery exercise unless authorized in the orders for gunnery exercises or special instructions from the Bureau of Ordnance."

"13. Special ammunition is issued for gunnery exercises, except when a part of the ship's allowance of service ammunition is designated for that purpose."

"16. The unexpended portion of such ammunition as may have been issued for a specific gunnery exercise or experimental firing shall be turned in as soon as practicable, after such firing, to an ammunition depot, unless additional firings are immediately authorized by the Navy Department."

B. PRIMERS

3B1. General. A primer is a device which provides a flame for the ultimate ignition of the propelling charge. In case ammunition this flame is applied directly to the propellant, while in bag ammunition it is applied indirectly through an ignition pad. The same size primer is used for all sizes of bag ammunition, but the amount of the black powder in the ignition pad is made proportional to the size of the smokeless-powder charge. A relatively large charge of smokeless powder requires a greater ignition flame, which is obtained by using a large ignition pad. In various types of case ammunition, however, different sizes of primers must be employed in order that each primer may contain in itself the amount of black powder required for the ignition of the propellant.

The two general classes of primers are: (1) the *lock primer* (all bag guns), and (2) the *case primer,* which is fitted into the base of the ammunition case. A primer that can be fired only by impact of a firing pin is called a *percussion primer;* one that can be fired both electrically and by percussion is known as a *combination primer.* Where it is necessary to increase the amount of ignition powder in the primer and to include an ignition tube inside the primer stock, the primer is known as an *ignition primer.* Combinations of these primer designations are employed to describe the types of primers in present use. The four primer types shown in figure 3B1 and examples of their use are as follows:

For case ammunition:

1. Case percussion primer (small-caliber cartridges).
2. Case percussion ignition primer (3"/50 cal.)
3. Case combination ignition primer (5"/38 cal.)

For all bag ammunition:

4. Lock combination primer.

3B2. Percussion element. The percussion element of a primer consists of the *primer cap,* a *cup* and *anvil,* and a *plunger* and *plunger cup* (except in a simple percussion element). The primer cap usually contains a mixture which has fulminate of mercury as a base. The composition of the mixture varies with the degree of heat, flame, and sensitiveness desired. One or more of the following materials are found in the ordinary mixtures: antimony sulphide, which increases the length of the flame; potassium chlorate, which increases the heat by its oxidizing action, and ground glass, which increases the sensitiveness. The anvil is pierced by holes or vents which allow the flame from the priming mixture to reach the ignition chamber containing black powder. In primers with a plunger, the method of firing is to strike the plunger, which action forces the primer cap against the anvil and explodes the pellet. The simple percussion element of a case percussion primer used in small-caliber ammunition does not have a plunger cup assembly. The primer cap is exploded merely by indenting an inverted cup, and thus driving the pellet against the anvil.

3B3. Electric element. Many primers having an *electric element* are also provided with a percussion element and are therefore called *combination primers.* The construction details of the electric element in combination primers are shown in figure 3B1. This type of primer has an *ignition cup* in which there is a mixture of pulverized guncotton and fine black powder, and a high resistance wire wrapped with a small wisp of guncotton which bridges through the mixture. The wire, attached at one end to the plunger cup, is electrically connected to the plunger through which the current from the firing source travels. The other end of the wire is grounded through the primer stock to the metal of the gun. An electric current heats the bridge wire and ignites the wisp of guncotton and the surrounding mixture in the ignition cup, producing flame. The flame transmitted from the ignition cup fires the primer. Insulation is used to separate the plunger and plunger cup from the ignition cup and primer stock.

The percussion element is a necessary feature of combination primers in case of failure to fire electrically. The normal procedure in firing such primers is to attempt electric firing first. If this fails, an attempt is made to fire by percussion. In firing by percussion, the flame transmitted by the primer cap ignites the mixture in the electric ignition cup, and the flame from both the primer cap and the ignition cup fires the primer.

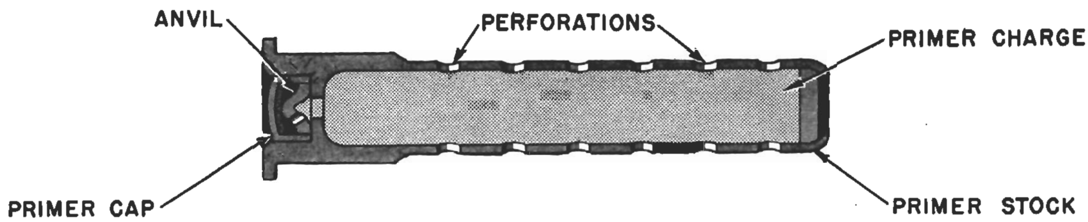
3B4. Ignition tubes. All sizes of bag guns use the same design of lock combination primer because the amount of ignition powder necessary for the particular size of main charge is contained in the base of each powder bag. However, the ignition charge is combined with the primer in case ammunition, and because the amount of ignition charge varies with the size of main charge, the design of the primer varies with each caliber. For small-caliber case ammunition a primer cap alone suffices to ignite the propellant. The primer for larger-caliber case ammunition requires a greater amount of ignition powder and therefore is fitted with a primer stock extension. The primer assembly for still larger case ammunition contains such a great amount of black powder in the stock extension that a perforated *ignition tube* must be placed inside the outer stock extension. This ignition tube contains a small amount of black powder which makes it possible to readily ignite the larger main-primer charge of black powder in the primer stock extension.

C. PROPELLING CHARGES

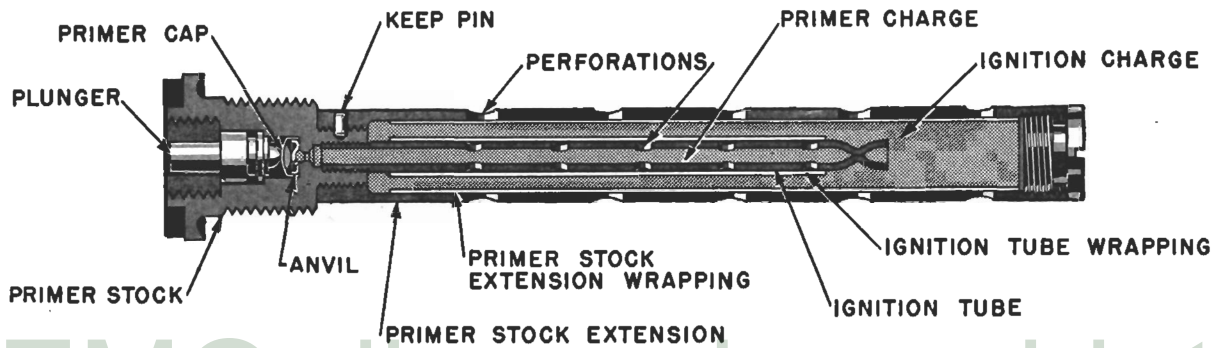
3C1. Powder bags. The general features of *powder bags* have been discussed in Chapter 2. The description therein is applicable to all bag charges except in such details as the size and number of bags required for a complete charge. At present, all powder charges are contained in silk bags, but scarcity of silk will undoubtedly lead to the development of a suitable substitute. The material used for the bags is of two weights: light, and heavy. The heavy silk is used for the body of the bag, the handling strap, and the lacing flaps which serve as a means to take up any slack in a loose bag. The light-weight cloth is dyed red and is employed for the ignition pad containing the black powder. An ignition pad is quilted on the base of each powder bag, quilting being necessary to keep the black powder spread evenly throughout the pad.

Two of the powder bags for a 16"/45 cal. gun are shown in figure 3C1. The markings on such a bag should be noted. On the body of the bag these markings indicate the caliber of gun, the index or identification number and the weight of the smokeless powder, the proportion the bag bears to a full service charge, the initial velocity obtained with a complete charge, and the initials of the inspector. On the ignition pad markings indicate the number of grams of black powder contained. Each bag is provided with an identification tag which supplies the above information in addition to other data necessary to make the identity of the charge complete.

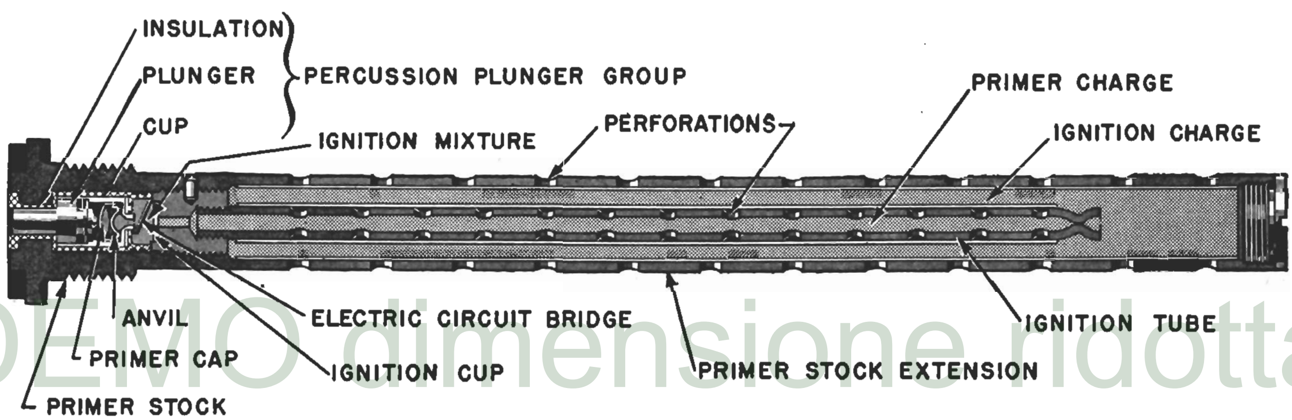
The necessity for airtight and watertight storage to maintain standard performance of smokeless powder has been discussed in Chapter 2. The addition of diphenylamine stabilizer only prolongs the life of the powder and does not prevent deterioration under adverse storage condition. It follows that powder tanks are important items of ordnance equipment. If a powder tank is leaky, the ether and alcohol volatiles escape, and air and moisture are admitted. It is important, therefore, to assure the integrity of such tanks at all times. Several types of tanks are to be found in service, but all must fulfill the same basic requirements for the storage of powder. One variety is illustrated in figure 3C1; others have variously constructed top-covers and special handling facilities such as



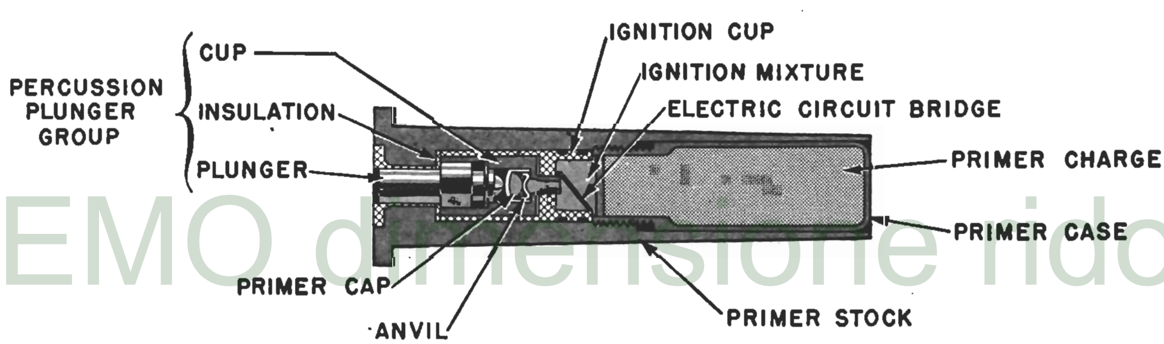
CASE PERCUSSION PRIMER (40 mm.)



CASE PERCUSSION IGNITION PRIMER (3"/50 cal.)



CASE COMBINATION IGNITION PRIMER (5"/38 cal.)



LOCK COMBINATION PRIMER (ALL BAG GUNS)

FIGURE 3B1. Primer types.

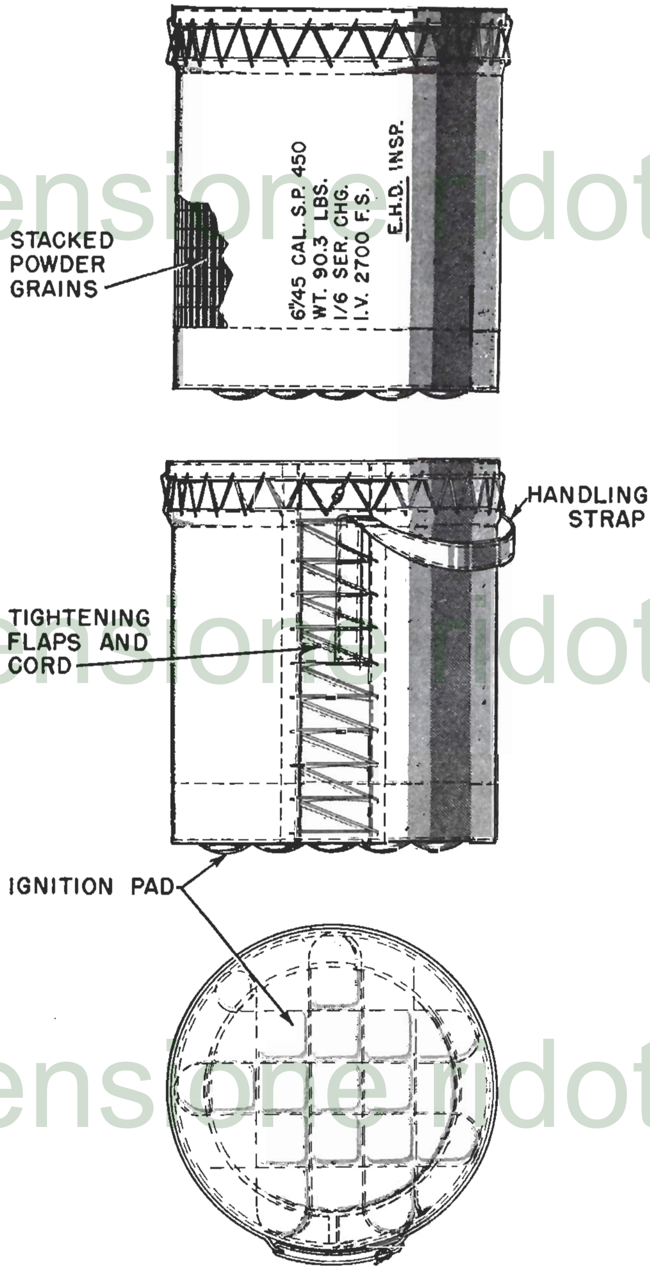


FIGURE 3C1. Bag gun charge and tank.

lugs (on large tanks) for use with slings, or handles (on smaller tanks). The top-covers are designed to permit quick opening, because the number of loaded tanks allowed open at any one time is limited by safety precautions.

For the purpose of obtaining definite velocities it is important that the powder charge should always be disposed in the gun chamber in the same way. The total length of all the powder bags placed end to end is within two inches of the powder-chamber length whether the charge be ser-

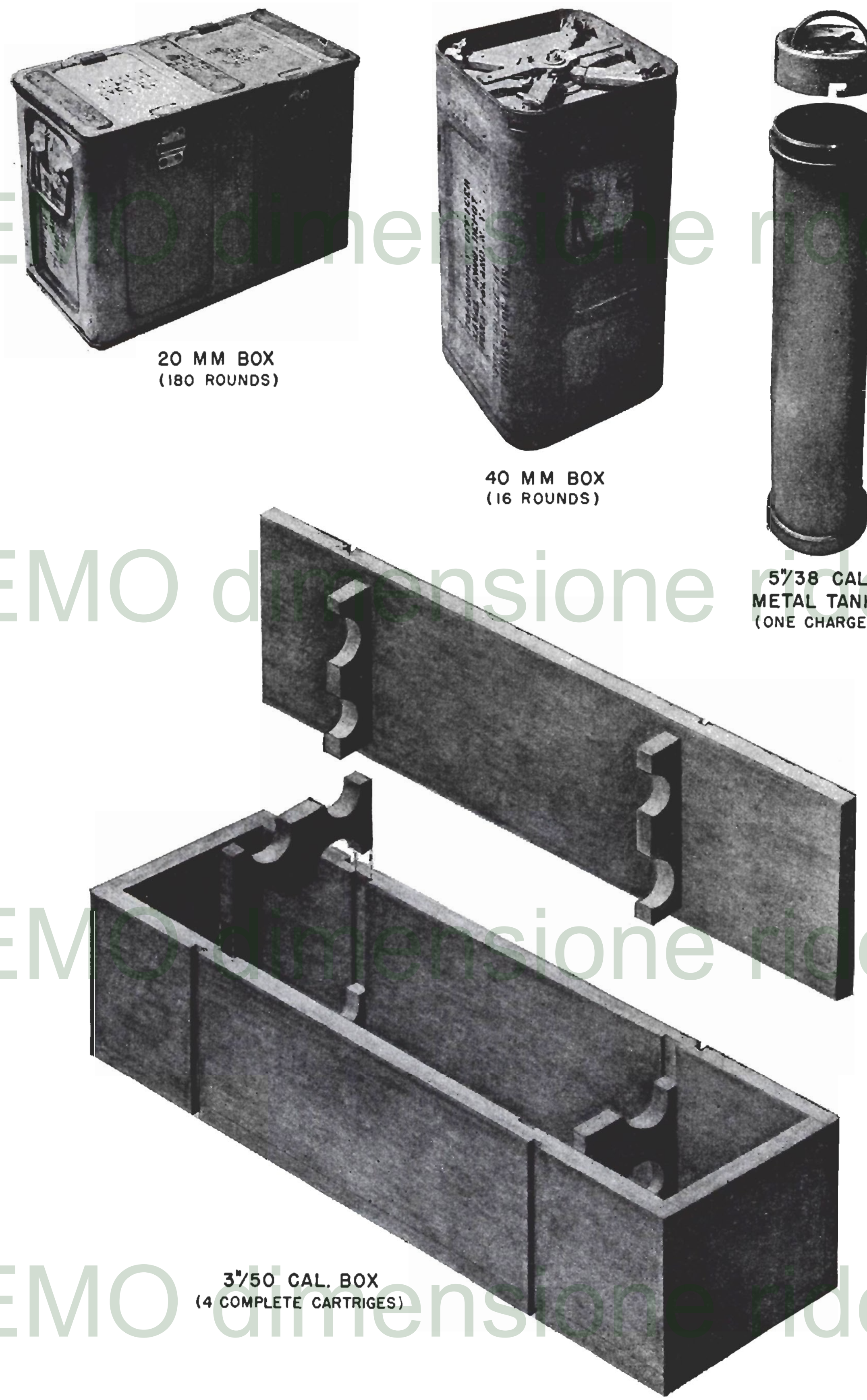


FIGURE 3C2. Ammunition tanks and boxes.

vice, special, target, or spotting. Thus, the *length* of each powder bag is the same in all cases, and the different effects are produced by varying the *diameter* of the powder bag. Therefore, the same number of bags can be placed in a constant-length powder tank regardless of whether these bags be a part of a service, special, target, or spotting charge. The tank is made large enough to accommodate the service charge, and will consequently accommodate the other types of charges which are of lesser diameter.

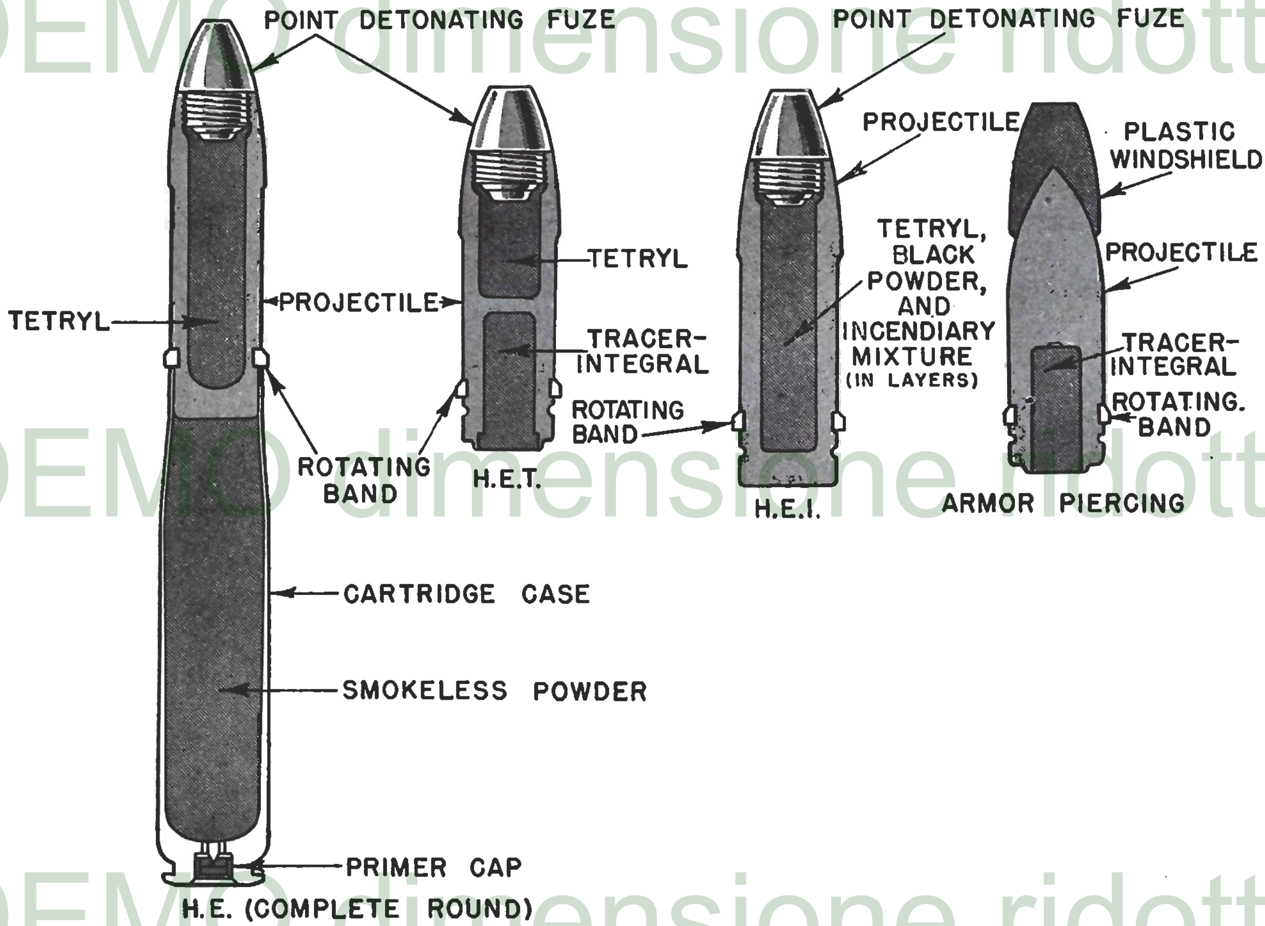


FIGURE 3C3. 20 mm. ammunition.

3C2. Case ammunition. The designs of various sizes of case ammunition are similar as may be seen from study of figures 3C3 to 3C6. The preparation of the case assemblies is comparable up to the point at which the mouth of a case is sealed. In fixed ammunition the projectile is the seal; a *mouth plug* is used in semi-fixed charges. There are four steps in the assembly of case ammunition: (1) priming, (2) loading the propellant, (3) fitting a *wad* and *distance piece,* and (4) inserting the *projectile* or mouth plug. In priming, the type of primer used is either screwed (40 mm., and larger) or force-fitted (smaller cartridge ammunition) into the base of the case. The desired weight of smokeless-powder grains is then dumped loosely into the case. In the case of 40 mm. and larger a cardboard disk, or wad, is forced in and a distance piece placed on top. The mouth of a semi-fixed case is then sealed by the insertion of a mouth plug as illustrated by the 5"/38 case in figure 3C6. In fixed ammunition, the mouth of the case is sealed by forcing in the base of the projectile until the rear of the rotating band makes contact with the case.

A distance piece consists of interlocked pieces of cardboard disposed as in an egg carton. The wad and distance piece are for the purpose of filling the entire case so that the propellent charge will not be shaken from around the primer. A mouth plug may be of cork, cardboard, tinfoil, or a combination of these materials, and must be of sufficient strength to keep the contents of the case from spilling out under any conditions of handling or loading. In small-caliber ammunition, the fitting of wads and distance pieces may not be necessary if the propellant fills the case. The brass case itself is a hollow cylinder with either a straight or bottle neck. The base has a rim around its circumference to facilitate extraction of the empty case from the gun. The empty cases can be used again after being reprocessed at an ammunition factory. They are required to stand six service rounds without deterioration, but actually, cases have been found capable of withstanding as many as 30 or 40 rounds before becoming useless.

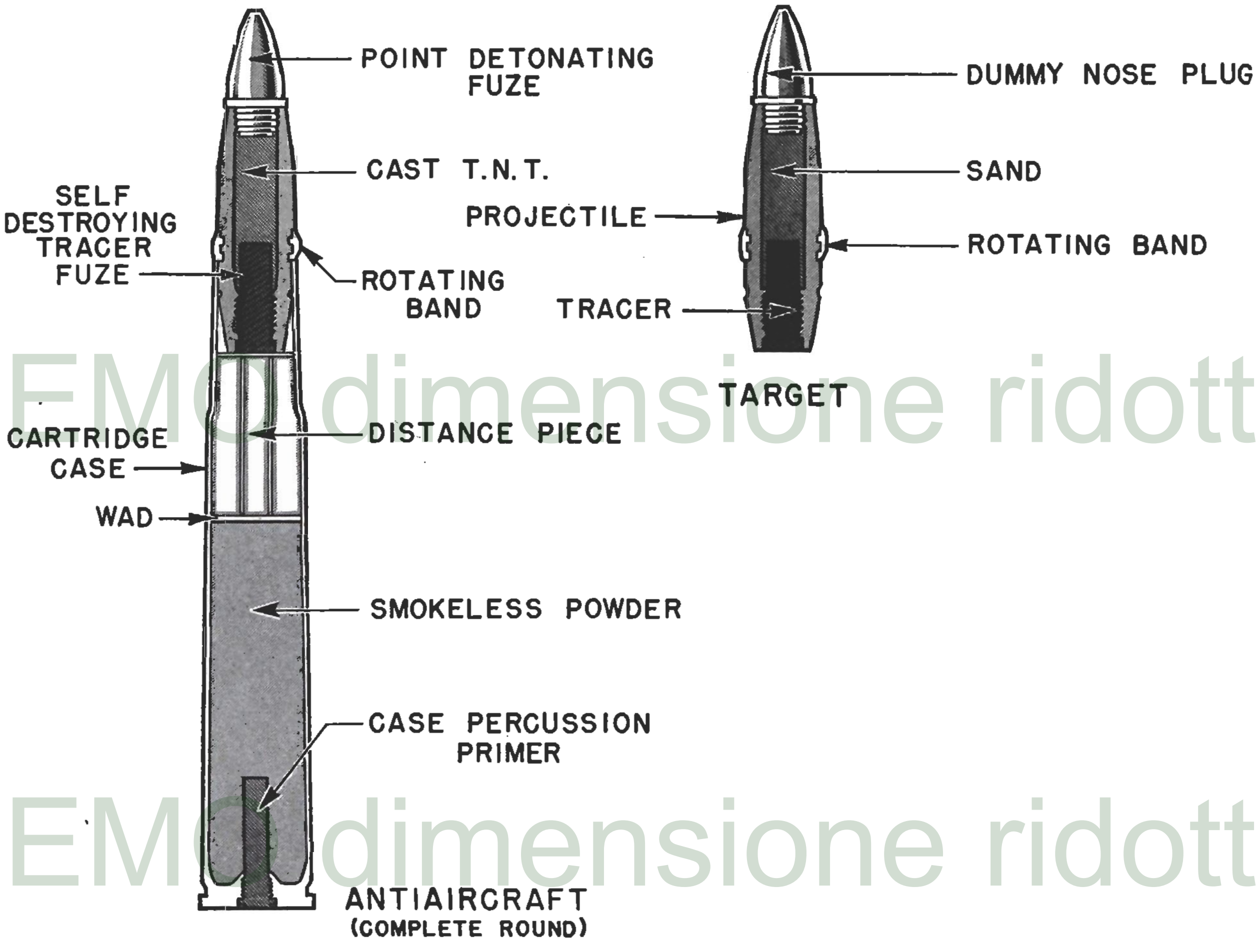


FIGURE 3C4. 40 mm. ammunition.

3C3. Ammunition containers. Since leaks may exist around the primer and the projectile or mouth plug, the case cannot always be relied upon to remain airtight. Therefore, like powder bags, case ammunition is transported and stowed in containers which provide air- and water-tightness. Such containers may be metal tanks or wooden boxes. Metal tanks are employed for case ammunition larger than 3 inches. Either metal tanks or wooden boxes are used for ammunition such as 3″/50 cal. and smaller, although generally wooden boxes which contain several complete rounds are favored.

There are several types of tanks and boxes in service, and no attempt will be made here to describe them in detail. Figure 3C1 shows a metal tank for bag ammunition and figure 3C2 shows ammunition containers for 5″/38 cal., 3″/50 cal., 40 mm., and 20 mm. ammunition. It is sufficient to state that regardless of varying design, the container must, above all, provide proper storage for smokeless powder. In addition, the container should be strong but not unduly heavy, should

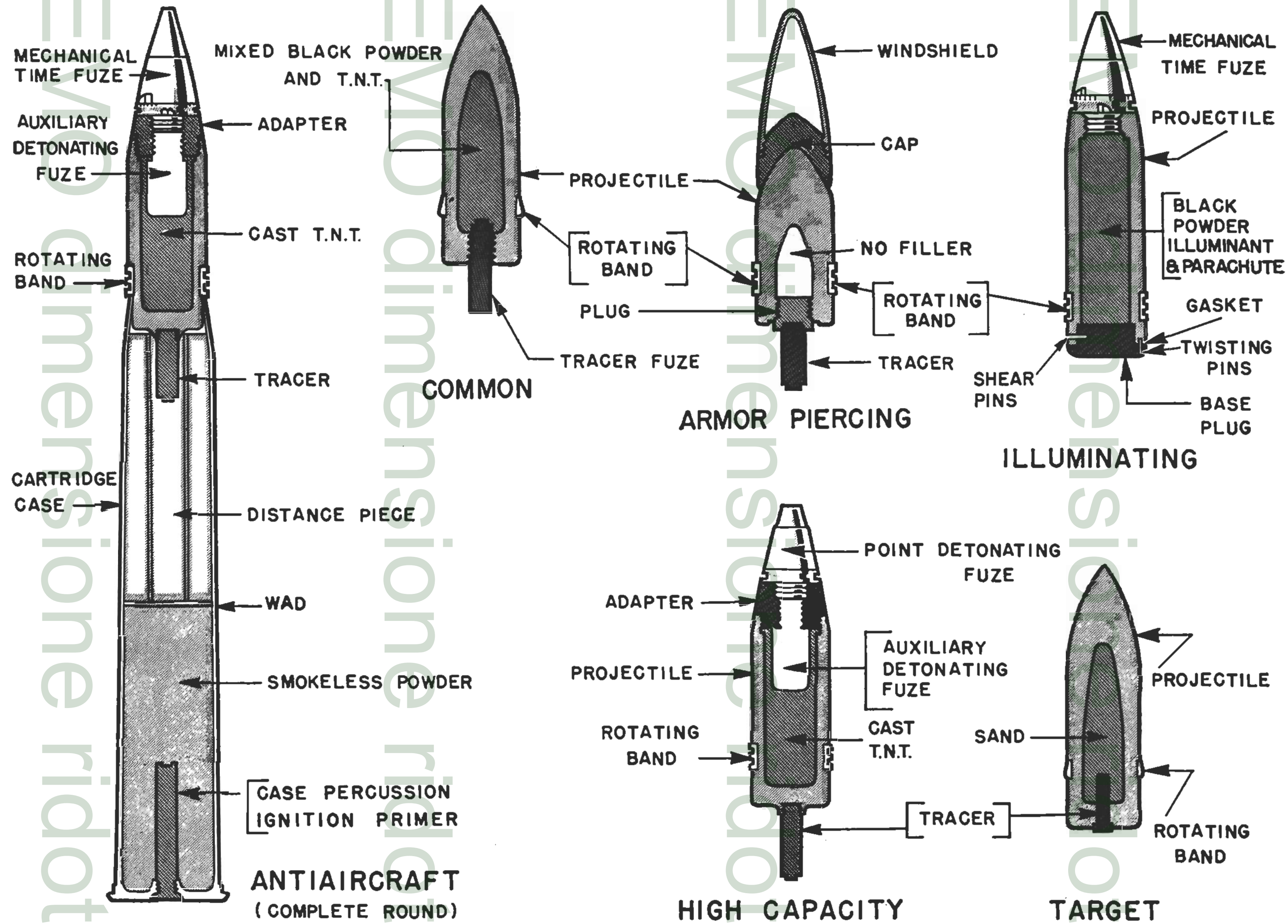


FIGURE 3C5. 3"/50 cal. ammunition.

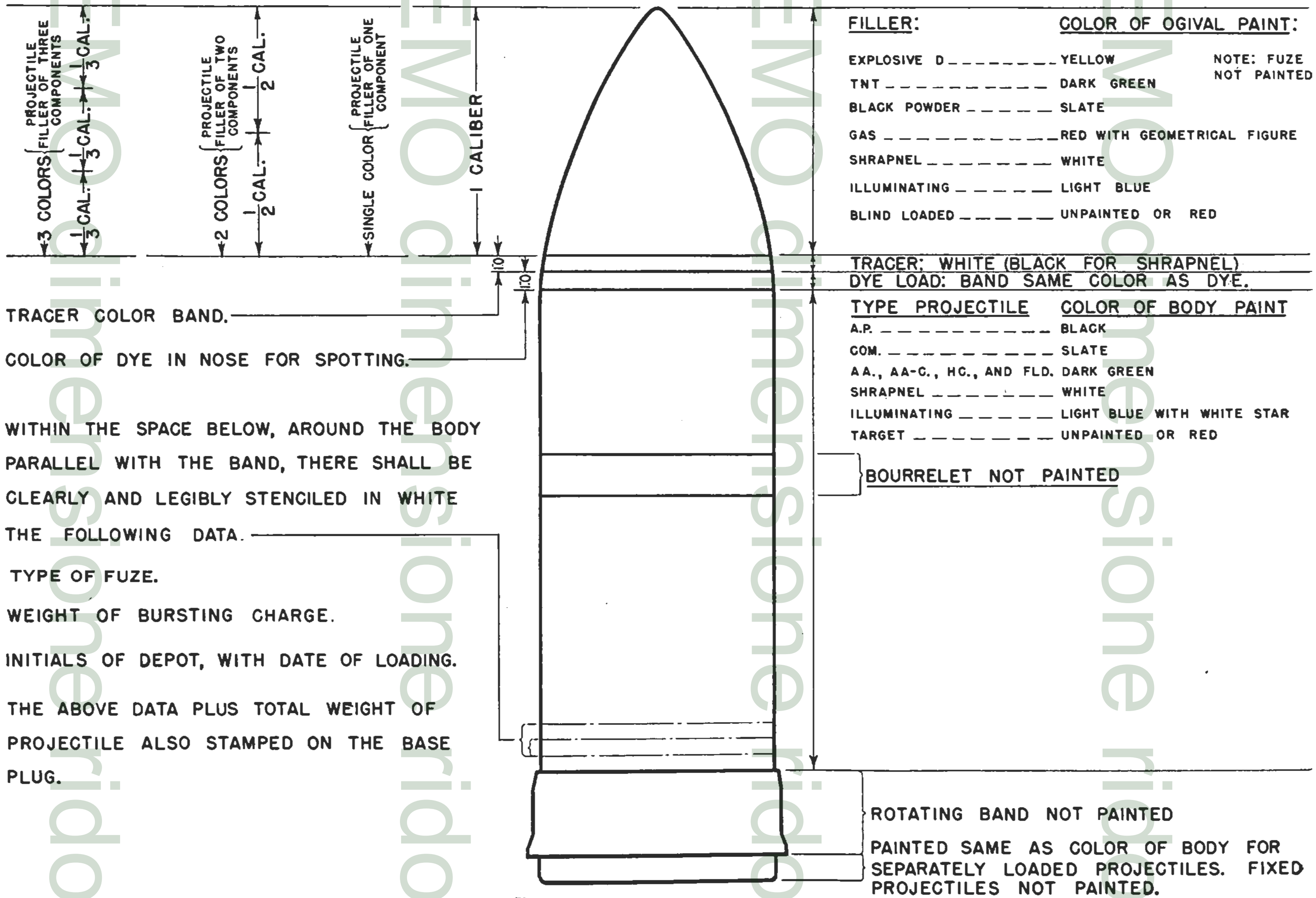


FIGURE 3D3. Projectile markings.

3D12. Safety precautions, selected from Article 972, Navy Regulations.

"18. Projectiles shall not be altered, nor shall fuzes or any other parts be removed or disassembled on board ship without explicit instructions from the Bureau of Ordnance. Projectiles shall not be allowed to rust or to become oversize through paint. Slings and grommets and other similar protective devices shall be removed before loading projectiles into guns. Since the slings are likely to jam the hoists, they shall be removed before sending up the projectile."

"49. Care shall be exercised to insure projectiles from slipping back from their seats, as unseated projectiles may cause abnormally high pressures."

E. FUZES AND TRACERS

3E1. General. A fuze is a device for detonating or igniting the filler explosive of a projectile either on or after impact, or while in flight. Only a few projectiles, such as star shells and shrapnel, may have fillers of black powder, which require an *ignition fuze* for initiation of their low-explosive reaction. Most fillers are high explosives which require a *detonating fuze.*

Fuzes may be grouped in two classes according to their position on the projectile: (1) *nose* or *point fuzes,* and (2) *base fuzes.* A nose fuze is at the extreme forward end of a projectile and is shaped to conform to the curvature of the ogive. A base fuze is located inside the after end of the projectile. It is fitted in a hole in the base or base plug and extends inward to the filler explosive.

Fuzes are further classified according to the methods by which they can be caused to function. A fuze functioning on impact is a *percussion fuze,* one functioning by its own internal action after a definite time in flight is a *time fuze,* while a fuze incorporating both of these features is called a *combination fuze.*

3E2. Fuze design. The designs of current standard fuzes for naval service are maintained in a confidential status: hence, the discussion here is limited to general types of fuzes and principles involved in their functioning. The names and uses of various fuze types may be seen by referring to figures 3C3 to 3C6. Listed by name these fuzes are:

1. *Mechanical time fuze* (time or combination).
2. *Point detonating fuze* (A percussion fuze, usually of a supersensitive type).
3. *Auxiliary detonating fuze* (A supplementary fuze. In the 5"/38 cal. projectile this fuze takes the explosion initiated by the nose fuze and passes it on to the main explosive charge).
4. *Base detonating fuze* (A percussion fuze with or without a delay element).
5. *Self-destroying fuze* (The burning tracer acts as a time fuze and bursts the projectile before the end of its flight).
6. *Ignition fuze* (not shown—A percussion fuze employed to burst black powder fillers).

These fuzes may be grouped into four general classes according to the designed function of the projectile, as follows:

1. *Instantaneous fuzes* on AA-Com and HC projectiles not expected to penetrate more than destroyer plating. There is no time-delay element between the primers of such fuzes and the burster charge.
2. *Supersensitive nose fuzes* on AA projectiles, such as the 20 mm., 40 mm., and the 1.1 inch, whose bursting action must occur immediately after penetration of very light plate or fabric.
3. *Delayed-action fuzes* on AP projectiles which are to penetrate 1½ inches or more of armor plate. There is a time-delay element between the primers of such fuzes and the burster charge.
4. *Time fuzes* on AA and HC projectiles which must function at the desired point in the air. Such fuzes cause the projectiles to explode at some definite time interval after they are fired from the guns.

3E3. Fuze terms. In the design of fuzes the following forces or elements may be utilized so that a fuze can perform its functions:

1. *Setback.* The action caused by the tendency of parts within the fuze body to remain stationary due to inertia as the projectile is accelerated forward.
2. *Creep.* The action caused by the tendency of those parts within the fuze, which are not decelerated by air resistance, to move forward with respect to the fuze body due to inertia.

3. *Inertia at impact.* The tendency of all parts of the fuze to continue in the line of motion when the projectile strikes an object.

4. *Centrifugal force.* The radial force resulting from the rotation of the projectile.

5. *Friction.* A force tending to slow down moving parts.

6. *Powder trains.* Timing devices operated by the burning of compressed powder pellets or trains.

7. *Clock mechanisms.* Mechanical timing devices operated by springs or centrifugal force.

3E4. Arming. A fuze is said to be *armed* when the firing point is in a position to strike a detonating cap. The fuze functions if the firing pin is made to strike this cap. There are three essential requirements for any fuze, as follows:

1. It must be safe to handle; that is, the fuze must not become armed if dropped or joggled.
2. The fuze must be safe within the bore of a gun and for a sufficient distance outside the muzzle to insure security of personnel in the vicinity.
3. The fuze must initiate the explosion of the filler at the proper moment, whether on impact with instantaneous or delayed action, or at the desired time in flight.

The principle employed in arming a fuze in conformance with these requirements, and particularly with regard to safety, is best illustrated by the Semple centrifugal plunger.

3E5. Semple centrifugal plunger. The mechanism, shown in figure 3E1, consists of a *firing pin* and *axis,* a *plunger, safety pins* and *springs,* and a *creep spring.* In the safe, or unarmed, position, shown in figure 3E1a, the small safety pin springs force the two safety pins inboard to lock the firing pin in the safe position. A side blow would dislodge only one of the pins but not both. Thus, the fuze is safe against side impact. The fuze is also safe if dropped because the firing point is housed in the plunger.

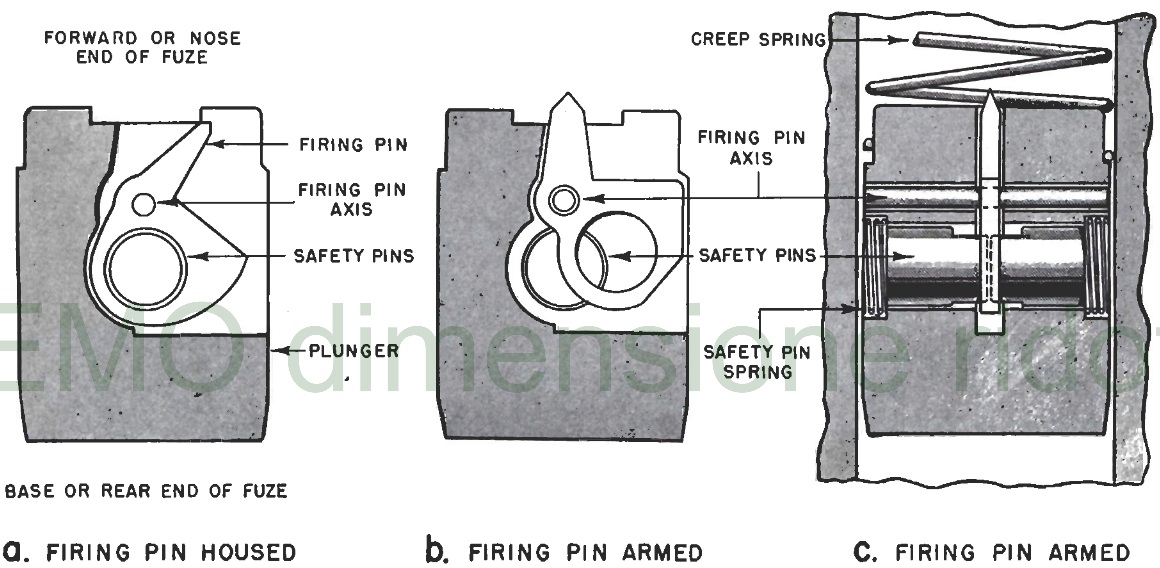


FIGURE 3E1. Semple centrifugal plunger.

The fuze is armed by centrifugal force at a predetermined rotational velocity of the projectile varying from about 1,500 to 3,000 r.p.m. When the projectile is rotated by the rifling, the safety pins are thrown out against the action of their springs by centrifugal force. The same force tends to rotate the heavier part of the firing pin about the firing pin axis to bring the firing point into the armed position. However, the inertia of the heavier part of the firing pin causes the movement of the pin to lag during acceleration of the projectile in the bore. Thus the firing pin is not rotated to the armed position until the projectile leaves the bore; then the firing pin assumes the position shown in figures 3E1b and 3E1c.

CHAPTER 4

GUN ASSEMBLIES

A. GUN BARRELS

4A1. Definition. A gun is a tube capable of containing and so controlling the explosion of a propelling charge as to discharge a projectile at high velocity. The term *gun* properly designates the tube or barrel, but it is commonly used to refer to the entire assembly of which the barrel is but one part. The terms *gun* and *barrel* are used synonymously in this section. Thus, a *gun assembly,* such as the one shown in figure 4A1, is composed of a number of components which can be grouped under these headings:

1. The gun, or barrel.
2. The breech assembly.
3. The mount.
4. The sight.

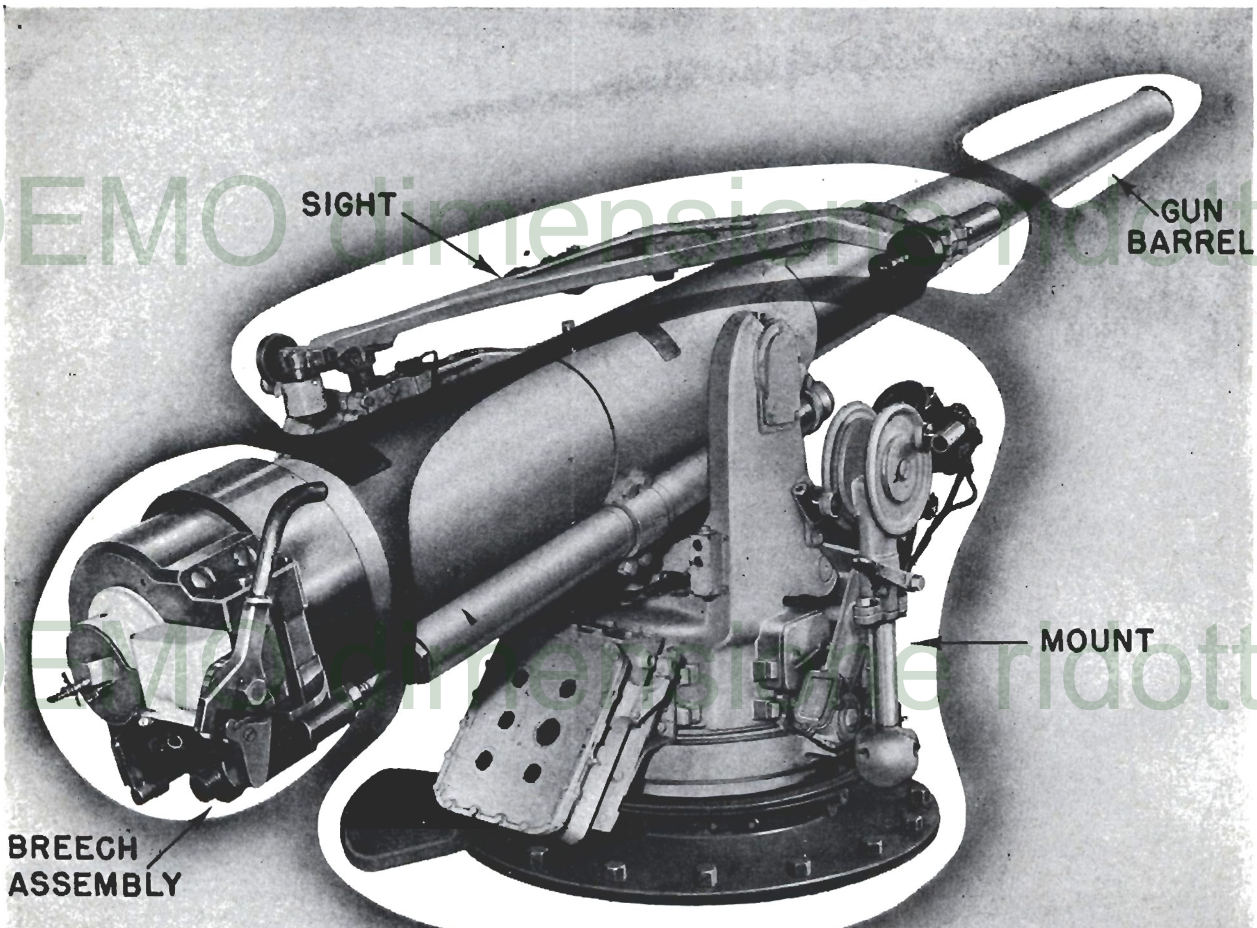


FIGURE 4A1. A typical gun assembly.

4A2. Designation by size. The diameter of a gun's bore is its *caliber,* usually expressed in inches. The length of the gun from the forward face of the breech plug to the muzzle is measured in calibers. A 16″/45 *caliber* gun has a 16-inch caliber, or bore diameter, and an overall length slightly greater than 45 calibers, or 720 inches (16″x45).

Some guns, such as a 1-pounder, may be designated by the weight of their projectiles. Others, usually of foreign origin, like the 20 mm. and 40 mm., may be referred to by the diameter of the bore expressed in millimeters. Grouped according to bore diameter guns are known as:

1. *Major caliber* if 8 inches or larger.
2. *Intermediate caliber* if between 4 inches and 8 inches.
3. *Minor caliber* if larger than 0.60 inches but not more than 4 inches.
4. *Small arms* if 0.60 inches or smaller.

Designation by size is not a complete description of a gun barrel. There are numerous variations among guns, requiring the use of the mark and modification numbers for identification. Variations among mounts may make it necessary to identify a gun assembly by designating the barrel and the mount.

4A3. Classification by use. Gun assemblies are classified by their use aboard ship as:

1. *Turret,* when mounted in a heavily armored revolving structure. These are the largest guns, and they are mounted on cruisers and battleships. Some intermediate-caliber guns are mounted in gun houses closely resembling turrets, but since the structures are not heavily armored, they are not true turrets.
2. *Antiaircraft,* when designed primarily to fire against aircraft.
3. *Antiaircraft machine guns,* when of the machine gun type and designed to fire against aircraft.
4. *Dual purpose,* when designed for use against both surface and air targets.
5. *Broadside,* when designed for use against surface targets and not installed in turrets. These guns were formerly common, but have been almost entirely replaced by the dual-purpose guns.

4A4. Guns in service. The guns most likely to be found on ships of the Navy at the present time are:

GUNS	CARRIED ON
14 inches and 16 inches	Battleships
12″/50 cal.	Large cruisers
8″/55 cal.	Heavy cruisers
6″/47 cal.	Light cruisers
5″/38 cal.	Battleships, cruisers, destroyers, carriers and auxiliaries.
3″/50 cal.	Submarines, destroyer escorts, subchasers, patrol craft.
40 mm., 20 mm., and caliber .50 machine guns	Any ship from patrol craft to battleships.

4A5. Gun construction. Naval guns in common use today are built in one of the four ways described in succeeding paragraphs. The method of construction is determined chiefly by the size of the gun, but the basic principle governing the design is common to all. This principle is best illustrated in a built-up gun.

4A6. Built-up guns. A gun composed of several concentric cylindrical pieces shrunk over each other is a *built-up gun,* such as that shown in figure 4A2. The outer cylinders, or hoops, are heated and assembled one at a time on the A tube. As the hoops cool, they shrink, and tightly grip the cylinders within them. The locking rings are then added to prevent longitudinal movement of the hoops. After the hoops and locking rings are assembled on the tube, the entire assembly is heated and shrunk on a liner. The 14-inch and 16-inch guns are examples of this construction.

The assembled barrel forms a cylinder within which high pressure is developed as the charge explodes. The effect of the pressure is greatest on the inner cylinder, and diminishes rapidly as it proceeds outward. If the outer hoops were assembled over the tube without shrinkage, they would be subjected to less strain than the tube, and the strength of the gun would be little more than the strength of the A tube. However, the shrinkage of the hoops squeezes the tube, at the same time stretching the hoops. The pressure of explosion can then be increased, for it must overcome the squeeze before it can stretch the tube. The shrinkage is calculated so that each hoop carries a larger share of the strain than it would with no shrinkage.

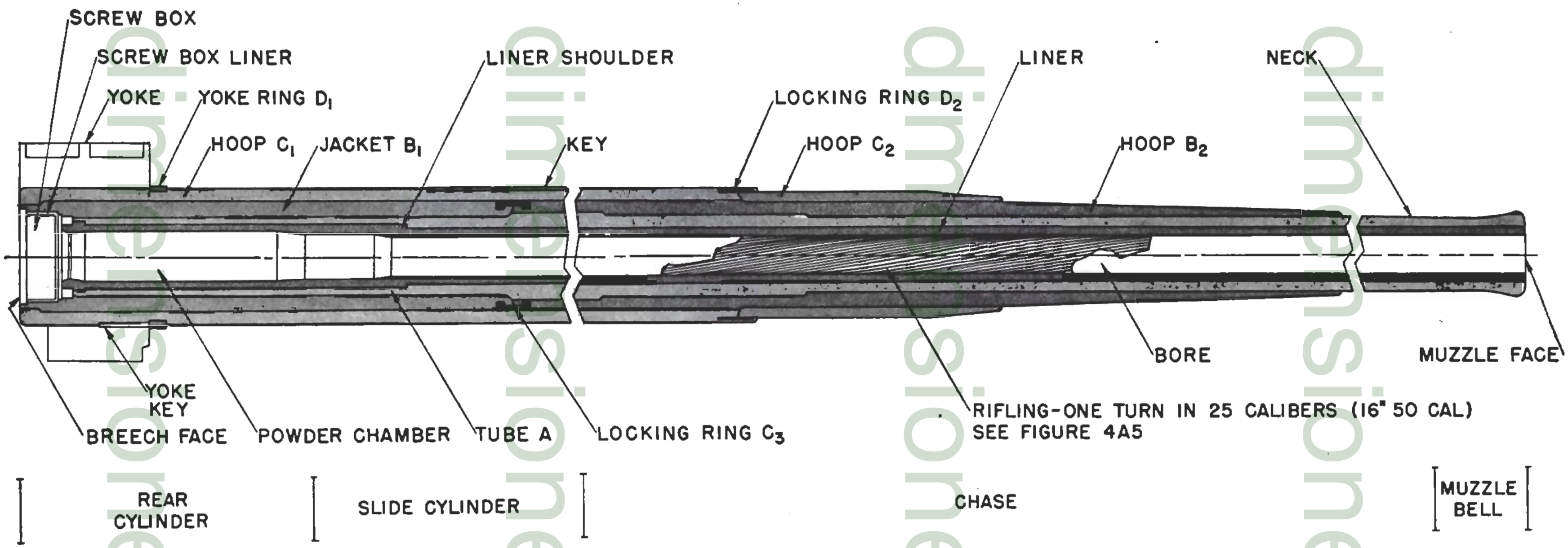


FIGURE 4A2. A built-up gun.

It is apparent that a built-up gun can withstand higher pressures than a gun made of a single untreated cylinder. This characteristic of built-up construction makes possible the large 14-inch and 16-inch rifles used by the Navy. An ordinary single cylinder, even if many times as thick as a built-up cylinder, could not withstand the high pressures developed in modern high-powered guns.

4A7. Radially-expanded guns. A gun made from a single cylinder which has been subjected to a radial-expansion process is called a *radially-expanded monoblock gun.* The process consists of applying high hydraulic pressure to the inside of the cylinder. The pressure, higher than that developed during firing, expands the entire tube radially. After the pressure is removed, each imaginary layer of the tube attempts to return to its original size. However, the inner layers, subjected to greater force and stretched proportionately more than the outer layers, cannot fully return to their original size. As a result, the outer layers grip the inner layers just as the hoops grip the tube in a built-up gun. The monoblock is then in a condition to withstand modern firing pressures without damage to its inner surface.

The radial-expansion process results in a cylinder in which the change from squeeze on the inner layer to stretch of the outer layer is uniform. The change in a built-up gun is in abrupt steps from hoop to hoop, and the strength of the metal is not fully utilized. The metal in a radially-expanded gun is used much more efficiently, hence strength for strength, radially-expanded guns weigh less than built-up guns. The decreased weight of the barrel permits a decrease in the weight of the entire gun assembly.

The radial-expansion process produces guns faster and cheaper than the building-up process. This fact, plus the saving in weight, make radially expanded guns preferable to others. However, the process is limited at present to moderate size guns because of the difficulty of obtaining a single forging large enough for those of major caliber. Typical guns having monoblock barrels are the 3″/50 cal. and 5″/38 cal.

4A8. Combination guns. The built-up and radially expanded features may also be incorporated in a single gun. Thus, the difficulty of obtaining a single forging big enough for the larger guns can be overcome. The 8″/55 cal. gun, for example, has a jacket shrunk on a radially expanded tube.

4A9. Simple one-piece guns. Many small guns such as the 40 mm. and 20 mm. are made from a single steel forging which requires neither the radial expansion nor hoops. The pressures developed per square inch in small guns may be higher than those in large guns, but this may be compensated by increasing the size of the forging which is not excessively large in any event. This type of construction is found in machine guns and small arms.

4A10. Nomenclature. The commonly used names of the various parts of a gun, generally applying to any one of the four types of construction, are labeled in figure 4A2 and defined as follows:

External:

1. The *breech* is the rear end.
2. The *yoke* is the large ring surrounding the breech end of the barrel, and is considered part of the gun. It provides a connection between the barrel and the mount. Shoulders on the gun prevent movement between the barrel and yoke.
3. The *rear cylinder* is the portion which extends from the breech to a point forward of the chamber. The yoke is attached to this part.
4. The *slide cylinder* is the portion of uniform diameter that supports the gun in a slide, through which the gun moves when it is fired. One or more longitudinal keys are inserted between the slide and slide cylinder to prevent rotation of the gun due to the reaction of the projectile on the rifling. The slide cylinder is sometimes made the same diameter as the rear cylinder to permit removal of the gun from the front of the slide.
5. The *chase* is the sloping portion forward of the slide cylinder extending to the neck.
6. The *neck* is the part of least outside diameter.
7. The *muzzle bell* is the part forward of the neck which flares outward to provide greater

strength and prevent enlargement of the bore at the muzzle. In some guns, especially of smaller sizes, the flare may extend past the end of the rifling to provide a shield which will minimize flash and muzzle blast.

Internal:

1. The *screw-box liner* is screwed into threads cut in one of the hoops. This liner contains the threads which engage the threads on the breech plug described later. A liner is used to facilitate replacement of the threads when they become worn.

2. The *chamber* is the space into which the powder charge is loaded. It is made larger in diameter than the bore in order to shorten its length and to facilitate loading. The details vary among guns, but slopes are provided to guide the projectile into the bore, and to provide a seat for the rotating band to insure uniform loading.

3. The *bore* is that interior part of the tube which is of uniform diameter and extends from the chamber to the muzzle. Its diameter is measured between diametrically opposite lands.

4. The *rifling* is the set of helical grooves cut in the bore. The raised spaces left between the grooves are the *lands*.

5. The *muzzle* is the forward end.

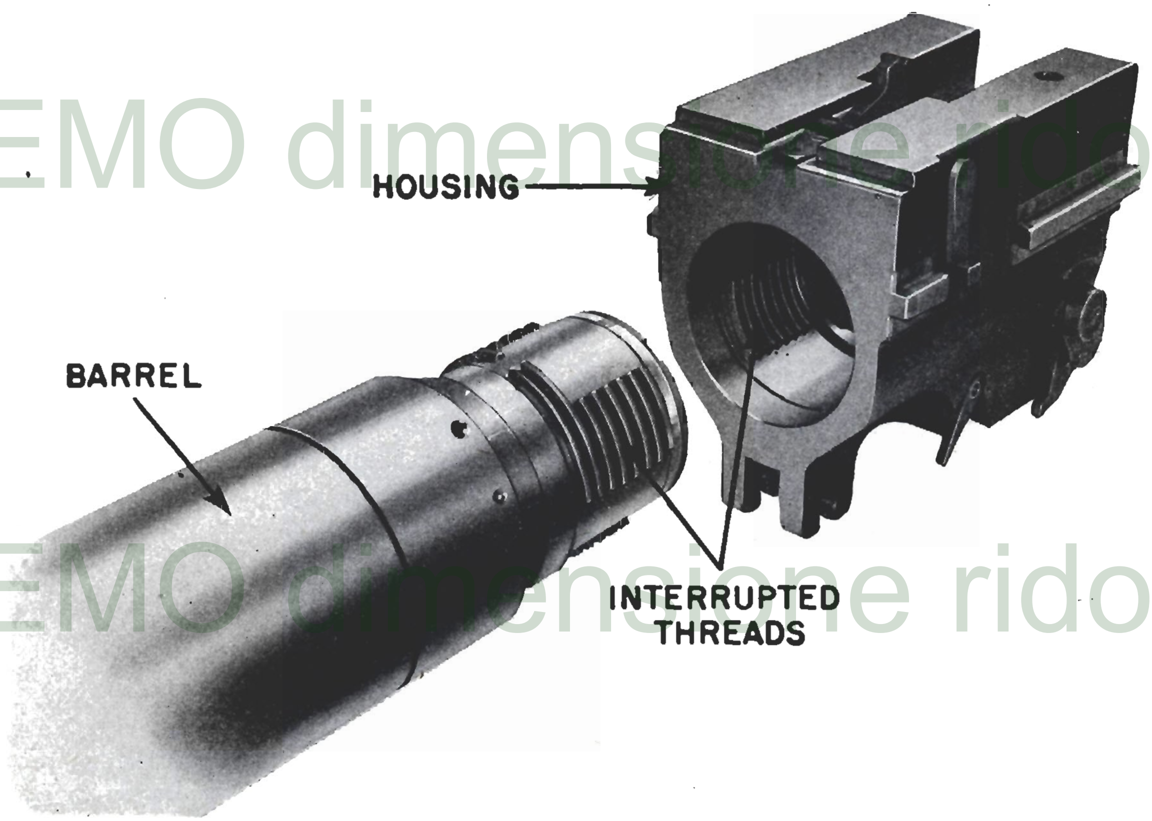


FIGURE 4A3. A typical bayonet-type joint.

4A11. Bayonet-type joint. Many of the smaller guns* now in use have a *housing* which takes the place of the yoke and screw-box liner. This construction, illustrated in figure 4A3, sometimes also permits the elimination of the slide cylinder, as will be seen when individual guns are studied. Such an arrangement permits the use of a *bayonet-type joint,* which makes it possible to remove the barrel without disassembling the entire gun.

The joint is similar to that formed between a screw and a nut. Threads on the barrel engage with threads in the housing, but they are interrupted (have sections cut away) in such a manner that the barrel can be inserted or removed after a partial revolution. This type of joint is employed

* A housing is used in guns through the 6"/47 cal., and this use is now being extended to the 8"/55 cal.