

NAVAL ORDNANCE

A TEXT-BOOK

PREPARED FOR THE USE OF THE MIDSHIPMEN OF THE
UNITED STATES NAVAL ACADEMY

BY

OFFICERS OF THE UNITED STATES NAVY

REVISED BY

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PREFACE.

The necessity of again revising the text-book of Ordnance and Gunnery having arisen, the task was undertaken and partially completed by the late Lieutenant Commander Roland I. Curtin. The revision has been finished, as far as possible, in accordance with data left by him.

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CHAPTER I.

METALS USED IN ORDNANCE-CONSTRUCTION.

Definitions.

Stress and strain.—When a force is applied to a body, the effect produced depends upon whether or not the body is free to move. A force applied to a free body produces motion. A force applied to a fixed body produces change of form.

Stress is the mutual action between two bodies, or the parts of one body, causing or tending to cause them to move relative to each other; it is any pair of equal and opposite actions each of which is called a force.

Strain is the change in volume or figure of any body under the action of the applied force.

Stresses are of different kinds, depending upon the manner of application of the force, as *tensile*, *compressive* or *torsional* stress.

A *torsional stress* is a compound stress, and may be resolved into a *tensile stress* on some elements of the material and a *compressive stress* on others.

Each kind of stress produces a corresponding strain, or effect on the material: the tensile stress produces *elongation*; the compressive stress, *compression*. Since all stresses may be resolved into tensile and compressive stresses, all strains may be resolved into elongation and compression.

Elasticity, elastic strength, modulus of elasticity, set.—The *elasticity* of a metal is the property it possesses of resisting permanent deformation when subjected to a stress.

All experiment and experience agree in establishing the five following laws for cases of simple tension and compression, which may be regarded as the fundamental principles of the science of the strength of materials:

(1) When a small stress is caused in a body, a small deformation is produced; and on the removal of the stress, the body springs back to its original form. For small stresses, then, materials may be regarded as perfectly elastic.

(2) Under small stresses the deformations are approximately proportional to the forces, or stresses, which produce them, and also approximately proportional to the length of the bar or body (Hooke's law).

(3) When the stress is great enough, a deformation is produced which is partly permanent; that is, the body does not spring back entirely to its original form on removal of the stress. This permanent part is termed a *set*. In such cases, the deformations are not proportional to the stresses.

(4) When the stress is greater still, the deformation rapidly increases, and the body finally ruptures.

(5) A sudden stress, or shock, is more injurious than a steady stress, or than a stress gradually applied.

The words "small" and "great," used in stating these laws, have very different values and limits for different kinds of materials and stresses.

The elastic limit of stress (sometimes called "*elastic strength*") is that unit stress at which the permanent set is first visible, and within which the stress is directly proportional to the deformation. For stresses less than the elastic strength, bodies are perfectly elastic, resuming their original form on removal of the stress.

Elastic limit of strain.—The limit of strain, or deformation, within which Hooke's law holds good, is called the *elastic limit of strain* (sometimes called "*elastic limit*"). Beyond the elastic limit a permanent alteration of shape occurs, or, in other words, the elasticity of the metal has been impaired and a *permanent set* is produced. It is a fundamental rule for all engineering construction, that materials cannot safely be strained beyond their elastic limit.

Fracture of a solid occurs when, under the action of a stress, a strain is carried so far as to cause actual division of the solid into parts.

The coefficient of elasticity of a bar, for tension, compression or shearing, is the ratio of the unit stress to the unit deformation (strain), provided the elastic limit of the material be not exceeded. Let S be the unit stress, e the unit deformation, and E the coefficient of elasticity. Then, by the definition, $E = \frac{S}{e}$ and $S = Ee$. By law (2) E is constant for each material, until S

reaches the elastic limit. Beyond this limit e increases more rapidly than S , and the ratio is no longer constant. Since E varies inversely with e , the coefficient of elasticity may be regarded as a measure of the stiffness of the material. The stiffer the material, the less is the change in length under a given stress, and the greater is E . The values of E for materials have been determined by experiments with testing-machines. E is necessarily expressed in the same unit as the unit stress. E is also called the *modulus of elasticity*.

General Remarks on Metals.

Physical properties of metals.—Metals have certain properties, which are of great importance in the case of metals used in gun-construction. These principal properties are *malleability*, *ductility*, *hardness*, *toughness*, *tensile strength*, and *elasticity*.

(1) *Malleability*.—A metal is said to be *malleable* when it may be permanently extended in all directions without rupture, by pressure (as in rolling) or by impact (as in hammering).

(2) *Ductility*.—A metal is *ductile* when it may be extended permanently by traction, as in wire-drawing. Only malleable metals are ductile, but their ductility is not necessarily in the same ratio as their malleability.

(3) *Hardness*.—A metal is said to be *soft* when it yields readily to compression without fracture, and does not return to its original form on the removal of the compressive stress; and on the other hand, a metal is said to be *hard* when it does not yield readily to compression; that is, when the ratio of the compressive stress to the permanent strain produced is very great. The terms *hardness* and *softness*, however, are only comparative when used in describing metals; thus, we have hard and soft leads, while any sort of lead is soft as compared with wrought iron, which latter is called soft when compared with cast iron.

(4) *Toughness* in a metal is a relative term to express the power of resisting fracture by bending or torsion, and is measured by the number of times to which a definite section of the metal can be bent through a certain angle on either side of the perpendicular without any fracture.

(5) *Tensile strength*.—The *tensile strength*, or ultimate strength, of a metal is the unit stress required to produce fracture.

Thus, if a bar whose cross-section is A breaks under a tensile stress P , the tensile strength of the material is $\frac{P}{A}$.

Tempering.—When steel is heated to a red heat and suddenly cooled, for example, by plunging it into cold water, it is hardened or tempered. The more sudden the cooling, the greater will be the temper. Thus, cooling in water gives a greater degree of temper than cooling in oil. Tempering steel increases its tensile strength and elastic limit, but makes it brittle and reduces its toughness.

Annealing.—If steel, tempered as above, is reheated to a temperature below a red heat and cooled either slowly or rapidly, some of the temper or hardness will be removed. The higher the temperature of reheating, the softer will be the product. If reheated to a red heat and allowed to cool slowly, all of the hardness due to the original tempering process will be removed. This letting down of the hardness is called *annealing*, and is due to the presence of carbon in the steel. With reference to that element alone, steel will begin to show temper upon being heated and plunged into water, if it contains about .40 per cent carbon, and will get extremely hard with about .65 per cent carbon. Annealing softens the metal and relieves the internal strains due to working or quick cooling.

As we are now especially interested in the metals used in gun-, armor- and projectile-making (steel and nickel steel), only a brief mention will be made of the others.

Copper, in its pure state, is too weak and soft for construction purposes. It is used for rotating bands of projectiles, and for electric wires.

Bronze, an alloy of copper and tin, is expensive, is too soft for the bores of large rifled guns, is injured by the heat of high charges, and is liable to flaws due to the segregation of its constituents. It is very ductile, is tough, but is low in elastic limit and tensile strength. It is now used for minor parts subject to no great strain, as sight brackets, hand wheels, liners to avoid the wear of steel against steel, etc.

Brass, an alloy of copper and zinc, is used in parts of the minor attachments, such as the firing connections, and for cartridge cases, primers, etc.

Cast iron is cheap, easily worked, but of low elastic limit and tensile strength. It can be fused and cast without difficulty, and is comparatively hard. It is not malleable, and cannot be welded, and is brittle. Castings are very uncertain in character, due to the method of manufacture. Many, apparently perfect on surface inspection, develop serious flaws in machining, and have to be rejected. Cast iron is not now used for either guns or mounts.

Wrought iron is almost infusible, but is readily welded. Its tensile strength and elastic limit are low; but on account of its ductility, it requires a large amount of work to extend it from its elastic limit to fracture, which makes it a comparatively safe material to use because it will give evidence of weakness before actual fracture takes place. The bores of wrought iron guns have been permanently indented or bruised by moderate firing, the metal not being hard enough. This is a serious defect under the high pressures modern guns must stand. Wrought iron is no longer used in either guns or mounts.

Cast steel has a higher tensile strength and elastic limit than wrought iron, but not so great a ductility. As forged steel is used exclusively in the manufacture of modern naval guns, so cast steel is used for mounts, and it is only the ability to obtain steel castings reasonably free from dangerous flaws that has made the strong, compact, modern naval gun-mount possible. The only difference between cast steel and forged steel is that the latter has been *worked*, either by *hammering* or by *pressing*, which results in a rearrangement of the molecules and a marked improvement in the physical qualities. But it is also possible to effect considerable improvement in the physical properties of steel castings by treatment, that is to say, by annealing and tempering.

Forged steel combines more good qualities for use in modern guns than bronze, cast iron, wrought iron, or cast steel. It is easily fused, is malleable, and is more or less weldable, according as it is soft or hard. It is tough and elastic, with a much higher elastic limit and tensile strength than wrought iron or cast steel. Its elastic limit, or elongation within that limit, is much higher than for the other metals above noted; and this quality makes it especially suitable for gun-making, in view of the strains which are set up in guns by heavy charges.

The properties of wrought iron are not sensibly modified by temper, which is ordinarily expressed by saying that wrought iron does not temper. Pure wrought iron contains no carbon at all; commercial iron may have as much as .30 per cent carbon. Soft or extra low steel may contain as low as .15 per cent carbon; there is, however, a great difference in the physical qualities of the two metals, due to the methods of manufacture. Steel proper may be said to contain from .20 per cent to 2.00 per cent carbon, and cast iron from 2.00 per cent to 5.00 per cent.

The properties of certain cast irons are considerably modified when, after having been liquefied, they are cooled suddenly; therefore we may say, from this point of view, that cast iron takes temper like steel.

To state in a few words the characteristics which may serve to distinguish wrought iron, steel, and cast iron, we may say: Wrought iron is forgeable, weldable, practically infusible, and *does not temper*; steel is forgeable, weldable, fusible, and takes temper; cast iron is neither forgeable nor weldable, it is relatively very fusible, and is susceptible of being tempered.

Steel in General—Composition of Steel.

Definition of steel.—Reasoning from the foregoing, steel is a *fusible, malleable alloy of iron produced in any way whatever, and containing a smaller proportion of carbon or other hardening element than is contained in cast iron, and is capable of receiving temper.*

Process for obtaining cast steel.—There are a variety of processes for removing a portion of the carbon from cast iron and producing steel, among which may be mentioned: (1) Melting in crucibles, giving *crucible steel*; (2) the open-hearth process, giving *Siemens* or *Siemens-Martin steel*; (3) the process of blowing air through molten cast iron, producing *Bessemer steel*. In whatever way made, the material is essentially the same, depending upon its chemical composition and physical structure for its properties.

High and low steel.—In consequence of the extension given to the word *steel*, we have to-day under this name metals which

present differences as regards both composition and physical properties. Hence, the different varieties of steel have been distinguished by the proportion of carbon—sometimes by numbers, and sometimes by more or less characteristic names. When the metal contains a large proportion of carbon, it is ordinarily called *high* or *hard steel*. If the proportion of carbon is small, it is called *low* or *soft steel*; if still smaller, *extra low steel*. In some manufactories, for example, the name of *low steel* is given to a metal containing .20 to .25 per cent of carbon, and a metal in which the proportion of carbon is less than .20 per cent is designated *extra low steel*.

All steel contains more or less carbon, together with varying amounts of certain other elements, the principal ones being manganese, sulphur, phosphorus, silicon, copper, and arsenic. Certain other elements are sometimes found in the iron ore used in making steel, or are added as alloys, in certain definite quantities, with the object of giving desired qualities to the product; among these are: nickel, vanadium, chromium, aluminum, tungsten, molybdenum, uranium, and titanium. Steel containing carbon and elements of the first group mentioned is usually called *carbon steel*; if it contains, in addition, some one or more of the elements of the second group, it is called an *alloy steel*, as *nickel steel*, *chrome steel*, etc.

Physical properties—how obtained.—The physical properties of any steel depend on: (1) Chemical composition, (2) heat treatment, (3) the amount and kind of mechanical work to which it has been subjected.

(1) The chemical composition of steel influences both its physical properties and its structure, owing to the definite compounds formed by the combinations of carbon, manganese, sulphur, phosphorus, and other constituents.

(2) Heat treatment includes the whole of the thermal conditions through which the metal is passed, and embraces both heating and cooling by different methods and under different conditions.

(3) Mechanical work to which the steel is subjected consists in rolling or forging to reduce the ingot to the desired shape and to impart to it the desired qualities.

Production of Steel.

As the chemical composition of steel is mainly determined and controlled in the first processes of manufacture, the principal methods in use will be briefly described; viz., *crucible process*; *converter process*; *open-hearth process*, (1) acid, (2) basic; *electric process*.

Crucible process.—This process consists in putting into a crucible a proper mixture of scrap, wrought iron, and charcoal and heating it until everything is thoroughly melted, the crucible being tightly closed to prevent the admittance of air. The crucibles are made, in America, of mixtures of graphite and fire-clay and hold about 100 pounds of metal; they last for about six heats. The crucibles are placed in a gas or coke furnace, and the metal takes from two to three hours to melt.

This process is a very old one, but in the long run is the most satisfactory. The chemistry of the crucible process consists in the elimination of the slag in the wrought iron, and the absorption by the metal of carbon, silicon, and manganese. There is also a slight increase in sulphur and phosphorus.

Converter process.—This includes the basic and acid Bessemer processes, both being founded upon the general truth that if cold air be blown through molten pig iron the combustion of the impurities in the iron will furnish sufficient heat to keep the metal in a fluid state.

In the acid process three elements are burned—the carbon, the silicon, and the manganese.

In the basic process the lining is made of basic material, usually hard-burned dolomite, *i. e.*, limestone containing 30 to 40 per cent of carbonate of magnesia.

In the acid process silicon supplies most of the heat, while in the basic the silicon is kept low, the element taking its place to supply heat being phosphorus. In the acid process phosphorus is not eliminated. The basic process requires more heat. The Bessemer process is applicable to only two kinds of ore: (1) Those low in phosphorus, giving iron suitable for acid process; (2) those high in phosphorus, giving iron containing .20 per cent of phosphorus, suitable for basic process.

Open-hearth or Siemens-Martin process.—This consists in melting pig iron mixed with more or less wrought iron, steel, or

similar iron products, by exposure to direct action of the flame in a regenerative gas furnace, and converting the resultant bath into steel; the operation is so conducted that the final product is entirely fluid.

The impurities are eliminated partly by the oxidizing action of the flame during the melting and partly by the action of oxides of iron formed during the melting period or added to the melted charge.

The acid process.—In this process neither the sulphur nor the phosphorus is to the least extent eliminated, and both therefore increase relatively in the finished steel as compared with the percentages in the original charge; hence the first essential in selecting pig and scrap for the process is that they be low in sulphur and phosphorus.

The basic process.—This depends, for the removal of phosphorus, entirely on the formation of stable *phosphates*, and this is effected by lining the furnace with a basic or neutral material, and by lime additions during the working of the charge. The furnace employed is, with the exception of the basic lining, identical with that used in the acid process, and the method of working is the same.

Electric process.—This process is confined practically to the production of high-class carbon and special steels from cold scrap, or to the refining of molten open-hearth or Bessemer steel in order to produce steel of better quality.

The furnaces used are: (1) *The induction furnace*, (2) *the arc-resistance furnace*.

Induction furnace.—This furnace is a large crucible, basic-lined, in which steel is melted by induced current, being practically protected from oxidation and completely protected from the action of furnace gases.

Arc-resistance furnace.—In this type of furnace heat is generated largely by the arc and the resistance offered by the furnace charge to a very powerful electric current.

Advantages.—The steel is of the highest quality—equal to the best crucible steel. It is employed only when superior quality is required.

Comparison of the products.—In order of quality the different steels may be arranged as follows: (1) Crucible and electric furnace, (2) acid open-hearth, (3) basic open-hearth, (4) converter.

Application of the Processes.

Steel for gun-castings.—Steel castings for parts of gun-mounts, gun-yokes, sight-brackets, and other ordnance purposes, are produced generally by the open-hearth process, although the electric process is used to some extent. The process used is not of great importance, but the metal must be reasonably free from injurious elements. The excellence of steel castings is largely determined by the method of casting.

Steel for gun-forgings.—In the manufacture of steel for gun-forgings, the Krupp works in Germany have, until recently, used the crucible process; at present they are using the electric process. In the United States the open-hearth process is used.

The crucible process has many advantages over the other processes in obtaining metal of greater purity, but on account of the impossibility of insuring identical composition in all crucibles, uniformity of composition cannot be obtained, on account of segregation.

There is no difficulty in obtaining by the open-hearth process—*i. e.*, by the dissolution in a cast-iron bath of a certain quantity of wrought iron or steel—a very pure metal, such as is required in the construction of guns; all depends on the purity of the pig iron and scrap charged.

Swedish pig iron is used at practically all steel-works when steel for gun-construction is made. This material is absolutely the best and purest iron known. It is by nature practically free from sulphur and phosphorus and contains a small amount of vanadium.

Steel for armor.—The armor used on ships of the U. S. Navy is face-hardened, excepting the thin plates for turret and conning-tower tops, which are of special-treatment steel. Face-hardened armor is designated as Class A and the special-treatment steel plates as Class B.

Protective-deck plating and splinter bulkheads are made of the same material, but are not classed as armor.

Class A armor may be cemented or non-cemented. In both cases the steel ingot is made by the open-hearth process.

The composition is predetermined, being low-carbon steel, containing inseparable ingredients of phosphorus and sulphur, the percentage of which it is endeavored to keep at a minimum, and

nickel, chrome, silicon, and manganese. For non-cemented armor the carbon content is somewhat greater than for cemented armor.

Steel for projectiles.—Steel for armor-piercing projectiles is made by the crucible process, open-hearth process, or in an electric furnace.

Recapitulation.

USE.	PROCESS.
(1) Gun-mounts and ordnance appurtenances.	Acid—open-hearth and electric.
(2) Gun-forgings.	Acid—open-hearth in the United States; electric at the Krupp works.
(3) Armor.	Acid—open-hearth for Class A; face-hardened.
(4) Turret and conning-tower tops.	Basic—open-hearth Class B; not face-hardened.
(5) Protective deck and splinter bulkheads.	Basic—open-hearth; not face-hardened.
(6) Projectiles.	Acid—open-hearth; crucible and electric process.

Method of Manufacture of Steel and Alloy-Steel Gun-Forgings.

Furnace practice.—Alloy steel and gun steel for gun-forgings are made in acid open-hearth furnaces, because of the increased probability of blowholes and gas bubbles in steel converted by the basic process, due undoubtedly to the fact that such steel is likely to be more highly charged with oxygen. The furnace charge is made up of about one-third pig iron low in phosphorus and about two-thirds plain or nickel-steel scrap, such scrap being parts of old ingots, cuttings, and turnings. The exact proportions of pig and scrap depend on the quality and quantity of the scrap obtainable, and also on the analysis of the pig iron (particularly its silicon content); but the pig iron generally constitutes from 20 to 30 per cent of the charge. The scrap, if the product is to be nickel steel, contains from 2 to 2½ per cent nickel. From six to eight hours are required to break down and thoroughly melt the charge, and as soon as this occurs samples are taken. A fracture test enables an experienced person to closely estimate the percentage of carbon contained in the charge. Other samples are sent to the chemical laboratory, where analysis is made for carbon, manganese, silicon, sulphur, phosphorus, and nickel. The nickel is not oxidized, and remains constant, and the amount to be added, if any,

is determined from the analysis and introduced in the form of pure nickel blocks or "plaques."

Every half hour after the charge is melted the carbon color test is made, until the carbon has been reduced to the desired percentage by oreing down. This consists of adding iron ore from time to time, Lake Superior hematite being generally used, the reaction being $\text{Fe}_2\text{O}_3 + 3\text{C} = 2\text{Fe} + 3\text{CO}$. For nickel-steel tubes and liners the carbon is reduced to between .35 per cent and .42 per cent, but for "gun steel" the amount of carbon will run between .42 per cent and .50 per cent. From the results of the analyses the various necessary additions are made to bring the manganese and chromium up to the required amount. Ferro-manganese, or spiegel-eisen, is added to increase the carbon and manganese, the former being used when a smaller increase of carbon is desired. Ferro-chrome is added if necessary. Loam is put in to increase the slag, limestone to thin the slag.

From 10 to 20 hours after the bath is melted, it is tapped into ladles. Ferro-silicon is added to the ladle to bring the silicon up to the required amount. The molten metal is allowed to run into a large refractory-lined ladle, and as the tap hole of the furnace is below the slag line, only a small amount of slag goes into the ladle, and this remains at the top; by using bottom-pouring ladles the amount of slag is still further reduced.

Ingot.—Two kinds of ingots are used—the corrugated ingot for gun-forgings and the fluid-compressed ingot. The ingot molds are tapered from top to bottom, the top being smaller. The size of the ingot is its diameter at the middle of its height. The ingots are top- or bottom-poured indifferently; some manufacturers top-pour all ingots, others bottom-pour, and some one-half bottom-pour and one-half top-pour. A tong hold is left at the top of ingots to assist in handling, which also serves as a sink-head to take care of most of the slag, segregation, and piping.

The Whitworth process of fluid compression frees the cylindrical ingot of much of its gas content and thus reduces the amount of blowholes and piping. The liquid metal is subjected to slowly increasing pressure until about 2300 pounds per square inch is reached. This pressure is held for four or five hours, or until the metal has entirely solidified.

The last samples, three in number, are taken during the pouring of the ingot; two are analyzed for carbon, manganese, silicon,

phosphorus, sulphur, and nickel, and the result of the analyses is sent to the forge, where it is used in determining the forging heat. The third sample is taken to a small forge near at hand and, without treatment, is forged into test bars to ascertain the approximate physical qualities; this, known as the "heat test," gives an idea as to what can be expected of the metal.

The following are average chemical compositions of gun-forgings:

	Gun steel.	Nickel steel.	Alloy steel. ¹
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Carbon.....	.50	.40	.36
Manganese.....	.70	.70	.66
Silicon.....	.27	.27	.28
Phosphorus.....	.03	.03	.03
Sulphur.....	.03	.03	.03
Nickel.....		3.00	1.83
Chromium.....			.61

¹ For mushrooms.

As soon as the ingot is cold enough, it is stripped from the mold and a number is placed on it; this number remains with it for identification until it has passed through all of the processes and forms a part of a finished gun. The ingot is immediately taken to an annealing-furnace, where it is slowly and uniformly heated. Soft coal is used for heating, and the furnaces are provided with baffle walls for protecting the ingot from the direct action of the flame. The ingot enters the furnace at a temperature of about 1400° F., and is kept at this temperature for about five hours, after which time the fires are allowed to die down and the ingot cools slowly with the furnace. From three to four days are required for the cooling of a large ingot.

The ingot is now sent to a machine shop, where it is slung on a large lathe, and the specified amounts of top and bottom discard are removed. If the ingot is to be used for hollow forging, it is put in a boring-mill and rough-bored to the required diameter. After the discard has been removed, and after boring (if this operation is required), the ingot, if not to be forged in one piece, is cut into blocks of the required sizes. This is done in the lathe used in cutting off the discards.

A separate number is stamped on each block made from an ingot, using the ingot number as the first part, and following it

with letters and numbers to indicate the relative position of the block in the ingot. These numbers always begin at the breech or bottom end of the ingot; thus, if ingot No. 12345 were cut into four pieces, the bottom block would be No. 12345B₁, the second block from the bottom No. 12345B₂, and so on. If the whole ingot, after discards have been removed, is to be used in a single forging, it carries its ingot number and is designated B₁. If any of these blocks are afterwards cut into smaller pieces, the number given these pieces would be No. 12345B₁F₁, No. 12345B₁F₂, etc., numbered from breech end of block. (The "F" stands for "forging.")

Before leaving the machine shop the block is examined by a sub-inspector for signs of piping, blowholes, and other defects, and the amount of discard is checked.

Forgings.—Forgings for pieces whose finished interior dimensions are small are forged solid; larger pieces are bored before being forged. For instance, the tube and jacket and "B" hoops of a 14-inch gun would be forged solid; the "C" and "D" hoops would be bored before being forged.

From the machine shop the block is taken to the forge, where it is brought to the desired forging temperature in an acid-lined regenerative, producer gas furnace, or other similar furnace. This temperature is usually about 2100° F. If the block is a long one, one end is heated at a time; the other end, projecting from the furnace, is used for handling the piece during the forging operations, the ends being alternately heated and forged under a hydraulic press. Small blocks go entirely in the furnace, and are heated uniformly. The length of time required to bring the block to forging heat depends on the size of the block, and the quality of the steel. Great care is taken not to heat too rapidly, this being particularly important with alloy steels.

The block having been brought to forging heat, it is balanced by means of a porter bar, and taken by an overhead crane to the hydraulic forging-press. There the operation depends upon the kind and shape of forgings to be made.

If to be forged solid, the block is forged down and drawn out by repeated workings, the forging being supported in a V-shaped anvil under a slightly concave die secured to the *tup* or head of the press, the pressure being applied gradually for about three seconds, with about one-second intervals between pressures. As

the forging operation is generally discontinued when the block has cooled to about 1550° F., several heats are necessary for tubes and liners.

The hollow forgings are forged on a mandrel which snugly fits in them. The forging is done as above described, between the V-shaped anvil and concave tup, as in the case of solid forgings; and in this manner the hole is not enlarged, but the wall thickness is reduced, and the metal is drawn out along the mandrel. With large forgings about eight heats are required for this operation, the mandrel being removed each time before the forging is put back in the furnace.

Short hoops of large diameter are forged on an *enlarging-bar*, the ends of which are supported on rests, or *jacks*, on each side of the press, with the forging hanging free on the bar between them and under the tup. By this means the thickness of wall is reduced and the hole enlarged without an appreciable change in the length of the forging. If it is necessary to lengthen a hoop thus enlarged, a mandrel is used for drawing it out as explained above.

Breech bushings, or screw-box liners, are first forged or drawn down before being bored. Thus, a forging of this kind for a 12-inch or 14-inch gun is made from an 84-inch corrugated ingot, forged down to a diameter of 54 inches, annealed to relieve it of forging strains, bored through the center, heated for re forging, put on an enlarging-bar, and the hole enlarged to the required dimensions. As these bushings are made of nickel-chrome steel, which is very apt to crack while under the press, they must be carefully nursed, and two or more reheats are necessary—one called the shaping heat, and one the finishing heat. Large breech bushings are always forged in pairs with their breech faces together, each end of the forging being forged down in steps as required by the drawings. After forging and subsequent annealing, they are cut apart in the lathe before being sent to the treatment department.

When the forging operation has been completed, the manufacturer sends a forging report and sketch of the rough forging to the inspector. The report contains the order number, drawing number, description of article, forging number, weight of discard, top and bottom, and size of bore. The sketch shows the general shape of the forging, with dimensions, and from this the forging reductions are figured.

From the forge all gun-forgings are returned to the annealing-furnace, and there annealed at a high temperature (about 75° above critical) for a considerable length of time to remove strains and to break up the previous structure. This annealing is done generally in an oil furnace. A button is taken and examined under the microscope to determine whether the metal is ready for tempering.

Machining.—After annealing, the forgings are sent to the machine shop, where the rough ends are cut off, steady rest bearings turned, and the scale removed. If a solid forging, it is put in a boring-lathe and bored out to about 1 inch less than finished dimensions. When these operations are completed, the forging is examined for cracks, signs of piping, or other defects. From the machine shop the forging is sent to the treatment department. On short pieces sufficient metal is left on the inside and outside to allow for warping in treatment; on larger pieces the forgings are machined to the required rough forging dimensions, and if warped in treatment are straightened under a press. Sufficient excess metal is left on each end of the forging to provide test specimens required by the specifications.

Treatment—tempering and annealing.—The method of treating and annealing the forgings, and a general description of the furnaces used by one of the larger manufacturing plants, are here given without any attempt to discuss the theory of heat treatment or special processes or details. Gun-liners, tubes, and hoops are lowered vertically by means of holding-rods and crane into pit furnaces and there brought to heat for tempering. These pits are of various sizes and depths, the largest being 60 feet deep and 70 inches in diameter. They are lined with fire-brick and heated with producer gas supplied through a number of nozzles or tuyères piercing the furnace in rings equally spaced; the direction of these nozzles being tangential to the walls of the furnace, the forging is not exposed to the direct action of the flame. The length of time that a forging remains in a furnace depends on the size of the forging, its carbon content, and the temperature of the furnace. Ten to 12 hours are generally required to thoroughly soak a forging to the desired temperature.

The oil wells into which the forging is immediately immersed after removal from the furnace are about the same size as the

heating-pits, and are also sunk in the ground. Forgings are immersed in the direction of their longitudinal axis. The oil is kept continually in circulation by means of a pump which forces it up through the bottom of the well, the overflow being carried off by a pipe at the top to a tank outside the building. After about 12 minutes have elapsed, the forging is taken out and put into the annealing-furnace, where it is supported, in a horizontal position, on narrow uprights, and gradually brought to the desired temperature. This takes from six to eight hours. The annealing-furnaces are heated with producer gas, and the forging is protected from the direct action of the flame. Self-recording pyrometers are used for measuring the temperatures. After being brought to proper heat, the forging is allowed to slowly cool. This is accomplished by a complete or partial reduction of the flame, as may be required, depending on the condition of the furnace. When cooled to about 300° F., the forging is removed from the furnace.

When entirely cool, the forging, if a tube, liner, or long hoop, is tested for straightness; and if warped enough to make this operation necessary, it is again heated (not over 850° F.) and straightened. It is then re-annealed from a temperature slightly above that given it for straightening. The forging is now ready for the company's test. Trial bars are taken, and if, in the opinion of the company, the forging is in proper condition, official submission is made on a form which gives the forging number, description, and order number, and on the back of the form the record of the last trial tests. Upon receipt of this form the inspector refers to his records; and if the treatment of the piece is satisfactory, the official test bars are laid out as prescribed by the specifications. These bars are slotted out and machined in a special shop, which is a branch of the treatment department and wherein only this class of work is done. The stamping of test bars and the witnessing of the test is done by a sub-inspector.

Determination of the physical properties.—This is accomplished by subjecting specimens of the metal to the action of different stresses in testing-machines, and observing the effect on the specimens in alteration of volume and figure by means of accurate measuring instruments.

Testing-machines.—The testing-machines are generally a combination of levers for recording the stress, and a system of gearing or hydraulic machinery by which the stress is produced.

Specimens are usually prepared to an adopted shape. In the case of gun metals they are cylindrical, and are turned to the same diameter for a certain length, usually not less than 2 inches and not more than 10 inches for tensile tests; and in addition, ends are allowed for the purpose of attaching the specimen to the machine. For compressive tests the specimen is also cylindrical, the height being twice the diameter. The capacity of the machine limits the diameter of these specimens.

In making a tensile test, the specimen is marked at two points as far apart as the finished length between grips will allow, and the length is carefully measured between these points. The diameter is also measured by micrometer calipers. It is then placed in the machine and subjected to successive tensile stresses, the elongation being noted for each stress, both when the load is on and after it has been removed.

The following table shows the minimum qualities of gun steel and nickel steel for gun-forgings of the different classes required by the specifications of the Bureau of Ordnance:

	Gun steel.		Nickel steel.	
	Under 8-inch caliber.	8-inch caliber and above.	3-inch caliber and under.	Above 3-inch.
<i>Tubes.</i>				
Tensile strength.....lbs. per sq. in...	90,000	86,000	95,000	90,000
Elastic limit.....do.....	50,000	46,000	65,000	55,000
Elongation.....per cent....	18	18	18	18
Contraction.....do.....	30	30	30	30
<i>Jackets.</i>				
Tensile strength.....lbs. per sq. in...	90,000	88,000	95,000	90,000
Elastic limit.....do.....	50,000	48,000	65,000	60,000
Elongation.....per cent....	18	18	18	18
Contraction.....do.....	30	30	30	30
<i>Cylindrical hoops.</i>				
Tensile strength.....lbs. per sq. in...	93,000	93,000	95,000	95,000
Elastic limit.....do.....	53,000	53,000	65,000	65,000
Elongation.....per cent....	18	18	18	18
Contraction.....do.....	30	30	30	30
<i>Trunnion hoops.</i>				
Tensile strength.....lbs. per sq. in...	90,000	90,000	.....	.....
Elastic limit.....do.....	50,000	50,000	.....	.....
Elongation.....per cent....	18	18	.....	.....
Contraction.....do.....	30	30	.....	.....

It will be seen, from an inspection of the table given above, that for the forgings of the larger guns the hoops are required to be stronger than the jackets, and the jackets stronger than the tubes.

It is desirable that the opposite rule should obtain, and that the tube should be the strongest part of the structure.

Explanation is found in the fact that it is impossible to make a large mass of steel as nearly perfect as a small piece. The smaller the forging the more uniform its texture and the more readily and the more perfectly will it yield to the processes of annealing, tempering, etc., the processes that affect its tensile and elastic strength. The Navy Department is forced to recognize these facts in its specifications.

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CHAPTER II.

NAVAL RIFLED GUNS.

General Discussion—Definitions.

A Gun is a metallic tube from which projectiles are thrown by the explosive force of a given charge of gunpowder with a given muzzle velocity, or by the expansion of some highly compressed gas.

A mortar is a short, heavy metallic tube using a high angle of fire.

A rifle is a gun whose bore has cut on its surface a number of spiral *grooves*, into which the soft metal of the rotating-band on the projectile is forced, thus imparting to the projectile a motion of rotation. The raised portions between the grooves are called *lands*.

A cast gun is one made by casting metal in a mold in the form of a gun, or approximately the form. Iron, bronze, and steel have been thus used. Cast guns are used in several foreign navies, but are used in our navy for drill guns only.

A built-up gun is any gun made up of different parts, the idea being to get an assemblage of parts best able to resist the pressures of the powder gas. The gun may be built up of different metals. The most usual forms are: (1) The built-up gun with initial pressure obtained by shrinkage, the exterior parts being heated to go over the interior parts; and (2) the "wire-wound" gun.

A low-power gun is any gun having a low muzzle velocity and a low pressure.

A high-power gun is any gun having a high muzzle velocity and a high pressure.

As the terms "low-power" and "high-power" are relative, no fixed velocity and pressure can be stated to distinguish between the two.

The bore of a gun is the hole in the gun extending from the breech face to the muzzle face of the tube. It forms a path for the projectile, and also serves to contain the powder charge before firing, as well as to confine the powder gases after firing.

The caliber of a gun is the diameter of a cylinder which touches the *highest* points of all the lands.

The word *caliber* is also used in connection with the length of the gun, meaning the length of the tube or *bore* divided by the diameter of the bore. A 50-caliber 12-inch B. L. R. is 50 calibers in length from the breech face to the muzzle face of the tube or bore.

The chamber of a gun is the space allotted to the powder charge, and is that part of the bore from the mushroom face, when the breech-plug is closed, to the point where the rifling begins, or from the base of the case to the rear of the projectile. Its *capacity* is the total cubical contents from plug face to base of projectile, when the latter is "seated" in position for firing. The powder chamber is made larger in diameter than the remainder of the bore in order to reduce its length.

The gun metal thickest over the chamber.—This is the case because at the point over the seat of the powder charge the pressure of the powder gas is the greatest. The powder pressures gradually decreasing toward the muzzle, the strain on the gun becomes less, and hence the gun may taper forward.

Parts of a gun.—A gun as viewed from the outside has the following parts: *Breech, rear cylinder, slide cylinder, chase, muzzle*, and, on some of the older guns, *trunnions*.

The *breech* is the rear end of the gun, while the *muzzle* is the front end, whence the projectile issues.

The *rear cylinder*, at the breech end of the gun, is that part over the chamber where the metal is thickest.

The *slide cylinder* is that part of a gun forward of the rear cylinder which fits in the slide and which contains the key.

The *chase* is the sloping portion forward of the slide cylinder extending to the muzzle, whether in one taper or in stepped tapers caused by hoops.

The end of the chase forms a curve at the muzzle of increased diameter, forming what is known as the "bell muzzle." The metal is increased at that point to give greater strength, to prevent enlargement of the bore due to high muzzle pressures.

The *trunnions* consist of two cylinders on the sides of the gun at right angles to the axis, at or near the center of gravity, to support the gun on the carriage. In cast guns the trunnions are in one with the gun, while in "built-up" guns they are carried on a

separate band. No gun, in our service, over six inches in caliber has trunnions.

The *rimbases* are the flat portions of the trunnion-bands to which the trunnions are attached.

Guns are now generally made *trunnionless*, being supported by slides within which the guns recoil. The recoil is checked by hydraulic cylinders attached to the slides, the pistons of which are connected by their rods to a yoke on the gun. These slides have trunnions that rest in seats on the gun-carriage. Sometimes the guns are provided with sleeves that are screwed onto the gun. The hydraulic cylinder forms a part of the sleeve, and the piston-rod is attached to a lug on the slide in which the sleeve recoils. The slide is provided with trunnions journaled in the carriage. Some of our heavy guns rest in saddles, and are held thereto by suitable straps passing over the gun body. The saddle recoils on the slide carrying the gun, and the recoil is checked by the hydraulic cylinders fixed to the mounting, the piston-rod being secured to the saddle.

Breech-loading rifle.—All modern guns are breech-loading, but the term is still used to designate guns that do not use metallic cases for the powder. A mushroom and gas-check pad are therefore required to prevent the powder gases, under the high pressures of explosion, from escaping to the rear around the plug.

Rapid-fire guns are those in which a metallic powder case is used, this case preventing escape of gas to the rear, so that no mushroom and gas-check pad are required.

Field-guns are of 3-inch caliber and are supplied with field-carriages for use on shore.

Boat guns are supplied with mounts for use in small boats.

Automatic guns are those in which the force of explosion is used to eject the fired cartridge-case and load another cartridge. When ammunition is properly supplied, no force but pressure on the trigger is required for continuous fire.

Semi-automatic guns are those in which the force of explosion ejects the fired cartridge-case and leaves the breech so that it closes automatically when another cartridge is properly inserted.

Machine-guns are those which, with proper ammunition supply, fire continuously when a crank or lever is turned. Unlike an automatic gun, the machine gun must have its mechanism operated by outside power.

Small arms are rifles, fired from the shoulder, and pistols.

Sub-caliber guns.—A gun is called a *sub-caliber gun* when it is used mounted inside or outside a larger gun, for short-range gunnery practice. One-pounders and small-arm rifles are used for this purpose.

Designation of guns.—Guns are usually named or designated either by (1) caliber in inches, followed by the length of bore in calibers and the mark of the gun; or by (2) weight of projectile expressed in pounds for small-caliber guns (1-pounders to 6-pounders), followed by the mark of the guns. Thus: 14-inch, 45-caliber, Mark I, Mod. I.

All guns of the same caliber, but of a different design, are distinguished from one another by being given different marks. The first design built of a caliber is called Mark I. If a new design is built with either new exterior or new interior dimensions, giving different ballistics from the previous design, this design is given a new mark, as, for instance, Mark II. If, however, a finished gun is modified, it retains the same mark, followed by a modification number, as 12-inch, Mark VII, Mod. II (the second modification made on Mark VII, 12-inch gun). Thus the 14-inch, Mark I gun, on being relined, would be designated as 14-inch, Mark I, Mod. I gun.

The usual *service method* is to write the caliber and the mark only; thus: 8-inch, Mark V, Mod. I.

This system of marking is carried out throughout ordnance, not only for guns, but for gun-mounts, breech mechanisms, sights, powder tanks, firing-locks, and, in fact, most articles that are units in themselves.

Guns classed aboard ship.—The following is the classification for battleships and armored cruisers: (1) Main battery; (2) secondary battery; (3) minor-caliber guns; (4) landing-guns; (5) field-guns, and (6) small arms.

Main-battery guns.—All guns of and above 8 inches in caliber constitute the "main battery."

Secondary-battery guns.—All guns of and above 4 inches in caliber, up to and including 7 inches in caliber, constitute the "secondary battery."

The torpedo-defence battery includes all guns designated to repel torpedo attacks. It generally consists of all secondary-battery guns, but may include main-battery guns.

On small vessels, such as destroyers, the guns carried constitute the "battery," without any prefixed designation.

Minor-caliber guns include all guns of a caliber greater than *small arms*, and less than 4 inches in caliber.

Rifling of Guns.

Advantages of rifling.—The penetration of oblong projectiles, other things being equal, is much greater than can be realized with spherical shot, while the bursting charge of oblong shells is as great as, or even greater than, that of spherical shells, on account of their greater length. These are very substantial advantages; but to secure them it is essential that the oblong projectile should keep point foremost in its flight; otherwise it would have neither range, accuracy nor penetration, but would waste its energy beating the air.

The only way to secure steadiness of flight to an oblong projectile is to keep its geometrical axis in the tangent to the trajectory it describes by giving it a high rotary velocity about its axis, thus imparting to it the properties of a gyroscope, whereby it resists angular motion. This is accomplished by *rifling*, as it is called; that is, by cutting spiral grooves in the surface of the bore into which a projecting copper band, securely encircling the projectile near its base, is forced as soon as the motion of translation begins, thus giving to the projectile a rotary motion in addition to its translation as it moves down the bore. The rifling may be such that the grooves (or *rifles*) have a constant pitch—that is, make a constant angle with the axis of the bore—or this angle may increase gradually. In the first case the gun is said to be rifled with a *constant twist*, and in the second case with an *increasing twist*. In all cases the twist at any point of the bore is measured by the linear distance the projectile would advance while making one revolution, supposing the twist at that point to remain constant. This linear distance is always expressed in calibers, and is therefore independent of the unit of length employed.

Increasing twist.—With a uniform twist the maximum pressure produced on the lands (on sides of the grooves) occurs near the point of maximum pressure on the base of the projectile, which point is near the beginning of motion. From this point the pressure on the lands decreases to the muzzle, where it is not generally

more than one-fourth of its maximum value. It is considered by our designers an advantage to have the pressure on the lands as nearly uniform as possible, and to this end recourse is had to an increasing twist.

From experiments conducted in England it was deduced that the loss of energy due to uniform rifling is 1.43 per cent, and for the parabolic or increasing-twist rifling 2.30 per cent. This greater loss is due to the constant alteration in form that the band undergoes. The coefficient of friction, deduced from the loss of energy with the uniform rifling, was roughly .20.

In nearly all countries an increasing twist is the form of rifling adopted. There is, of course, with the increasing twist, a less maximum pressure on the driving surfaces; but so far as energy is concerned, both theory and experiments concur in showing that there is a distinct and very appreciable loss resulting from its employment. An advantage of uniform twist would be the possibility of using two rotating-bands on the shell, thus insuring more accurate centering of the projectile.

Pitch of grooves.—The purpose of rifling, as previously stated, is to impart to the projectile such a velocity of revolution about its longer axis that its trajectory may be sufficiently stable to insure accuracy of fire. To obtain this result we must so establish the trace of the developed groove, and the form, position, and dimensions of the forcing-band, that during its brief passage in the bore neither deformation nor stripping takes place, and the projectile becomes centered as nearly as possible.

In order that, at the first instant of motion of the projectile, the pressure thrown upon the rifling by the guiding or forcing band be not excessive and do not result in detrusion, and thus interfere with the accuracy of fire, it is considered advisable to incline the groove at the origin less than at the muzzle.

In fixing the elements of the rifling, the most important to consider is the final pitch of the groove. Upon this depends the velocity of rotation and the stability of the projectile. From successful experiments the following values in calibers for the final pitch of the groove have been deduced:

From 45 to 35 for rifles firing projectiles from 2.5 to 2.8 calibers in length.

From 35 to 25 for rifles firing projectiles from 3 to 4 calibers in length.

Most U. S. naval guns have a final inclination of one turn in 25 calibers.

It is readily demonstrated by the generally accepted theory of rifling that grooves of little inclination result in moderate pressures on the lands at the beginning of motion of the projectile, and that the pressures become more elevated near the end and are somewhat higher than those resulting from uniform twist of the same final inclination as that of the increasing rifling. The resistance due to friction in the latter case is about double that for rifling of constant pitch. Accepting these conditions, the initial inclination of the rifling is sought by means of a parabola.

In order to steady down the projectile, the rifling with increasing twist is uniform for about two calibers back from the muzzle. In U. S. naval guns the twist at the origin varies from zero to one turn in 50 calibers.

The best and most generally adopted form of groove is one in which the bottom of the groove is made concentric with the circumference of a right section of the bore, and whose sides are parallel to the medial line of the bottom of the groove. There are two forms of groove in use in our navy, the hooked section and the plain section. The theoretical depth is made equal to $\frac{D}{100}$ for all calibers. Practically, the depth is .05 inch for all guns of caliber from 5 inches to 10 inches, and .075 inch for 12-inch and 14-inch guns. The depth for 4-inch and 3-inch guns is .025 inch.

Relative width of grooves and lands.—In our service guns the number N of grooves (or lands) is given by the equation $N=6d$, in which d is the diameter of the bore in inches; and is a whole number for all guns. If $W_{(g)}$ is the width of the groove, and $W_{(l)}$ the width of a land, we have the relation

$$W_{(g)} + W_{(l)} = \frac{\pi d}{6} = \frac{\pi}{6} = .5236 \text{ in.}$$

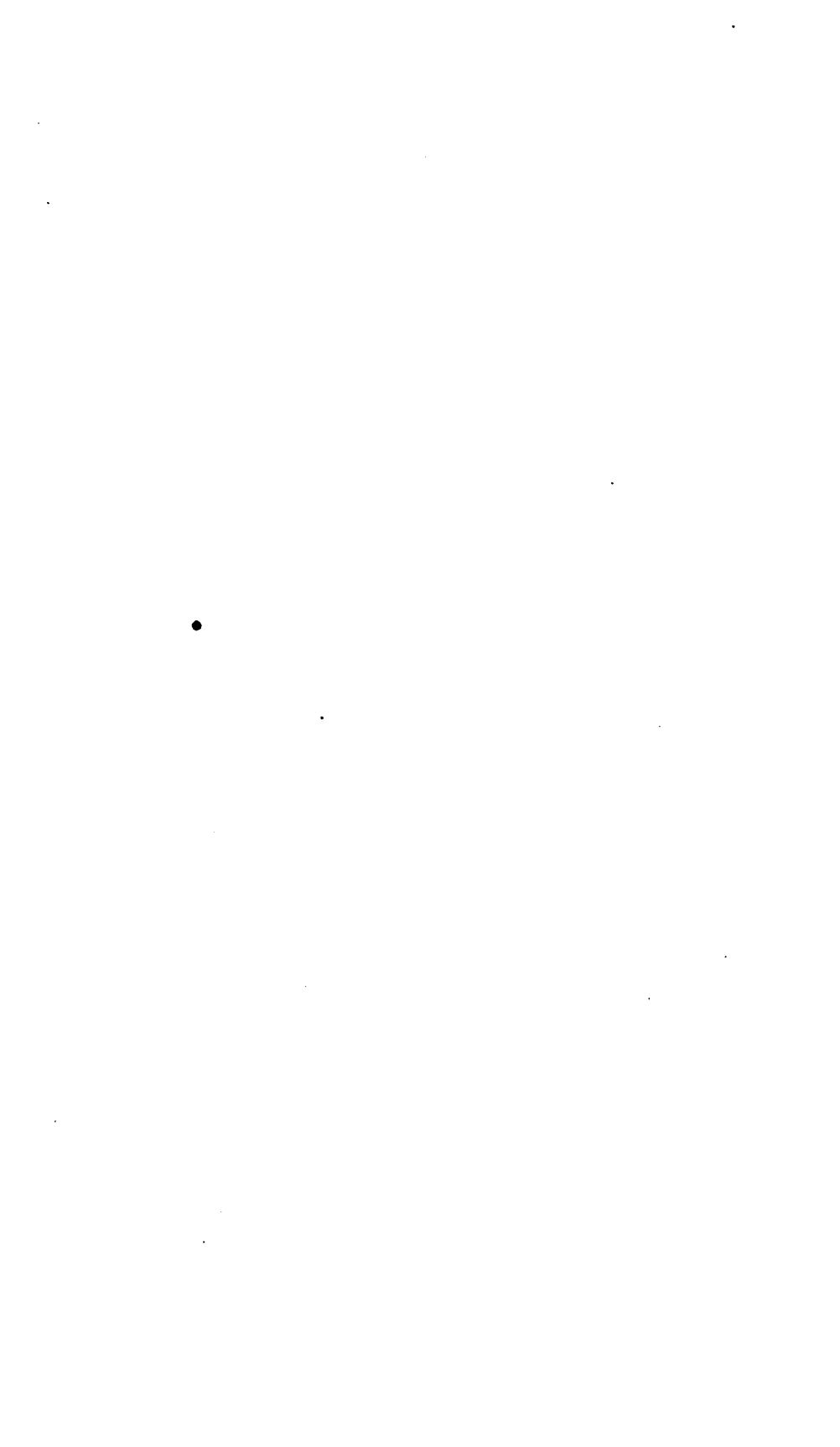
The best authorities lay down the rule that the width of the groove should be about double that of the land. In the larger naval guns the grooves are wider at the muzzle end of the rifling than at the breech; this widening is called the "increased forcing" of the projectile, and is generally .08 inch in 1000 inches for the 14-inch and 12-inch guns, increasing for the smaller calibers to .3487 inch in 1000 inches for the 5-inch guns. There is no increase

of width in the 4-inch and 3-inch guns. The idea of this increase in forcing is to insure the gas-tightness of the band at all points of travel, but its necessity with increasing twist is not clearly demonstrated. All U. S. Army guns have a constant width of groove; the lands are made .15 inch wide, and the grooves are therefore .3736 inch wide.

Forcing-band.—We now arrive at a study of the forcing-band of the projectile by means of which the grooves impart to the projectile a rotary motion about its axis. Its determination in accordance with the elements of the rifling is of the highest importance, and worthy of careful study by the ordnance designer. In this connection we are also to fix upon the form and dimensions of the projectile seat and compression slope which unite the powder chamber with the bore proper, and which have direct relations with the forcing-band in reference to the centering of the shot in the loading position, and during the passage in the bore, and in the regular and gradual indentation of the copper band by the lands.

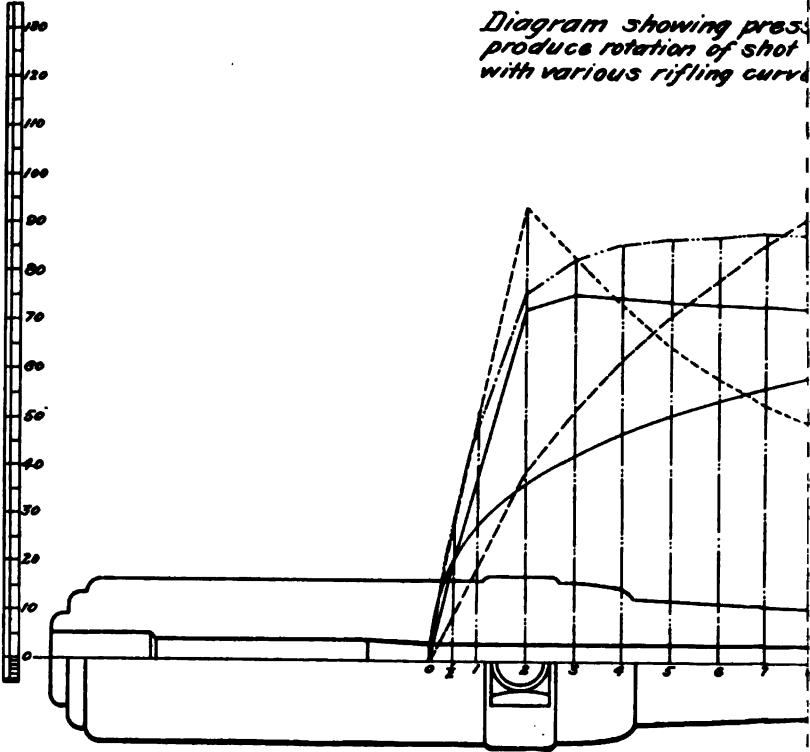
The diameter of the body of the band is made equal to $D + 2p + .020$ in., where D is the diameter of the bore, p the depth of the groove, and .020 inch the excess of the band body over depth of groove. The base of the band consists of a cone or lip of greater diameter which takes against the front slope of the chamber; and this insures approximately the same shell seating, regardless of the wear at the origin of the rifling. Upon the surface of the band body are cut grooves which serve to hold a part of the copper cut away by the lands, and which are generally filled with grease for lubricating the bore. The width and spacing of the grooves are so determined that the total work of friction between band and lands shall not exceed a certain fixed figure deduced from successful experiments. The general outline of shell bands consists of a cylindrical body having truncated cones at base and forward end. The front cone has a slope of $7^{\circ} 30'$, and the rear cone of 10° , for all shells.

It is important to fix upon the position of the forcing-band and the precise distance from the rear edge of the band to the base of the projectile, and even more important, when the caliber is smaller, than the forcing and indentation of the grooves. The resultant of pressure on the base of the projectile is seldom axial



CHAPTER II. PLATE II.

THEORY OF THE
ROTATION OF SHOT



with the bore ; it is usually inclined to this axis, and does not pass through the center of the base. This eccentric and oblique action of the resultant gives rise to a couple, which tends to rotate the projectile about one of the diameters of the forcing-band, and to produce jolting or beating along the walls of the gun ("*balottement*") ; the projectile leaves the piece with perturbations, which do not allow an efficient overcoming of the air resistance, and which produce a sensible diminution of range and accuracy of fire. Experiments have shown that there is one particular position of the band in which this couple, to which the projectile owes its perturbations, is reduced to a minimum, and to which, as a part of other conditions, the maximum range and best stability of flight correspond. In this position the rear edge of band is one inch from the base of the projectile.

The dimensions of the projectile seat and compression slope depend directly on the form, dimensions, and seating of the rotating-band. The bourrelet has a play of .015 inch on the bore diameter, which does not seriously affect the accuracy of the fire, and insures the projectile being less in diameter than any small choke of the bore. The slope which unites the projectile seat and powder chamber is of great importance ; it is a truncated cone, the length and inclination of whose generatrix depends on the diameter and position of the forcing-band. Its slope should be the same as that of the conical part of the rotating-band, in order to have perfect contact between the two.

With the above considerations, we can conveniently determine the form of band and slope contemporaneously, supposing the projectile to be in its loading position. The design can in this way be rapidly and accurately drawn.

As previously stated, increasing twist is used to diminish the strain on the lands, and with this in view a variable or increasing twist must be adopted such as to keep the pressure between the lands and the incisions cut in the band of the projectile constant throughout the travel of the shell. The pressures obtained can best be judged from the curves taken from "Notes on Construction of Ordnance, No. 49," U. S. Army. (Plate II.)

The increasing twist has been used in all naval guns except those built from 1908 to 1911, inclusive.

Principles of Gun-Construction.

Basic principle of gun-construction.—*No fiber of any cylinder in the gun must be strained beyond the elastic limit of the metal of that cylinder.*

Present requirements for guns demand muzzle velocities of from 2500 to 3150 feet per second. Lower velocities give less striking force, and, more important still, a projectile fired at low velocity would describe a curve so high in the air, for long ranges, that hits could not be made unless the range were known with great accuracy. Since the accurate determination of range is the most difficult problem in naval gunnery, the high-power gun is a necessity. High velocity of projectile is produced, of course, by high pressure upon it while traveling through the bore. No heavy gun of a single piece of metal, whether cast or forged, could withstand the high pressures generated within the gun, and therefore the peculiar methods of modern gun-construction are employed.

A gun may be considered as a tube destined to withstand a given pressure from within, throwing a projectile which shall produce certain effects at given distances. In constructing such a tube, we must first consider what pressures it will have to withstand at the various points of its length, and then make it strong enough to insure perfect safety. The bore should also be of such material as to stand the wear and tear of firing a large number of rounds without being so damaged by expansion or abrasion as to interfere with the shooting.

Not only must the gun be sufficiently strong, but it must not be too heavy; so it is important that the material shall be arranged in such a manner that there may be no waste of its strength—in fact, so arranged that every part shall perform its own share in withstanding the pressure from within. Shortly after the shot begins to move, the pressure inside the gun decreases, and continues to decrease as the projectile approaches the muzzle; for this reason the gun is made stronger at the powder chamber than toward the muzzle end.

The designing of guns, like the manufacture of other ordnance material, is the gradual development and improvement of a type, as the result of years of practical experience in perfecting models as needed to meet the increasing ballistic demands.

The three general subdivisions of the preliminary gun design are: (1) The *mechanical*, (2) the *ballistic*, and (3) the *service conditions*.

(1) **The mechanical conditions.**—It is necessary that the gun should be able to resist the pressures developed in the bore when fired. This is accomplished by the choice of a suitable material, and by a careful determination of the method of assembling the various constituent parts of the gun.

(2) **The ballistic conditions.**—The gun is designed to produce a certain ballistic result under the best possible conditions. The formulæ of interior ballistics enable one to determine the weight of charge, the density of loading, and the quickness of the powder to be used. From these are deduced the dimensions of the powder chamber.

(3) **The service conditions.**—The gun should meet the requirements of service afloat in regard to loading, elevating, the operation of the breech-mechanism, relining of gun, etc. These requirements affect the forcing-cone, the outline of the powder chamber, the type of breech-mechanism, the center of gravity, and the weight.

Stresses.—Looking simply to the construction of a gun cylinder, we find that the two principal stresses to which such a cylinder is subjected upon the explosion of a charge are, first, a circumferential or *tangential stress* or tension, coupled with a *radial stress*, tending to split the gun open longitudinally; second, a *longitudinal stress* tending to pull the gun apart in the direction of its length.

It has been ascertained as the result of experiment that the greatest stress experienced by the metal of the gun is the tensile stress set up in the direction of its circumference by the pressure of the powder gases; in addition, it also experiences a longitudinal stress. If now we exert pressure upon the tube from without, the initial pressure exerted by the powder gases must first neutralize this outside pressure before it can subject the tube to any additional tensile stress. The amount of the external pressure must not, however, exceed the elastic limit of the metal, as otherwise permanent deformations would be produced in the inside layers of the gun. The amount of the external pressure must be so computed that the tensile strength of the metal of the bore of the tube will be fully utilized in firing, and it must therefore merely equal

the difference between the gas pressure and the limit of resistance to tensile strain of the metal.

The least complicated method of making a gun would seem to be that of casting it as a homogeneous hollow cylinder; but if we take such a tube, made of one material throughout, we find that its tangential strength to resist a pressure from within does not increase uniformly with its thickness.

We find, practically, that with a given material we soon reach a limit beyond which *any additional thickness of wall aids but little* in enabling the cylinder to withstand pressure. Supposing the metal to be incompressible, this limit is taken at about half a caliber, so that—for example in the cylinder of an hydraulic press—if the thickness of the walls be equal to one-half the diameter of the piston which works inside, then the cylinder will be nearly as strong as if it were ten times as thick.

It is generally conceded that no possible thickness can enable a simple cylinder to bear a continued pressure per square inch from within *as great* as the tenacity of a square-inch bar of the same material; that is to say, if the tensile strength of cast iron be 12 tons per square inch, no cast-iron gun, however thick, could bear a charge which would exert that pressure on each square inch; for, on the first round the interior layer would be ruptured before the outer portion could come into play, and every succeeding round would tend to make matters worse.

From the above it is clear that guns made by casting iron, bronze, or steel into homogeneous cylinders cannot be made strong enough. The working pressure which we require a high-power gun to withstand is not less than 18 tons per square inch, and we require, further, that this pressure shall not strain the gun beyond the elastic limit of the metal, in order that the bore of the gun shall not be permanently enlarged. The elastic limit of cast steel is from 15 to 20 tons per square inch, and we have seen that steel has a higher elastic limit than either iron or bronze, so that, allowing a margin of safety, it will not do to make a high-power gun of cast homogeneous metal even when we use steel. We must resort, then, to what is termed the *built-up system*, and it can be shown mathematically that a built-up gun, properly constructed, of the same dimensions and material as a homogeneous gun, is much stronger than the latter.

The thickness of the walls.—Having settled upon the built-up gun as the proper construction to follow, it only remains to describe in general terms how the thickness of the walls is determined.

Experiments with crusher gauges placed at different distances along the bore of a gun, and formulæ for constructing pressure curves, have enabled gunmakers to form a good idea of the pressures at different distances from the bottom of the bore. Hence a curve of pressures can be constructed for a given powder that will approximate to the truth for practical purposes; a good margin of safety is always allowed, and the various thicknesses of metal to withstand the pressures at different points of the length of the bore follow at once, the caliber and length of the gun having previously been fixed by the amount of work the gun is expected to perform.

After the preliminary drawing of the gun has been completed, the elastic strength to resist powder pressure is computed at all points, together with the shrinkages. The strength curve is then compared with the pressure curve, and if there is not a sufficient margin of safety, a readjustment of the dimensions of the parts of the gun is made, and the elastic strength is recomputed. It is also necessary to compute the stresses which the parts undergo in the *state of rest* to determine that the tube will not be crushed by the shrinkage.

A built-up gun is one in which the principal parts are separately constructed and then united in a peculiar manner; and guns so constructed may be composed of different kinds of metal, or of the same kind of metal throughout. We now come to the two principles of construction for strong and heavy guns.

(1) **The principle of varying elasticities.**—This consists in placing that metal which stretches most *within its elastic limit* around the surface of the bore, so that by its enlargement the explosive stress is transmitted to the other parts exterior to it. This method is exemplified in guns which have a steel tube surrounded by wrought-iron coils, and in the Palliser system, in which a wrought-iron or steel tube is surrounded by cast iron. With different grades of steel—high and low steel, for example—the steel which shows the greater elongation within the elastic limit is the more suitable to be placed next to the bore. Carrying out

this theory in practice is another matter, because in the case of very long tubes there is more difficulty and uncertainty of manufacture with the higher grades of steel than with the lower, and the difficulty increases with the size. *For this reason the principle of varying elasticities is only applicable where the different parts of a gun are made of different metals.*

(2) **The principle of initial tensions.**—This consists in giving to the exterior portions of the gun a certain initial tension, gradually decreasing toward the interior, and giving to the interior parts a certain normal state of compression by the grip of the outer cylinders and coils.

If by the system of initial tensions the interior can be put in a state of compression, within the elastic limit of the metal, the amount of that compression is so much additional strength, since it must be first overcome before the powder gases can exert a tension on the fibers of the interior tube. In order to exert compression, then, the outer coils or hoops must be in a state of normal tension, and in addition to that they must have a margin of strength within their elastic limits to withstand the additional tension transmitted by the explosion of the charge, this additional tension being, of course, much less than would be put upon *free* metal next the bore.

The exact amount of tension and compression for all parts of the gun when at rest, or when resisting the explosion of the charge, so that all parts shall be strained to a point not exceeding their elastic limits, is a matter for mathematical calculation, and is treated at length in works on the theory of gun-construction.

Shrinkage.—Practically, the compression of the interior and tension of the exterior is effected in manufacture, after the amounts for each have been calculated, (1) by *shrinkage*, (2) by forcing upon one another by hydraulic pressure two cylinders having slightly coned surfaces, or (3) by winding steel wire, or riband, over a steel tube.

If the method of shrinkage be employed, the hoops or tubes to be shrunk on must be accurately bored, and the outer cylinder must be expanded by heat until it is sufficiently large to slip over the inner. The inner diameter of the outside cylinder when cold must be a little smaller than the outside diameter of the inner tube, and this difference of diameters is called the *shrinkage*.

While the outer cylinder is cooling and contracting it compresses the inner one, making the diameter of the latter a little smaller than before. The amount by which the exterior diameter is decreased is called the *compression*.

Again, the outer cylinder itself is stretched on account of the resistance of the inner one, and its interior diameter is slightly increased. This increase is called the *extension*.

The *shrinkage* is always equal to the *compression* plus the *extension*, and the exact amount must be previously calculated by the known extension and compression of various metals under certain stresses and given circumstances.

The principle of initial tensions, carried to an extreme limit, would be exemplified in the case of a gun composed of an infinite number of infinitely thin hoops properly shrunk together. When so assembled, the tension in a gun, when the powder pressure acts, would be uniform throughout the thickness. The greater the number of hoops the nearer this theory is approached in practice, but there are practical difficulties in manufacturing, such as the accurate machine work necessary and the greatly increased cost; for this reason it is not considered practicable to use more than four layers in the case of guns now designed. In the case of wire guns, or ribbon-wound guns, this theory is better exemplified, and when successful manufacture is possible in these cases, stronger guns of the same weight must be the result.

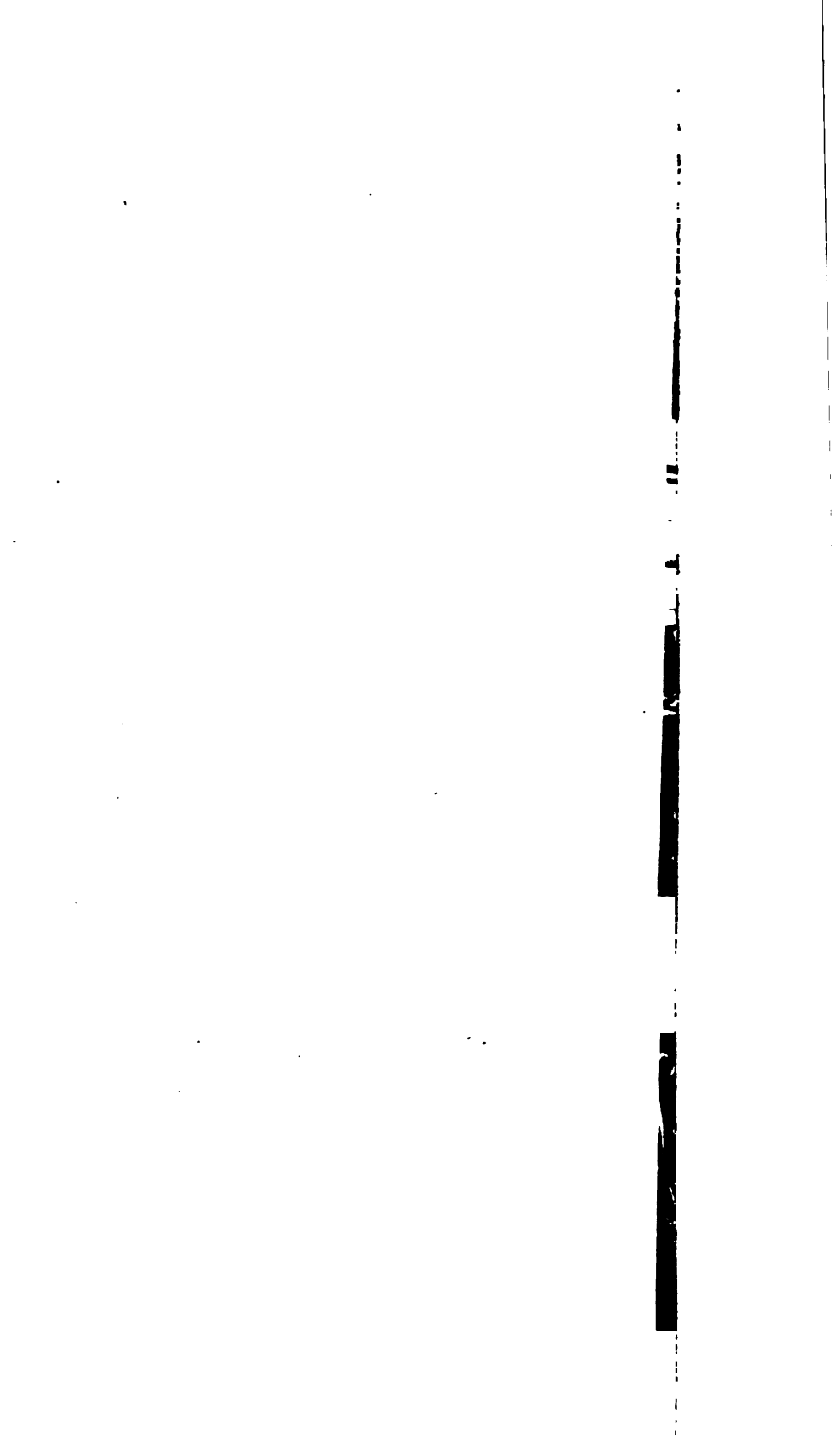
The principle of initial tensions is followed in all built-up guns for the navy; and as all parts of the gun are made of high-grade steel, it is practically impossible, in following the principle of initial tensions, to secure, also, the advantages of varying elasticities, because, the tube being much larger than the jacket and the jacket much larger than the hoop, the elastic strengths of the several parts will vary inversely as the size, and thus the principle of varying elasticities will be violated.

The wire-wound gun.—As stated above, this is an example of the initial-tension system. The wire is wound in layers around an inner tube of steel. Each layer is wound with a different tension of the wire, and each exerts a compression on the layers which are inside of it. The result is that, when completed, the outer layers are in extension, gradually diminishing to the inner layers, which are in compression—all within the elastic limit. As wire can be

made of enormous strength (as much as 200,000 pounds per square inch tensile strength), this type of gun is the strongest for the same weight of any yet developed.

Built-up guns in the service.—These comprise all guns of the main battery, and the larger part of the secondary battery. The 3-pounder Mark VII, 6-pounder Mark IX, and 6-pounder Mark IX, Mod. I, are *single* forgings.

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CHAPTER III.

DETAILS OF CONSTRUCTION OF NAVAL GUNS.

The major-caliber guns for the naval service are manufactured at the Naval Gun Factory and at private plants, such as the Bethlehem Steel Co. and Midvale Steel Co., and also at the United States Army Arsenal, Watervliet, N. Y. The greater portion of the work, however, is done at the Naval Gun Factory, and the method of manufacture and inspection in use there are herein described.

Preliminary.

The following general remarks apply to all main-battery guns, and will be followed by a detailed description of the assemblage of the 14-inch gun.

Parts of a gun.—(1) A modern built-up gun is composed of a *tube* and *hoops*. They are designated as the A tube, and the B₁, B₂, . . . , C₁, C₂, . . . , D₁, D₂, . . . , etc., hoops.

(2) The B₁ hoop, usually called the *jacket*, is immediately over the rear end of the tube and extends well forward on it.

(3) Hoops over the forward part of the tube are called *chase hoops*.

(4) Hoops over the jacket are called *jacket hoops*.

(5) *Locking hoops* are those which hold two adjacent parts together. Inner ones are shrunk on; outer ones may be screwed or shrunk on.

Receipt and assignment of forgings.—(1) Forgings, when received at the gun factory, are weighed and examined for the marks required at the steel-works and by the naval inspector at those works. No work is to be done unless these marks are found. The forgings are measured to see if they are of proper dimensions to work out to finished drawings; only .02 inch tolerance is allowed over the drawing dimensions for the forgings. An examination is made for gouges, etc., and for defects in the forgings which would not disappear in the finish machining.

(2) All forgings in any gun are from the same steel-works, if practicable.

Setting the forging in the lathe.—(1) The forging is brought to the lathe by a crane, and one end—the breech end, for instance—is gripped by the four to six large jaws on the face-plate. The muzzle end is likewise gripped by a *pot-center*, a large iron ring with several arms screwing through it radially.

(2) The forging is now on live centers. By revolving the forging and screwing the jaws of the face-plate in or out, the breech can be centered, as shown by the mark of a tool on the surface of the forging.

(3) The muzzle end is similarly centered. Then the forging is revolved while the tool is run along its carriage. This is done to see whether the forging is warped. Should it be warped, the screws at each end are moved so that the work is thrown to one side or the other to offset the warping. If the forging is so badly warped that it cannot be trued up by this means, it is rejected. A surface is now turned near the muzzle end for a steady-rest. In all long work, one or more steady-rests are used to prevent springing, and the work must be supported by them in boring. The steady-rest is placed in its bearing, and the pot-center is removed so that the balancing-rod can be inserted and the eccentricity of the bore be noted. It may be necessary, because of eccentricity of the bore, to throw the center a little to one side or the other, but in any case there must be sufficient metal both inside and out to work out to the finish dimensions. When the direction is finally determined, the steady-rest surface is trued up, if it has been thrown out, and surfaces are turned for additional steady-rests.

(4) A bearing is also bored out at the muzzle end, in which is to be placed a dead-center for use in turning. For boring, the work is supported in the steady-rests.

Turning.—All except very short hoops are at once given a rough cut, on the outside, to remove the scale and take out the spring. This cut is only made deep enough to remove all scale, though in the case of a badly warped forging this may require a deep cut on one side and a shallow one on the other. In this and all turning, the work is revolved while the tool is fed along in its carriage. Fig. 1, Plate I, shows the forging for a 14-inch tube, set for turning.

This rough cut is the only outside one taken until after the parts to go on over the piece have been bored and star-gauged and the

shrinkage sheets made out. Then the turning is continued, sometimes using as many as four tools at the same time on two or more carriages. For finishing cuts, tools 1 to 2 inches wide are used, and dimensions are kept correct to .001 of an inch. Steel snap-gauges previously set by steel points of known lengths are used to get the diameters.

Boring.—(1) For boring short hoops of large diameter a *boring-bar* is used. The tool is set on the end of the bar to give the proper cut, and fed along by the carriage as the work revolves.

(2) For long cylinders there would be too much spring in the boring-bar, and *packed bits* are used. These are cylinders of oak-wood, on iron frames, carrying two tools. The wood is a few thousandths of an inch larger than the hole to be cut, so that, by its forcing, the tools are held rigidly and accurately. Fig. 2, Plate I, shows a 14-inch C1 hoop set for boring, with the packed bit used.

(3) Frequent inspections are made during the boring to see that the hole is true, as, owing to wear of tool, spring of metal, etc., errors constantly creep in. The bit is first carefully centered in the lathe by mounting it on its bar and revolving it while a small spring indicator, mounted on a small base, is pressed against it. This indicator shows any eccentricity to .001 of an inch. By putting liners of thin metal or paper between the stem of the bit and the socket in the end of the bar, it is moved until centered. Then the cut is started, the bit being run in about 8 inches and then withdrawn. The hole is "*indicated*" with the instrument later described, and is tested with steel points set at right angles, to see that it is of the proper diameter. If satisfactory, the bit is again entered, and the cut is continued. Every few feet the bit is withdrawn and the bore is indicated and tested with points for diameter—the frequency of this testing depending on whether the cut is a fine or a rough one, and on what the first measurements show in the way of accuracy. If the bit is running out considerably, as sometimes happens on the first rough cut, the work may be reversed after the cut has gone half way through, and the bore be finished from the other end. Any eccentricity may be corrected by truing up the bore with a slightly larger bit. Four cuts are usually required to finish a bore—two rough and two fine ones.

(4) In boring out cylinders which are stepped and have two or more internal diameters, all work, except perhaps the first rough cut, as noted above, is done from the end where the diameter is largest, usually the breech. After the rough cut has been taken, the largest diameter is accurately bored out. A packed bit is then prepared with the forward end and tool set at the diameter of the smaller hole to be cut, while the after end is left at the larger diameter. This bit is run in and the smaller bore is started. The bit is then withdrawn and the bore is indicated and star-gauged.

(5) In all boring, the bits are kept well lubricated by oil run into the bore.

Balance-rod or indicator.—To ascertain whether a hole has been bored true with the line of dead centers, a simple device known as a *balance-rod* or *indicator* is used. This device con-

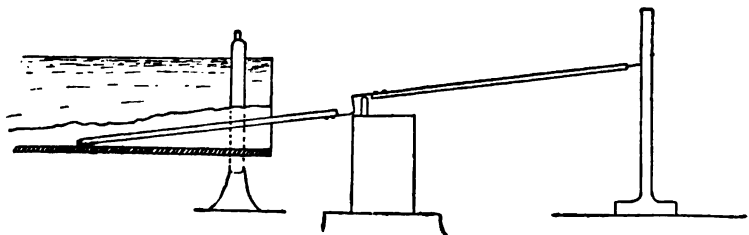


FIG. 1.—BALANCE-ROD, OR INDICATOR.

sists of two wooden rods joined together end-on by a right-angled strap of iron. One rod, the one which enters the bore, has a small roller on its end. The other rod holds a pointer. The rod is inserted in the bore and balanced on a knife-edge under the iron strap, the roller resting on the bore. A vertical stand is placed so as to record the marking of the pointer. A zero point is first marked by the pointer, and then the work is slowly revolved. Should the hole be eccentric, the pointer will move up or down and serve as a means of indicating the amount of eccentricity of the bore at the point where the roller is. These indications are taken every two feet. A long forging that is being bored will be indicated about three different times during a cut, to see whether the bit is running true. Should the bit be running out, the centers are thrown and the bore is trued up with a slightly larger bit. After an

accurate hole has once been bored there is little danger of the bit running out in succeeding cuts. (See Fig. 1.)

For guns which are set in lathes where there is not room to use this type of indicator, another one is used. This, as shown in the photograph (Fig. 3, Plate I), is mounted on the tool carriage at the end of the gun. A heavy, rigid beam carrying a small wheel on its end enters the bore, the wheel resting on the surface of the bore. The beam is supported on a knife-edge near its other end, and by a system of levers delivers its movement to a pointer traveling over a scale. A weight on the pointer rod is used to balance partly the beam. The allowable travel of the carriage between the breech of the gun and the fixed guide on the lathe for the dead center, is only a few feet; so, after indicating part of the bore, the beam is replaced by a longer one. This is continued until the entire bore has been gone over.

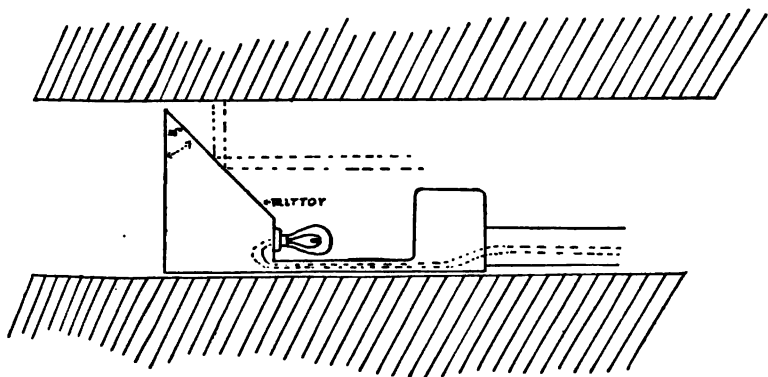


FIG. 2.—BORE-SEARCHER.

Bore-searching.—(1) Every forging, when finish-bored, is bore-searched, and all bore-searching is done by officers. The bore is also inspected after each cut, by a foreman with an electric light.

(2) The *bore-searcher* is simply a wooden frame, holding a mirror inclined 45° to the axis of the bore. Three incandescent electric lamps furnish the light, and a hood is provided on the frame to obscure the direct light from the observer. The bore-searcher is moved slowly through the bore by a long wooden

handle. About 90° of the bore is illuminated at once, and four lightings are required completely to search it.

(3) The bore is inspected for any discoloration, cracks, or streaks, or any flaws that may have developed in the boring; opera-glasses or binoculars are used, if considered necessary, in inspecting long bores. If any flaws are noticed, they may be scratched with the *pricker*, a steel point mounted on a light wooden rod at right angles to it, to see that what appears to be a flaw is not merely a spot of dirt.

Star-gauge.—(1) The *star-gauge* (Fig. 3) is used to measure accurately the inner diameters of any long cylinder. This instru-

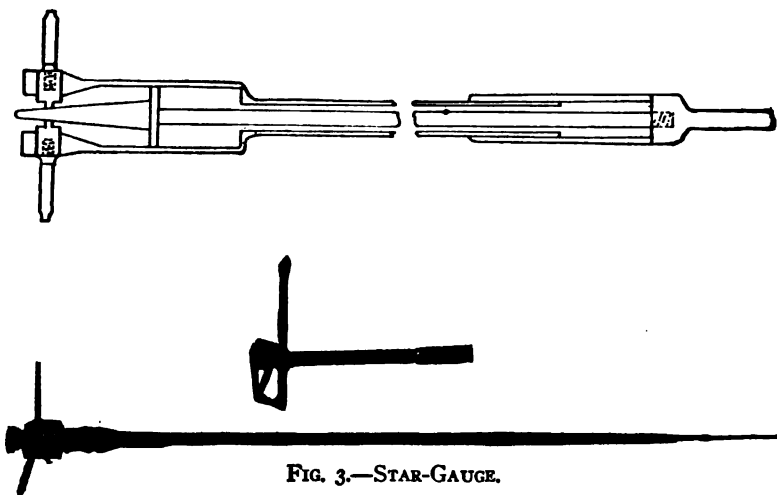


FIG. 3.—STAR-GAUGE.

ment is a graduated brass or steel tube, built in sections so as to be adapted to any length of work. It carries a *head* and a *handle*.

(2) The head contains three sockets, 120° apart, pressed upon a coned rod by springs. Into these sockets are screwed points of lengths suitable to the work to be measured. The coned rod is simply the extension of a rigid steel rod passing through the tube and securing to the handle. Any forward movement of the handle causes the points to be pressed out a known amount, which is read from a scale on the tube and a vernier on the handle.

(3) The star-gauge is always adjusted before use by trying the points on a ring of known diameter. A set of rings of different diameters is supplied with the instrument. By adjusting the position of the handle the scale is made to read zero when all three points just touch the ring. In measuring the diameters of the bore the readings of the scale must be applied to the diameter of the test-ring to get the correct diameters. The bore, whether of forging or of gun, is star-gauged at each inch of length and the powder chamber at each half-inch. The points are first set thus: ☉ and then a second series of readings is taken with the points reversed, thus: ☿

(4) In star-gauging the gun, after it has been rifled, guides are used on the head. These guides follow grooves and thus keep the points always on the same lands or in the same grooves. On the muzzles of all our guns the letter "S" will be found in four places. From the positions of this letter the lands and grooves which were star-gauged are known. Double readings are taken of both lands and grooves, the second reading being with the points reversed.

(5) The readings of the star-gauge are correct to the .001 part of an inch. The record of every star-gauging, whether of gun or of forging, is kept on file.

Shrinkage.—The shrinkages for the different parts are prescribed by the Bureau of Ordnance. They are computed and are the same for all guns of a type if the material used in the different guns is of about the same strength. The different layers of the gun have different shrinkages, and the shrinkage in any one layer is not necessarily the same throughout.

Measurements.—(1) The figured dimensions on drawings are used. The rear face of the tube is taken as the origin for all measurements.

(2) In all machining the workman is furnished with the necessary gauges, graduated rods, and steel points for the dimensions on his drawings. All measurements originate in the measuring department, and all gauges are frequently referred there for verification.

(3) In general, diameters are given in thousandths of an inch and lengths in hundredths. Certain tolerances are allowed in machining, and these are never exceeded.

(4) Outside diameters are measured either with snap-gauges or with beam-calipers. Inside diameters, with steel points or the star-gauge. (See Fig. 4.)

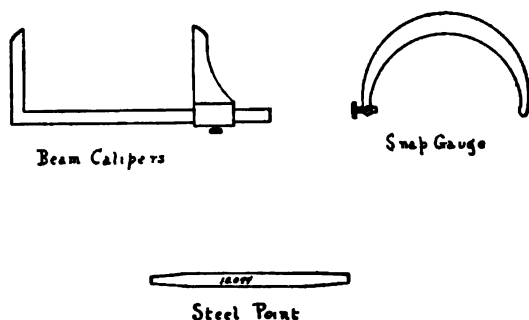


FIG. 4.—INSTRUMENTS FOR MEASUREMENT OF DIAMETERS.

Building up the Gun.

Jacket.—(1) The B1 hoop or *jacket* is the first forging worked upon. A rough cut is first taken off the outside to remove spring, and then the forging is set for boring and bored out to exact dimensions. This usually requires two rough cuts and two finishing cuts with packed bits.

(2) The forging is faced off, inspected for flaws on the outside, and then removed from the lathe and bore-searched, any flaws being noted. It is star-gauged at each inch of length, the gauge being run through twice, as noted above. The length is divided into four parts by cuts on the outer surface; these distances are measured and the outer diameters are calipered. These divisions and diameters are again measured and calipered after assembling, to note what extension of diameter has been given the jacket, and to see if the longitudinal contraction has been uniform.

(3) The B2 hoop is at the same time prepared for assembling by the same processes of machining, inspecting, and star-gauging. The shrinkage sheet for the tube is then made out as follows: To the internal diameters of the B1 and B2 hoops, as found by star-gauging, are added the shrinkages assigned by the Bureau of Ordnance for each point. The resulting measurements are marked on a blue-print of the tube, giving the desired external diameter of the tube at each point. The tube is then machined.

CHAPTER III. PLATE II.



SHRINKING OF
A, Heating-Furn

THE
AMERICAN
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INDUSTRY

Tube.—(1) After a rough cut has been taken from the outside of the tube, it is set for boring, and the bore is cut out to within .35 of an inch of finished diameter, two cuts with a packed bit being required.

(2) The tube is again set for turning, faced off true, and turned down to the dimensions given on the shrinkage sheet, the tolerance allowed being .001 of an inch only. It is inspected while in the lathe by an officer, who assures himself by numerous measurements that the shrinkage surface is of correct dimensions, and that no flaws exist in the metal. The tube is then removed from the lathe and bore-searched and star-gauged. It is now ready for assembling.

The Shrinking-pit.—(1) The tube is placed in the *shrinking-pit* breech end down. The shrinking-pit is a well of square sec-

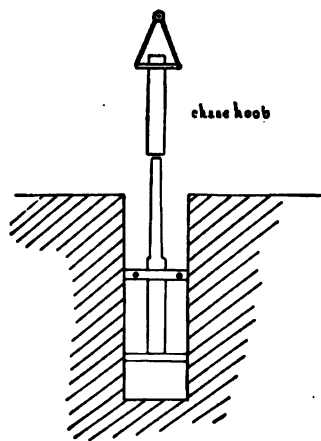


FIG. 5.—SHRINKING-PIT.

tion having two movable tables. On the lower table, and also on the floor of the pit, are heavy mandrels which enter the bore of the tube; and by screws alongside of these the tube can be made perfectly vertical. When pieces are to be shrunk on from the breech end, the tube is held vertical by four adjusting-screws in the upper table. For small guns the lower table is moved up to fit the length of work. Long pieces, as 12-inch 50-caliber or 14-inch tubes, rest directly on the floor of the pit. To keep the tube cool, water is pumped in at the bottom, rising to the top and flowing down again through a central pipe.

Heating-furnaces.—(1) A heavy collar, carrying two trunnions to which the chains of the crane can be hooked, is bolted to the jacket, and it is lowered, breech end first, into a *hot-air furnace*. This furnace is a vertical cylinder, built in sections to suit the particular lengths of jackets, and is made of fire-brick lagged with asbestos. Heat is absorbed from air which has been passed in pipes over petroleum burners. Large pipes lead from the air-heater to each end of the furnace, and also, in a furnace now being installed, to the middle. Air is passed in at the bottom and out at the top of the furnace, or vice versa, as needed to maintain a regular rise of temperature, as shown by electric pyrometers at the top, bottom, and middle. Hot air is admitted at the center to "boost" the heating at the exhaust end when desired. At A, Plate II, is shown a furnace with the top cover removed.

(2) For short hoops a shorter furnace is used, in which petroleum burners play into a space between brick walls, the gases and flame rising around the pieces to be heated. This causes deposits of soot on the hoops, but the furnace is only used for hoops so short that they can be easily swabbed out before assembling.

(3) In heating a gun for putting in a liner, it is difficult to get the required temperature in the heavy parts around the chamber; so an electric *booster* is used. This is a cylinder of fire-brick, lagged with asbestos, and has resistance wires wound around on its inner surface. A 220-volt alternating current is used. A temperature of 1000° F. can be obtained with 30 kilowatts of current. There are two sections, each 50 inches long, which can be inserted in the hot-air furnace where they are most needed.

(4) Air-heating is regular, and practically no local heating or warping occurs. Furthermore, the jacket is kept free from dirt. The heating takes place gradually, a large jacket requiring 30 hours to attain the desired temperature. Every precaution is taken to keep the heating uniform throughout, reversing the direction of flow of the hot air when necessary. The temperatures used depend on the amount of shrinkage assigned, and on the amount of clearance necessary for assembling. In small guns, as little as .005 inch is sometimes considered sufficient, but in all 14-inch work .025 inch clearance is desired, requiring the diameter of the hoop to be .05 inch greater than that of the part over which it goes. The coefficient of expansion of steel being .0000075 for 1° F., the necessary temperature is easily found.

(5) While the jacket is in the furnace, its diameter is measured by lowering steel cross-points into it. The lengths of these cross-points are equal to the original diameter of the jacket plus the desired expansion.

(6) The 14-inch jacket is given a temperature of 725° F. at the breech end and 825° at the muzzle end, so as to insure its gripping first at the breech end.

First assemblage.—(1) When the jacket has received the desired expansion, it is hoisted out of the furnace, and tried for diameter with cross-points, previously checked. The bore is wiped out with a moist muslin sponge. The jacket is swung over the tube, centered by men with asbestos gloves, and lowered over the tube until it brings up at the proper point. It is guided down by the workmen and turned to prevent sticking and to assist the centering. When it is in place, a cold spray from one of the several rings of perforated pipe is turned on the part which it is desired to have grip first—in this case the breech end. Water is in the meantime circulated inside the tube. When the breech end is considered cooled enough to grip, other sprays are turned on, at intervals of one minute, and then the rings of perforated pipe are hoisted slowly up the jacket, spraying water and cooling it, so that when they reach the top, the whole jacket has gripped the tube. It is then allowed to finish cooling gradually. Plate II shows a 14-inch CI hoop being lowered over the gun in the pit.

(2) Should the jacket "gall" or stick while being lowered, it is at once hoisted off and allowed to cool. The abrasions are filed off, and after being heated it is tried again.

(3) The tube has already been turned to proper size to receive the B2 hoop, so it is left in the shrinking-pit, while the B2 hoop is heated. When proper temperature is obtained, the B2 hoop is shrunk on, water being applied to make it grip at the end nearest the breech, as was the case for the jacket.

(4) After the gun has cooled, it is removed from the pit. The jacket and hoop are measured on the marks previously scribed, to get their expansion in diameter, and longitudinal contraction, and the bore is star-gauged. The internal measurements, showing contraction of the bore, serve as an efficient check on the shrinkage, and if the contractions do not correspond closely to those calculated, the question must be referred to the Bureau of Ordnance.

Successive assemblages.—(1) Each hoop is prepared for assemblage by having a rough cut taken from the outside to remove spring, then being bored out, bore-searched and star-gauged, after which the shrinkage sheets are made out as previously described.

(2) After the B1 and B2 hoops are assembled, the C1 hoop is prepared. The gun is placed in a lathe, and the outside of the B1 jacket and B2 hoop is turned down to the dimensions given on the shrinkage sheets, the gun is inspected, and placed in the shrinking-pit. The C1 hoop is heated and shrunk on, water being applied to make it grip first at the breech end. When cool, the bore is star-gauged and the compression is noted.

(3) The D1 and D2 hoops are now prepared for assembling, and the gun is placed in the lathe and turned down to the dimensions on their shrinkage sheets. The D1 hoop is shrunk on, and as soon as the gun is cool the D2 hoop is assembled. All these hoops go on over the muzzle end, and all are made to grip first at the end toward the breech.

(4) The D3 and C3 hoops being locking hoops, a different procedure must be followed in putting them on, as is seen from an inspection of the drawing. This procedure is as follows: The hoop D3 is rough-turned and bored out to the finish dimensions. The shrinkage sheet is made out for the C2 hoop, and it is turned down. Then the C2 hoop is placed in the shrinking-pit, end toward the breech up; the D3 hoop is heated in the short furnace, using the direct flame and gases of the oil burners, and is shrunk on. Great care must be taken in this operation to have the D3 hoop in exactly the right position on the C2 one, because if the shoulder on D3 did not enter accurately in the recess in C2, it would grip some of the metal too hard, crushing it, while other places would not be gripped at all. The assembled C2 and D3 hoops are star-gauged to note compression, when cool, and are then placed in a lathe, and bored out to finished inside diameters. The shrinkage sheet is made out, and the partially assembled gun is placed in a lathe and turned down to receive the two hoops. They are then heated together, and shrunk on the gun, the same care being used to make the D3 hoop grip in the proper place on C1. In a similar manner, C3 is assembled on B3, and the two are assembled on the gun. After the final assemblage, the bore of the

gun is star-gauged and the compression caused by assembling D1, D2, D3, C2, C3, and B3 is noted and checked up.

(5) The assemblage of the gun is now complete, and it is ready for the finish machining, rifling, etc.

Finishing the Gun.

(1) The assembled gun is now put in a lathe, muzzle end to the face-plate, whose jaws grip on the extra metal purposely left for the bell muzzle. It is carefully centered, especially with regard to the bore, and then tested with the balance-rod for spring. The centers are thrown to compensate for any spring or warping, and then the outside is turned down to within .02 inch of finished diameter. The balance-rod is used as necessary to see that the spring is completely removed.

(2) The bore is now brought down to the finish diameters, two cuts with packed bits being required. The first cut brings the bore to .1 inch of finished diameter, the second to exact size. Great care is required in this operation to get the bore exactly true, and as close as possible to the finish dimensions.

(3) All finish boring for new guns is done from the breech end, so that if the bit runs out slightly in the final cut, the center of the muzzle may be thrown slightly and the muzzle turned concentric with the bore. In relined guns, the finish boring is done from the muzzle end.

Chambering.—(1) While the gun is in the lathe for boring, the chamber is bored out with a packed bit, and the compression slope is cut with a packed bit of the proper taper. This completes the chambering for guns with chambers whose diameters are the same from entrance to compression slope, as is the case in the 14-inch, and they are ready for rifling. Guns with narrow-neck chambers may also be rifled at this stage if desired, the chamber having been bored out to the diameter of the neck, or they may be sent to the chambering-machine, where the chamber is finished by a special *chambering-bar*. This has a bearing in the bore just forward of the chamber, and the tool is fed along by gearing working inside the bar. To obtain the proper slopes the tool is fed in and out by a lug working in a slot in a key which extends along the bar.

(2) In guns using cartridge-cases, the chamber is cut to the required form by packed bits, the finishing-bit carrying a long tool set to the correct taper. The chamber is inspected by fitting in it a dummy case of the exact form desired.

Bore-searching and star-gauging.—(1) The gun is now carefully bore-searched for any defects that may have appeared in finish boring or chambering, or for any rough spots or tool marks, etc.

(2) The bore and chamber are then star-gauged at each inch of length, except that the slope of the chamber is not star-gauged, as a slight error in the position of the gauge would make a large difference in the reading, and the record would have no value.

Rifling.—(1) The *rifling*, which consists of cutting spiral grooves in the surface of the bore from the compression slope to the muzzle, is done, as noted, either before or after the final chambering.

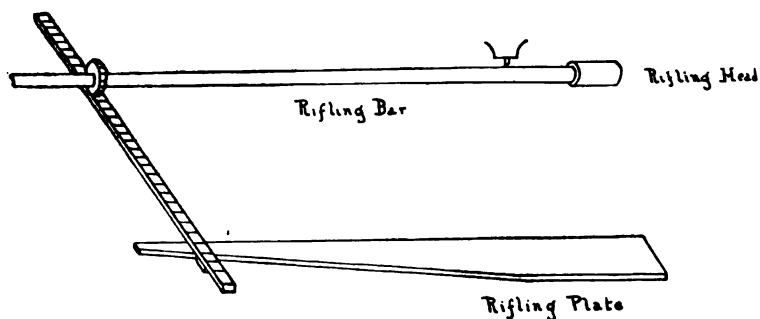


FIG. 6.

(2) Before rifling a gun of a new type, it is necessary to construct a *rifling-plate*, and from it a *rifling-bar*. The following is the procedure: A drawing is made of the curve of rifling in the bore developed on a plane surface, and an iron template is constructed with one edge straight, while the other is cut to the developed curve of the rifling. For uniform twist, this is a straight line at a constant angle to the straight side, but for increasing twist it is a curve. This plate is secured to one side of the lathe used for cutting rifling-bars, and has pressed against its curved side a roller carried in an arm extending across the bed-plate. The top of this arm is a rack which, through a series of pinions, drives the head carrying the rifling-bar. As the rifling-bar is fed along, it is



FIG. 1.—RIFLIN



B

FIG. 2.—LAPP

turned the necessary amount, so that the rigidly held tool against which it is fed makes on its surface a curve like that desired in the rifling. A heavy weight sliding between two uprights on the carriage, suspended from a strap wound round a wheel on the head, serves to keep the roller always tightly pressed against the edge of the template.

The slot cut in the surface of the rifling-bar is about .5 inch wide and .5 inch deep. To cut grooves wider at the breech end than at the muzzle, as is done with practically all guns, a secondary slot must be cut in the rifling-bar, in the same manner. This is like the first, but differs from it enough to widen the grooves the necessary amount.

(3) All rifling is done from the muzzle end. To cut the grooves, the rifling-head is keyed in the socket in the end of the rifling-bar, and carefully centered with the gun. This head (Fig. 1, Plate III) is a hollow steel cylinder, slightly smaller than the bore of the gun, holding eight cutting tools arranged in pairs 90° apart. By means of wedges controlled by screws on the front face of the cylinder, the tools can be set out separately, or together, a graduated collar surrounding the central screw giving a means for reading the amount when all are moved together. The cylinder is capable of rotation on its shaft, pins engaging in holes in a ring on its after end holding it in one position while grooves are cut, when it is moved to the position for a new cut. For small guns, the rifling-head cannot be turned on its shaft, but the gun itself is mounted in a graduated collar which is turned as necessary, a pointer attached to the lathe serving to indicate the amount of movement.

The head being mounted, and the tools set for the first cut, the rifling-bar is fed into the gun. A lug on its forward steady-rest engages in the groove, and revolves it so that spiral grooves of proper curvature are cut in the bore. Very small cuts are taken, to keep the metal from jamming in front of the tools, so that from 15 to 30 cuts are necessary for one set of grooves. After all grooves have been cut, the lug on the steady-rest is engaged in the secondary slot in the rifling-bar, and the work is gone over, giving each groove the required enlargement toward the breech.

The cutters are kept well lubricated with oil fed in the breech during the entire operation. A semicircular brass sleeve is pushed

into the bore, by proper mechanism, at half the speed of the head, and helps support the shaft.

(4) After rifling, the lands are star-gauged at every inch of length, and the grooves at every half-inch for the first eight calibers from the origin of rifling.

Finish turning.—(1) After rifling, if the gun has been chambered, it is returned to the lathe, where the outside is turned down to finished diameters, the bell muzzle is finished, and the gun is faced off to the correct length. In guns which are hooped to the muzzle, the tube projects about .25 inch beyond the end of the hoop. During the turning, any opening of outside joints is closed by "rolling"—i. e., forcing a tool carrying a small wheel against it as the gun is revolved.

Determination of droop.—(1) In order that the gun, when finally mounted, may be in the most advantageous position, it is now tested to ascertain the point of least droop. It is centered in a lathe, the breech end is gripped by the jaws of the face-plate, and the point where the gun will be supported by the trunnions is held by steady-rests. The gun is now revolved, and by means of a small spring indicator held against the muzzle, the points of greatest and least comparative droop are determined. These are marked, and then the absolute droop at these two points and two other points diametrically opposite is measured, using the tail-stock of the lathe for reference. From the information thus obtained, the position of the gun in which it shows least droop is noted, and the top of the breech is marked to show where to start the thread for the screw-box collar.

Chasing thread for screw-box collar.—(1) In all guns from 4 to 14 inches, inclusive, the screw-box threads are cut in a separate collar which screws into the breech of the gun—in some cases into threads cut in the jacket; in others, as the 14-inch, into threads cut in the C1 and D1 hoops.

(2) The gun is put in the lathe with muzzle end to the face-plate, and the after ends of the A tube and B1 jacket are faced off true as one surface, both extending the same distance to the rear. The C1 hoop is then faced off at exact distance in rear of the end of the A tube and B1 jacket, determined by an accurate gauge. Finally, the D1 hoop is faced off at an accurately gauged distance in rear of the end of the C1 hoop.

(3) Then the C₁ and D₁ hoops are bored out to exact diameters, using a tool mounted on a head and fed in by its carriage while the work revolves. These diameters having been checked up by steel points, a slot the depth of the thread to be chased, usually .25 inch, is cut in D₁ where it joins C₁, and in the C₁ hoop where it joins B₁, to allow clearance for the tool which is to chase the thread.

(4) The thread is then chased, starting it at the point determined by the droop measurements, so that when the screw-box collar is screwed home the right part of the gun will be up.

The thread in the D₁ hoop is first chased, and then that in C₁, the latter being an exact continuation of the former. The thread is tested for accuracy with gauges, which must fit the threads in both C₁ and D₁ hoops at the same time.

(5) The screw-box collar, prepared as noted in the manufacture of breech-mechanisms, is fitted to the gun while it is still in the lathe, so that any further work necessary for fitting may be done at once. This work must be very accurate, as the collar must take up firmly against both the ends of the tube and jacket, and the D₁ hoop at the same time. In the fit with the end of the C₁ hoop, .001 or .002 inch clearance is tolerated.

(6) The breech is now marked for holes for heavy countersunk screws to keep the collar from turning, and these are drilled and threaded. The screws are put in place and the collar is secured.

Lapping.—(1) The bore of the gun is now lapped to remove all burrs, etc. First a head (A, Fig. 2, Plate III) holding four segments of wood covered with emery cloth, held out against the bore by spiral springs, is run through, while emery flour and water are put in with a swab. This smooths the lands. For the grooves a similar head is used, but with segments of lead cut to fit the grooves (B, Fig. 2, Plate III). Finally, a head covered with bur-lap and waste is run through to clean out the bore thoroughly (C, Fig. 2, Plate III). Clean waste is put on this head and tied in place with twine, as required. The heads are drawn back and forth through the gun by a machine which reverses itself at the end of the travel each way.

Fitting breech-mechanism.—The necessary holes for fitting the breech-mechanism are drilled, the hinge-plate or hinge-bolt is put in place, and the breech-block is fitted. Previously to fitting the

breech-block, it is fitted in a dummy gun, so that when actual fitting takes place the work will not be so difficult. There is always considerable hand-work in fitting every breech-mechanism. When the fitting is complete, the block is marked with the number of the gun.

Milling keyway.—Whenever convenient during the final finishing work on the gun, the keyway on its top, to take the key which keeps the gun from turning in its slide, is cut. A special portable milling-machine operated by an electric motor is strapped on top of the gun for this purpose.

NOTE.—The processes of finishing, from rifling on, are not carried out in any regular order; the gun is routed through the shops as the machines are ready to receive it, the only requirement being that it must be finish-bored, finish-turned on the outside, and measured for droop before the threads for the screw-box collar are chased. In some cases the breech-mechanism has been fitted before the gun was rifled, while in others the rifling has been done before the final chambering.

Putting on yoke.—(1) The yoke, of forged or cast steel, may be put on in several ways. In the smaller guns it is often screwed or shrunk on, but in most large-caliber guns, including the 14-inch, it is put on over the breech and abuts against a shoulder on the DI hoop which prevents its forward movement. Just aft of the yoke an annular slot is turned in the gun, in which two sections, each about 60°, of a steel ring are secured by countersunk screws, one at the top and one at the bottom of the gun, to prevent backward movement of the yoke. This annular slot for the backing ring is cut whenever convenient during the finishing processes of the gun. The yoke is now considered part of the gun.

Balancing for center of gravity.—The gun with breech-mechanism, with a projectile and charge, is balanced on knife-edges to find the center of gravity. This is done for only one gun of a type. The center of gravity of each gun is previously computed, in addition, for convenience in designing.

Weight.—(1) The gun, with breech-mechanism, is now weighed, and this weight is marked on the face of the breech. The weight of the breech-mechanism is also marked on the block, but this is included in the weight of the gun.

Final inspection and marking.—(1) The gun is now finally inspected, the dimensions are verified, the breech-mechanism is

tested, etc., after which the gun is marked according to the standard marking, which gives place of manufacture, year, mark, number, and weight of the gun, and initials of superintendent and inspecting officer.

The gun is then fitted to the slide and as much of its mount as may be necessary, and is sent to the Naval Proving Ground for proof firing. After it has been proved, it is returned to the gun factory and, if satisfactory on proof, is relapped, bore-searched, star-gauged, and issued to the service. If unsatisfactory on proof, the defects noted are remedied if possible, and the gun is returned for re-proof.

Re-lining.

After a number of service firings, or a greater number of reduced-charge firings, the bore of the gun becomes eroded and the gun gives undue dispersion. This is remedied by boring out the gun, inserting a liner, and then chambering and rifling the liner. Until recently cylindrical liners have been used, but now conical liners are inserted.

The operation of lining a gun consists in the main of boring the gun, machining the liner, shrinking in the liner, and finishing the gun. In the first, the gun is placed in the lathe and accurately centered. The bore is then roughed out by packed bits, and the final boring to taper is done by the employment of a number of tapered bits. All boring is done from the breech, and the taper is .003 inch to the inch, the diameter increasing from muzzle to breech.

The rough boring is done similarly to that described on page 39. The cuts are made successively from the breech, and there are two or three shoulders, so that, as far as possible, the amount of metal to be removed by the tapered bits may be reduced.

After roughing out with packed bits, the bore is smooth-bored with tapered bits. The bit for the muzzle section is first run through to the muzzle. Then the next bit in rear is run through to within a few inches of the beginning of the cut made by the muzzle bit, and then this bit is withdrawn, the two cuts are star-gauged, and the bit is replaced and worked carefully up to the line between the two cuts, taking care that no shoulder or ridge is left. This merging of the one cut into the other is known as

"blending"; the forward end of each bit is made with the diameter for several inches coincident with that of the last few inches of the previous bit, so that the "blend" may be made smooth by overlapping the cuts. The several bits are put on in turn, each cut being blended into the previous one, until the entire length of the gun is bored. The feed is very slow, about 6 to 7 inches an hour.

After the boring is completed, the bore is star-gauged throughout its length, and a shrinkage sheet for the liner is made out. The shrinkage is very small, only from .005 to .006 inch for 12-inch guns, and less for smaller. This shrinkage is enough to hold the liner in place, without undue strain thereon, since, in the calculations of the gun, the liner is not considered as an additional layer for giving elastic strength by shrinkage. The liner is rough-turned from the forging, bored out to within .65 inch of its final diameter, and then replaced in the lathe for turning. With the shrinkage sheet prepared for it, it is finish-turned, using a head which feeds the tool slowly along, and is then smoothed down by filing any rough spots. It is then coated with a mixture of graphite and machine oil. (It may be left dry, but this coating prevents "galling" in shrinking.)

The gun is placed, muzzle down, in the furnace, and is heated thoroughly to a temperature of 400° to 500° F. A brass plug is then screwed into threads cut in the muzzle of the liner (to keep the hot air in the gun from getting inside and expanding the liner as it is inserted), and a steel lifting-plug is screwed into the breech. Into this lifting-plug are shackled the crane falls. A rope sling is placed about the muzzle end of the liner and the whole is hoisted, the liner in a horizontal position, and then the sling is slacked until the liner is hanging vertically, when the sling is removed. The crane is then moved until the liner is hanging directly over the gun. The heat is turned off and the lid of the furnace is removed. The vertical position of the liner is verified by a spirit level, and its position over the center of the gun is tested by placing a wooden batten against the liner at four quadrantal points, and noting the position, on the breech of the gun, of a pointer attached to the batten.

The liner is slowly lowered until its muzzle is within the breech of the gun. It is then lowered rapidly, checking as it is about to pass each shoulder, until in place. The crane falls are unhooked,

and a heavy iron head is put over the liner, a hydraulic jack is placed above this, and over all a heavy yoke which takes under nuts on the tops of two heavy tie-rods passing down through the sides of the furnace. Pressure is put on the jack, and the liner is held firmly in the gun, preventing its backing out on cooling. The gun is then allowed to cool, no water being sprayed on, but one section of the furnace being removed to allow free access of air. After four or five hours, or when it is considered that the liner has "set," the jack is removed, and the lifting-block is unscrewed and removed.

After the gun is thoroughly cooled it is removed, and then chambered, rifled, and finished as described above.

In fitting a cylindrical liner the process is similar, but, after the rough boring, smooth boring is done by straight packed bits instead of the tapered bits, and one bit is sufficient for each section between shoulders. The cylindrical liners are generally thicker than the tapered, and the shrinkages greater.

Some guns have been built with liners in them originally, as is the case of the 12-inch, Mark VII. These liners are cylindrical, and fit smoothly, without shrinkage, inside the tube. The processes of boring and turning the tube and liner are similar, respectively, to those of fitting a cylindrical liner to an old gun. In assembling, the tube is heated to 500°, and lowered over the liner. On cooling, it makes a snug fit with the liner, and the gun is then assembled complete on the lined tube, as above described. The great objection to cylindrical liners is that they may not be readily removed when they are worn out, but must be bored out, thus slowly cutting away all the metal of the liner, with great loss of time and labor. The replacement of conical liners, however, is very simple. The gun is placed in the shrinking-pit and heated to about 500° F. The cold water is turned through the liner. As the liner cools, it contracts, and may be allowed to fall out (gun being in the pit with muzzle up, and blocked several inches off the bottom) or may be pulled out by the crane (gun being breech up).

Inspections—Gun-Structure.

The inspections pursued in the course of the manufacture and assemblage of the gun itself—disregarding the breech-mechanism

—have been noted as they occur in the progress of the work. They may be summarized, for reference, as follows:

(1) **Inspections by officers.**—The inspection officer in charge of major-caliber guns is in general responsible for all work on the guns, and his initials are stamped on the breech of each gun. His duties, aside from general supervision, are:

(a) The bore-searching of all forgings after rough boring, and the checking up of marks put on them by the steel-works.

(b) All bore-searching of finished or unfinished pieces, whenever noted in the description of manufacture. The officer also signs the statement in the star-gauge record book, giving date of inspection and any defects found.

(c) The checking up of the measurements marked on each shrinkage sheet with the star-gauge readings, and the checking of the measurement of the external diameter of the male part, when the finish-turning is completed, to see that it conforms to the shrinkage sheet.

(2) **Inspections by workmen.**—During the progress of the work, measurements are taken by the workman as often as necessary to insure accuracy. For all work, except turning conical liners, the men are furnished with steel points of the exact length of the desired diameters. These points are prepared in the tool shop, and are checked up on the special measuring-machine in the gun-shop office. They are either used directly for measuring or are used in setting snap- or beam-calipers. For conical liners, the diameters are taken with snap-calipers fitted with micrometer gauges. These gauges, as received from the manufacturer, are calibrated on points previously checked by the measuring-machine, so that all measurements refer to this machine.

All internal diameters are measured by the star-gauge, as noted. The rings for setting this gauge are checked by points calibrated on the measuring-machine.

All fillets, screw threads, and curves, such as the bell muzzle, are tested during turning by profile gauges, made in the tool shop and issued to the workmen.

To measure the distances between surfaces, such as the rear faces of the tube and hoops, right-angled gauges which bear on one surface and have a leg which should just extend to the other

are used. The clearance between this leg and the surface it should touch is tested in accurate work with feelers or cigarette papers. If the paper can just be pulled out without tearing, the clearance is .001 inch ; while if it is held firmly, the clearance is not more than half that amount.

As each job is finished by the workman it is inspected by a responsible leading man or quartermen, using the appropriate gauges and steel points.

CHAPTER IV.

BREECH-MECHANISMS.

Definition.—A *breech-mechanism*, or *fermeture*, is a mechanical device for closing the rear end of the chamber or bore of a breech-loading gun. The term includes the *breech-block* or *plug*, all mechanism contained in or with it, and the necessary operating-gear.

Requirements for a breech-mechanism.—The following may be said to be the principal requirements for a successful breech-mechanism:

(1) *Safety*.—To be safe: (a) The gas must be restrained from escaping to the rear; this sealing or obturation must be automatic, greater pressure insuring better obturation. (b) The breech of the gun must not be weakened by the fitting of the breech-mechanism. (c) The parts must have ample strength to prevent any portion from being blown to the rear. (d) The danger of premature discharge must be minimized. (e) The breech-block must be securely locked to prevent opening on firing.

(2) *Ease and rapidity of working*.—Otherwise, rapid and continuous fire cannot be maintained. Hence this would include facility in loading and certainty of extraction for rapid-fire guns.

(3) *Not easily put out of order*.—In other words, it must be able to meet service conditions and hard usage. Parts should have a reserve of strength. All the mechanisms should be so designed as to be protected by the gun itself.

(4) *Ease of repair*.—Parts most exposed to wear should be so designed as to permit being replaced. This will also include accessibility to parts, so that breakage of a part will not disable a mechanism for a long time.

(5) *Interchangeability*.—Not only should individual parts be made interchangeable by accurate workmanship, but the whole

mechanism should be capable of being mounted on similar guns. This is to meet service conditions.

The breech-block or plug is the movable piece closing the breech of a gun, withdrawn for loading, closed before firing. In some built-up guns it is carried by the jacket. In the latest guns, however, it is carried by the jacket, or partly by the jacket and partly by a hoop, within a *screw-box liner*, or *bushing*. The term applies to any shape of piece or for any system of fermeture.

In small arms and certain special guns the term *breech "bolt"* is often used, instead of "*plug*" or "*block*," and "*breech-action*" is a better term in this case than "*breech-mechanism*."

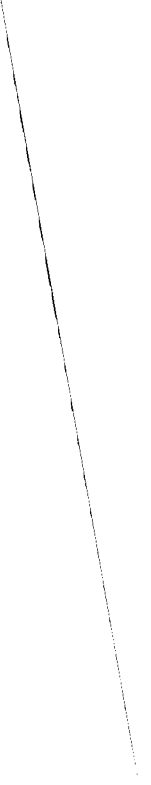
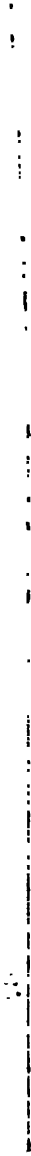
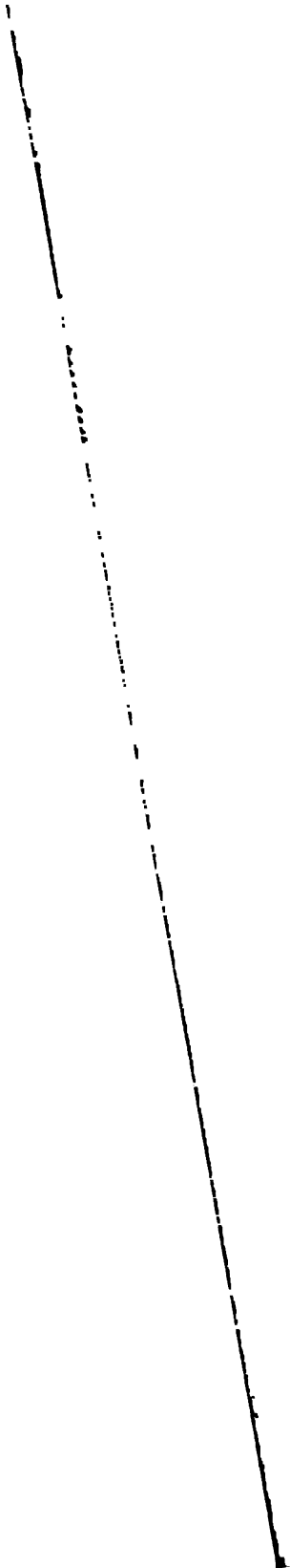
Systems of breech-blocks.—There are four principal systems of breech-blocks used in the U. S. Navy; viz.: (1) The *interrupted screw*, (2) the *sliding wedge*, (3) the *combined sliding and rotary system*, and (4) the *sliding-bolt system*.

The interrupted-screw system is, in general, used for all guns of and above 3 inches in caliber. Secondary rapid-fire guns use systems (2) and (3). Military rifles, as well as certain automatic guns and machine-guns, generally use the sliding-bolt system.

Special guns, such as automatic guns, machine-guns, etc., more properly use "*breech-actions*," in which the different steps in closing the breech and operating the entire mechanism are very intimately connected. The systems in these cases are defined by the names of the guns.

In the U. S. Navy the interrupted-screw system is found in nearly all of the main-battery guns; the sliding-wedge system in the Hotchkiss 6-pounder, 3-pounder, and 1-pounder rapid-fire guns, and the Maxim 6-pounder and 3-pounder semi-automatic rapid-fire guns; and the combined sliding and rotary system in the Nordenfelt 6-pounder and 3-pounder rapid-fire guns.





The interrupted-screw system, also called "slotted screw," is divided into three classes: (1) *French interrupted screw*; (2) *Elswick interrupted screw*; and (3) *Welin interrupted screw*.

In general, an *interrupted-screw plug* is a plug which, after having been threaded, has two or more sections of the thread removed in the direction of the axis. Similar interruptions are made in the female thread of the screw-box in the gun, in order that the plug may be entered or withdrawn in one motion, and only a portion of a turn be given to lock or unlock the same in the screw-box.

The **French interrupted screw** is the *ordinary* system of ferreture, and has been long in use. The breech-plug, cylindrical in shape, has cut on its circumference a male screw thread, the character of which varies according to particular designs. It is then divided into a number of *equal sections* in the longitudinal direction (always divisible by two, usually six, eight, or twelve), and the threads of alternate sections are then planed or slotted out. The female thread in the screw-box is similarly slotted. In closing the breech, the threaded sections of the plug are brought opposite to the blank sections of the screw-box; the plug is pushed in either by hand or by some sort of mechanism to the proper distance; and a fraction of a turn to the right or left is given so as to interlock the threaded sections, the amount of turn necessary depending upon the number of divisions. Six divisions would require 60° ; eight divisions, 45° ; etc. The system is independent of the methods of operating the mechanism.

The **Elswick interrupted screw** differs from the French, or ordinary, in that the forward part of the plug is conical and the rear part cylindrical. The threaded sections of the coned portion correspond longitudinally with the blank or planed sections of the cylindrical part. The superiorities *claimed* for this arrangement are: (1) The working of the mechanism is facilitated, as the translation and swinging out or in can be accomplished in one motion; (2) the arrangement of the threaded sections distributes the strain throughout the entire circumference of the plug; (3) the cone shape enables the engagement to be distributed over a large transverse section of the gun. This system, as given, is independent of the methods of operating the mechanism.

The **Welin interrupted-screw** or "stepped-thread" system has the block divided circumferentially into six equal sections, each

semicircle having a blank and two step-threaded sections. The blanks have the greatest diameters and the step-threaded sections are in two lesser diameters, the larger step being diametrically opposite the smaller step in the other semicircle. The blanks are cut concave and convex with the hinge pin as a center; and the upper part of the teeth of the first step, with the adjoining edges, are also cut, both cuttings being to give clearance to swing the plug.

The combined rotary and sliding-wedge system is exemplified in our service in the Nordenfelt 6-pounder and 3-pounder rapid-fire guns only. The breech-block may be said to consist of two parts, the *block* and the *wedge*, the latter sliding on the front face of the former in the locking or unlocking movement; while to cover or uncover the bore, both rotate about a transverse axis, the top falling to the rear in opening.

The sliding-wedge system, exemplified in the Hotchkiss guns, has a rectangular wedge-shaped block (containing the firing-mechanism) that slides up and down in a vertical mortise within the square-shaped breech of the gun, guided by vertical ribs. It is moved by means of a crank, journaled in the right cheek of the mortise; a stud on the other end of the crank moves in a cam groove in the side of the block. The wedge completely closes the mortise when up, and gives only a sliding movement to the cartridge-case in shoving it home.

Some field-guns have the block working transversely to the axis of the gun instead of vertically.

The sliding- and rotary-block system.—In this system, to open the mechanism the block slides downward and is then rotated on a transverse axis, the upper part falling to the rear.

This system is exemplified in our service by the Driggs-Schroeder only. It has a rectangular block with rounded top, working entirely within the breech-housing, and is locked by means of collars on top of the block engaging corresponding grooves in the housing. The grooves are inclined slightly to the front, so that the final movement in closing is upward and to the front, pushing home the cartridge-case. The operating is through a cam within the block, moving against curved surfaces in the block's recess. The cam is moved by a transverse axis.

The sliding-bolt system.—In this system a more or less cylindrical piece, containing at least the firing-pin and spring or hammer, moves longitudinally in a “receiver” attached to the gun-barrel, and may be worked either by hand, as for small-arm rifles, or by certain mechanism, as in the Colt automatic gun. The bolt may have only a direct movement to the rear and front, giving the name “*straight-pull*,” or have a part attached which is turned for locking or unlocking, giving the name of “*turn-bolt*.”

Types of ordinary system of operation.—There are four types: (1) *Service*; (2) *modified Farçot*; (3) *improved Farçot*; (4) *Naval Gun Factory design*. The difference between (2) and (3) is so slight that it is usual to class both under (2).

Types of quick-acting system.—There are five principal types: (1) *Rapid-fire*; (2) *semi-automatic rapid-fire*; (3) *automatic rapid-fire*; (4) *quick-fire*; and (5) *machine-gun breech-action*.

A **rapid-fire breech-mechanism** is a quick-acting one, *without a gas-check*. It is provided with an extractor and special firing-mechanism for use in guns using primed metallic cartridge-cases, or, in other words, for rapid-fire guns.

A **quick-fire breech-mechanism** is a quick-acting one provided *with a gas-check* and a firing-lock for use on guns where the charge is not put up in a metallic case, or, in other words, when loaded in the “ordinary manner.”

There is in reality no distinction between the rapid-fire and the quick-fire, so far as the operating-gear is concerned; but the name is given because the guns differ in their ammunition, or rather in the manner of putting up the same. The breech-mechanism differs, no extractor being necessary for the latter.

The term “quick-fire” is apparently indiscriminately used abroad for guns having a quick-acting mechanism, whether using metallic cartridge-cases or powder charges in bags. It is well that a distinction should be made, as in the U. S. Navy.

Semi-automatic rapid-fire breech-mechanisms are quick-acting, part of the operation being by hand and part automatic. This gives rise to the name, both as “rapid-fire” and as “semi-automatic.”

Automatic rapid-fire breech-mechanisms are those in which all the operations are performed automatically by utilizing the energy of recoil. The name also defines the gun.

The breech-actions of machine-guns are essentially quick-acting, and their special features are the distinctive features of the gun.

Systems of Gas-Checks.

Gas-check.—This is a device to prevent the escape of the powder gas to the rear around the breech-block or through the vent.

There are three systems in use: (1) The *Broadwell ring*; (2) the *cartridge-case*; (3) the *De Bange check*.

The Broadwell ring is the invention of Broadwell, an American, and has been largely used abroad by Krupp.

The cartridge-case as a gas-check.—The metallic cartridge-case used in rapid-fire guns forms a perfect gas-check. The heat and pressure of the powder gas on firing expands the mouth of the case against the powder chamber and restrains the gas from escaping to the rear. When the projectile is loaded in the case, the powder gas, being confined, will swell the case before the projectile leaves it. When the shell is separately loaded, a *mouth-cup* or heavy wad is usually used to close the case, in order to confine the gas at first. The mouth-cup also serves to retain the charge and protect it from moisture, etc.

The De Bange gas-check, or "*pad obturator*," is the type used in the U. S. Navy for all modern guns that are not rapid-fire. It is the invention of Colonel De Bange, of France, and in many special forms has been and is used by practically all countries. The De Bange system of breech-mechanism, considered by the French as the original interrupted-screw system, does not take its name from the gas-check.

The De Bange check consists of a mushroom-headed piece of steel with a shank passing through an axial hole in the breech-block. Between the rear face of the mushroom head and the nose of the block surrounding the shank are two steel disks or rings inclosing an obturator pad of asbestos and tallow within a canvas cover suitably shaped. Nuts screwed on the rear part of shank within the recess of the plug bind together the parts.

The pad and mushroom project beyond the screw-box into the chamber, the front disk and pad bearing on a smooth sloped surface of the gun chamber, called the *gas-check slot* or *slope*.

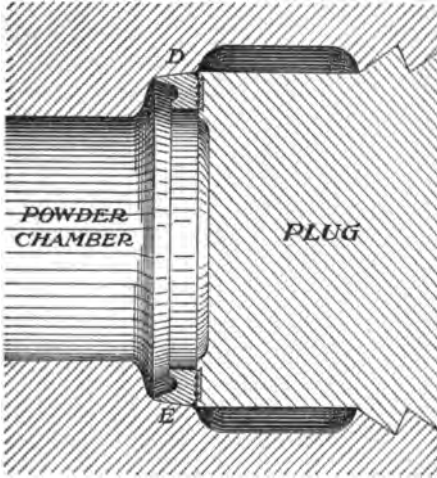


FIG. 1.—D. E. Broadwell Ring.

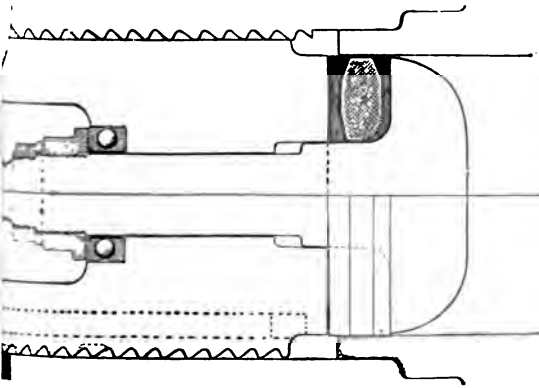


FIG. 2.—The De Bange Gas-Check, with Disks.

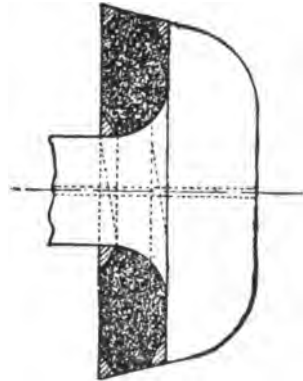


FIG. 3.—The De Bange Gas-Check.
(Later form, showing split-rings.)

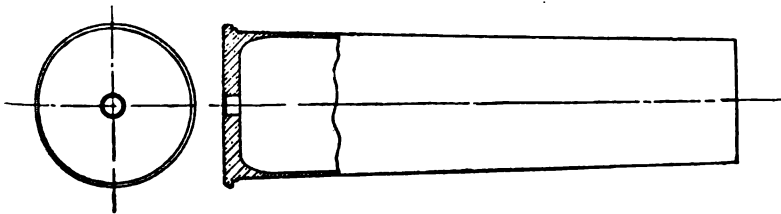


FIG. 4.—Cartridge-Case
SYSTEMS OF GAS-CHECKS.

The action is thus: On firing the gun the powder gas acting on the front face of the mushroom forces it back, compressing the pad between the disks or rings against the breech-plug. This causes the pad to expand radially and equally all around against the gas-check slope, sealing all escape of gas to the rear. The greater the pressure the better will this pad check the gas. It is equally as effective in large as in small guns, though it took many years to prove it practically.

The advantages of this type are durability, certainty of action, easy adjustment, no great accuracy of fitting, and the ease with which it is replaced. Some pads have stood a thousand rounds; all should stand two hundred.

The canvas on the edges of the pad wears from the working of the mechanism, but the cover can be replaced. It is better to put on a *new cover* rather than a patch.

Designation or Names of Breech-Mechanisms.

We have seen that there are three general systems used in connection with breech-mechanisms: (1) *System of breech-plug*, (2) *system of operation*, (3) *system of gas-check*. There is still another that might be added—the “firing-mechanism.” As the latter two may differ in the same general make-up, they are not considered. The name or designation may be given for either of the first two systems or for both, or for one of their subdivisions. The general rule may be said to be: For all quick-acting breech-mechanisms the name is that of the *inventor*, to which may be appended whether rapid-fire, quick-fire, semi-automatic, automatic machine, etc., or simply the “mark”; for others, the system of breech-plug operation followed by the particular “mark,” or simply the “mark,” is given. The latter has been alluded to before. Examples of the former are: “Dashiell 4-inch rapid-fire breech-mechanism, Mark III,” or “Mark V,” or simply “Mark III, or Mark V, breech-mechanism, 4-inch”; “13-inch breech-mechanism, Mark II,” or “Mark II breech-mechanism, 13-inch”; “12-inch breech-mechanism, Welin type,” or “Mark VI breech-mechanism, 12-inch.”

The names or types of quick-acting breech-mechanisms in the U. S. Navy.—These are: (1) Hotchkiss rapid-fire, (2)

Driggs-Schroeder rapid-fire, (3) Dashiell rapid-fire, (4) Fletcher rapid-fire, (5) Elswick or Armstrong quick-fire, (6) Vickers quick-fire, (7) Maxim-Nordenfelt rapid-fire, (8) Nordenfelt rapid-fire, (9) Bethlehem Steel Company design, (10) Naval Gun Factory design; (11) Maxim-Nordenfelt automatic, (12) Colt automatic, (13) Benét-Mercie.

Firing-Mechanism.

Definition of firing-mechanism.—The term “firing-mechanism” is used to designate that part of the breech-mechanism which directly explodes the primer and thus fires the gun.

Guns are fired by percussion and by electricity. Percussion primers are used for guns of 3-inch caliber and below, while guns of larger caliber use combination primers which may be fired either by percussion or by electric current. For large guns electric firing is considered preferable, percussion firing being used only as an alternative.

Current for electric firing is furnished by batteries and by motor generators, connections being made so that either may be used as desired.

Generally speaking, for the *percussion firing-mechanism*, the firing-pin, surrounded by a spiral spring, has a rectilinear axial movement within the plug, the “cocking” being performed either automatically during the opening of the breech-mechanism, or, in continuous firing-mechanism, by hand.

The electric firing-mechanism has an insulated firing-pin within a *firing-case*. The electric contact is made when the breech-block is nearly closed.

The *firing-lock* consists essentially of a *receiver* (that screws on the rear of the mushroom shank) conveying a *wedge* made so that the primer seat may be closed or unmasked for priming. It has a suitable *latch* for locking, an *extractor* for ejecting the primer-case, a *firing-bolt* with spring, a *sear* and *spring* for holding the firing-bolt cocked, and a *trigger* to release the sear and to which may be secured a firing-lanyard. The wedge for percussion firing contains a *firing-pin* and *spring*, the shank of the former being struck by the firing-bolt, when released.

Definition of firing-attachments.—These are a part neither of the firing-mechanism nor of the breech-mechanism, but are cer-

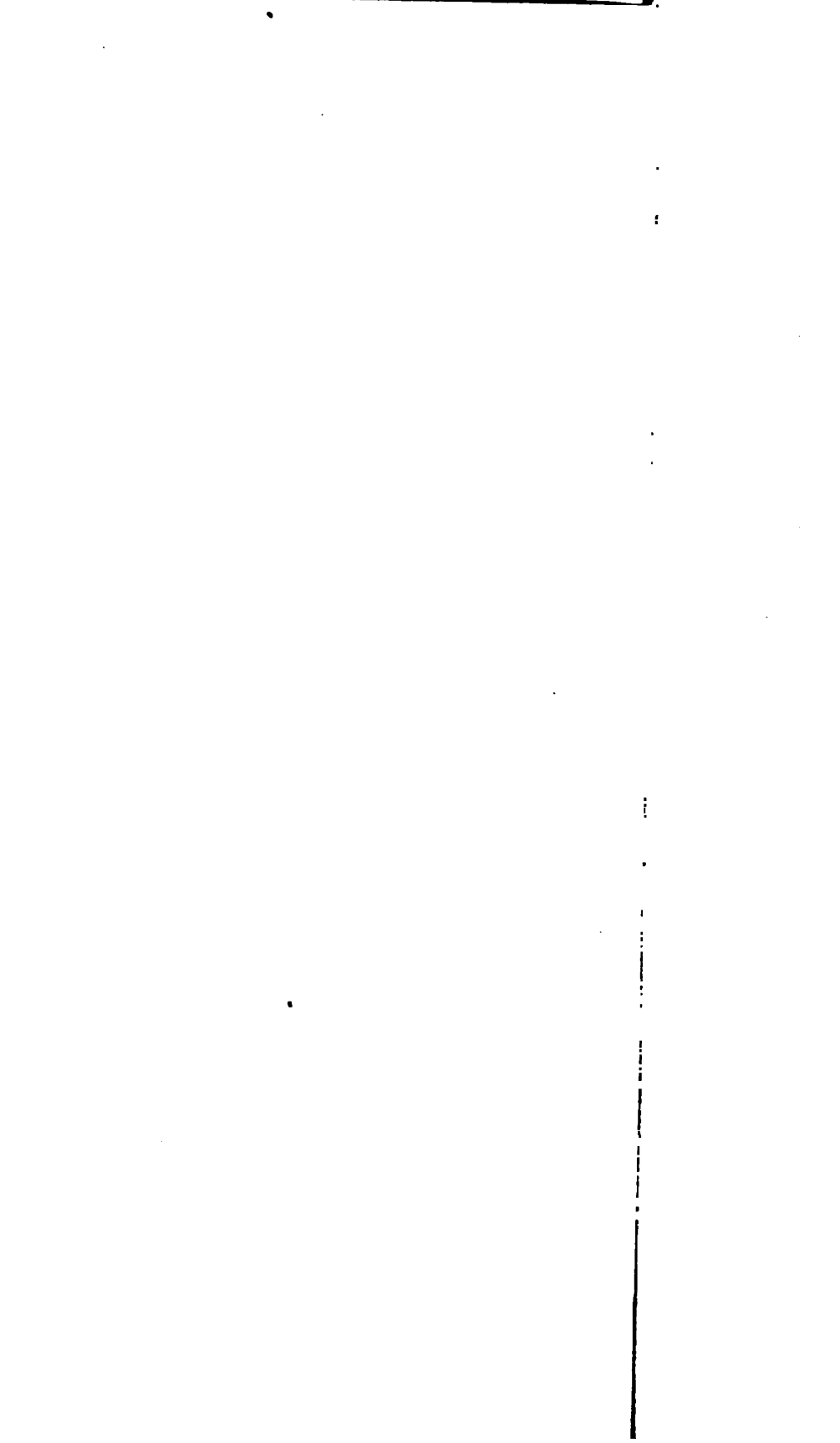
tain appliances used to put in operation the firing-mechanism. The *lock-string*, electric *firing-battery*, wires, terminals, *firing-keys*, etc., are attachments.

The two terms "*firing-mechanism*" and "*firing-attachments*" should not be confused.

Definition of percussion and electric firing-mechanisms.—

A *percussion firing-mechanism* is one in which the blow of the hammer or firing-pin explodes a cap in a primer.

An *electric firing-mechanism* is one in which an insulated firing-pin, suitably connected to a firing-battery, or other source of electricity, transmits an electric current to the primer and heats a fine wire or *bridge* therein to a sufficiently high temperature to explode the primer charge of powder.



CHAPTER V.

BREECH-MECHANISMS OF MINOR-CALIBER GUNS (1-POUNDER TO 3-INCH INCLUSIVE).

All minor-caliber guns now being manufactured for the navy are of the semi-automatic type, and such is likely to be the practice in the future on account of the greater rapidity of fire of this type over the rapid-fire type.

As the 1-pounder, 3-pounder, and 6-pounder R. F. guns are similar to the semi-automatic guns of the same caliber, with the semi-automatic features omitted, only the S. A. types are described.

The different S. A. 1-pounders, 3-pounders and 6-pounders are designated Vickers' Sons and Maxim, Hotchkiss and Driggs-Seabury; however, the intention is to use "marks" solely; for example, the 3-pounder Mark IV is a Hotchkiss, S. A., 50-caliber 3-pounder.

A semi-automatic gun is one which performs some of the loading operations automatically, requiring hand assistance for the others. Generally the cartridge has to be loaded by hand, while the energy of recoil and counter-recoil is utilized to automatically open the breech, eject the empty case, cock the piece and store energy in a breech-closing spring. This spring closes the breech when the cartridge is loaded into the gun.

The important advantages over ordinary R. F. guns are greater rapidity of fire and smaller gun-crews.

The disadvantages, which are being eliminated or minimized by numerous improvements, are more complicated mechanism, greater liability to jams and broken parts, more costly and heavier guns, and, on account of the jarring of the gun when the breech is suddenly closed, vibrations which derange the pointer's aim. Also, in some instances the members of the crew are struck by empty cartridge-cases which are violently ejected.

1-pounders in ships' launches and cutters will often give better results when worked by hand than if worked semi-automatically. The unsteady platform and the motion of the boat make

rapid, accurate shooting impossible; so consequently a slight loss of time is not of great importance. On the other hand, automatically ejected empty cases strike or disturb the pointer, and small parts of the S. A. mechanism are likely to break.

The Hotchkiss S. A. Mechanism. (Plate I.)

Many 1-pounders, 3-pounders and 6-pounders in the service are of this type. The sketches are not exact and are intended simply to show clearly the general features of the mechanism.

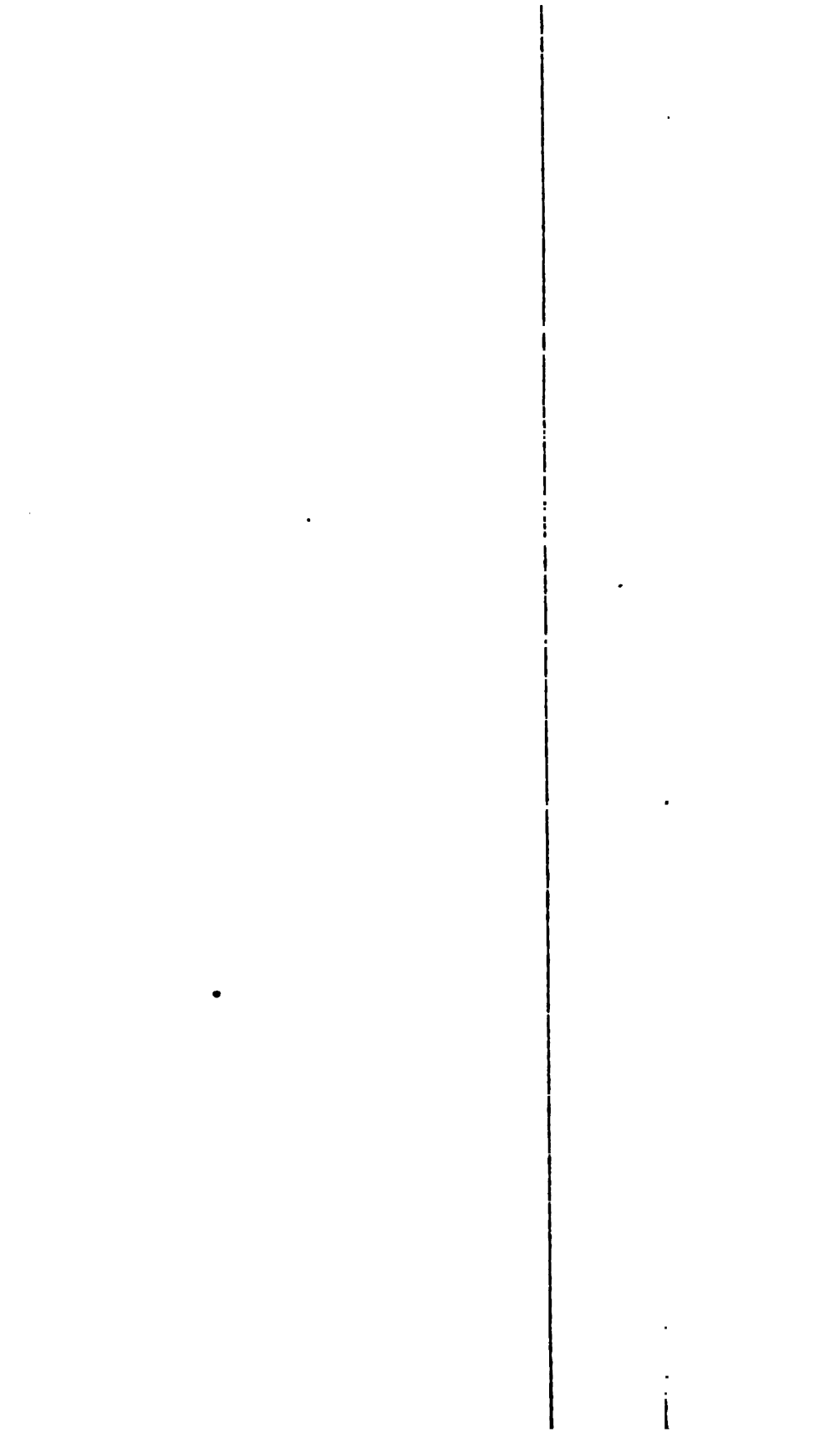
Opening and closing of breech (Figs. 1 to 4 inclusive).—The *breech-block* is a rectangular block of steel with an approximately square cross-section, and is cut away in various places to allow for the proper working of the mechanism or to provide for the housing of certain parts.

When the *operating-lever* (Fig. 1) is moved to the rear, the *crank-shaft* (Figs. 1 and 2) is rotated and the *crank-stud* moves in the *crank-stud groove* (Fig. 3.) This groove is so cut that the first part of the movement of the operating-lever does not lower the block while cocking the gun. The latter part of the motion of the lever and crank drops the block and opens the breech.

A *stop-bolt* (Fig. 4) goes through a hole in the left curtain of the gun and projects into a *stop-bolt groove* on left side of block, shown in dotted lines in Fig. 3. This stop-bolt catches and stops the block when it drops down. Conversely, the reverse motion of the operating-lever closes the breech.

Semi-automatic mechanism (Fig. 1).—When the gun is fired, it recoils and slides to the rear in its slides. As one end of the *breech-closing spring* is secured to the operating-lever and the other end to the non-recoiling slide (or rather to the arm of the *thrust-rod* which is pivoted on the slide), this spring is extended and exerts a pull on the operating-lever. At the same time the thrust-rod bears down hard on the *thrust-rod roller* (on operating-lever), and the rear end of thrust-rod drops when the roller strikes the cut-out portion (*roller-cam surface*).

Upon counter-recoil the thrust-rod pushes against the roller, moves the operating-lever and opens the breech. When the breech has been opened, the thrust-rod again rides up over the top of the roller. As shown later, the extractor holds the block down until a cartridge is loaded into the gun.



Firing-mechanism (Fig. 5).—It is seen (Fig. 1) that the first movement of the operating-lever to the rear rotates the *rock-shaft* through the *cocking-toe* and the *cocking-arm*.

The *hammer* (Fig. 5), being on the rock-shaft, is swung back, and the gun is cocked as shown. The *main spring* has its lower end locked to the breech-block and is compressed by means of its sleeve, which fits over main spring and has a projecting toe against which a lug on the hammer presses.

The *sear* (with spiral *sear spring* pressing against it) engages the *cock notch* of hammer and holds same cocked until the *firing-lanyard*, which is attached to the *hook* shown, is pulled.

A *safety-sear* (dotted lines, Fig. 5) also engages the cock notch until the breech is closed, preventing the release of the hammer until the block is all the way up.

Extractor and holding-down mechanism of breech-block (Figs. 6 and 7).—The *extractor* has a T-shaped cross-section and slides longitudinally in its slot in the left cheek of breech of gun. This longitudinal motion is given the extractor by means of its *guide-stud* and the *guide-stud groove* in breech-block.

The rear face of the breech-block is slightly inclined downward and to the rear, and so consequently the block moves a little to the rear when going down. This slight motion to the rear enables the extractor to start the empty cartridge-case before it is thrown out of the gun when the sharply curved part of the slot strikes the extractor guide-stud as the block descends.

The sectional sketch of the extractor shows how the *extractor claw* is pivoted in the *extractor slide* with its *tail* pressed back by a *spring*. When the block drops down, the spring forces this tail outward into a recess and its nib snaps into the notch of the *stop-pin*. As the extractor cannot now move forward, the extractor guide-stud holds the block down until a cartridge is loaded and its rim strikes the extractor claw, when the extractor nib moves out of the stop-pin notch, the extractor moves forward and the breech-closing spring throws the block up again.

Adjustments of the mechanism.—The breech-closing spring should be so adjusted that it is just strong enough to surely close the breech when a cartridge is loaded. If too strong, the block may catch empty cases when they are extracted, extractor guide-stud and other parts may break or gun may fire on breech-closure.

If recoil cylinders of gun are filled very full or clogged, the gun may not recoil enough to open the breech.

The preventer sear should be so adjusted that it releases the hammer just as the block gets all the way up.

3-INCH BREECH-MECHANISMS.

Only S. A. 3-inch guns are now being manufactured for the navy, but, in view of the fact that there are now in service a large number of the rapid-fire 3-inch fitted with the Mark III breech-mechanism, this is described here.

As most S. A. guns and the R. F. 3-inch described below may be fired on breech-closure by holding the trigger, it is not out of place to say that *these guns should never be fired automatically on breech-closure*. The result of so doing is a very slight gain in time and a very considerable loss in accuracy, due to the throwing off of the gun on breech-closure and the fact that the pointer does not know when the breech will be closed and the gun be fired. This procedure has almost invariably produced many misses in target practice.

3-Inch Breech-Mechanism, Mark III. (Plate II.)

Opening and closing the breech.—The *breech-block* (Fig. 2) is cylindrical and has on its curved surface alternate raised *threaded segments* and sunken *blank segments*. Thus it may be entered into the breech of the gun and rotated so the threaded sections of the block engage those of the *screw-box*, locking the block to the gun.

Rotation of the *operating-lever* (Fig. 1) on its axis, the *hinge-pin*, first rotates and unlocks the plug and then withdraws and swings it around to the right so the gun may be loaded. The *plug-rotating teeth* on operating-lever engage the teeth of the *plug-rotating arc* (Figs. 1 and 2).

The *carrier plate* (Fig. 3) has on its front face a circular *projecting boss* to which the plug is screwed, and on which it rotates sufficiently for locking and unlocking the screw-threads.

When opening the breech, the rotation of the plug is stopped, as soon as it is unlocked, by the edge of the *plug-rotating arc plate* (Fig. 2) striking against the end of a cut on the rear face of the

gun. Then the motion of withdrawal begins, with the plug, its carrier plate and the operating-lever all rotating together around the hinge-pin.

The *plug-locking plunger* (Fig. 4) fits into a circular recess on the front face of the carrier plate (dotted lines, Fig. 3). When the plug has been rotated and is just beginning to swing to the rear, this plunger moves forward into the recess on the edge of plug (Fig. 2) and locks the plug to its carrier plate. On breech-closure a part of the front face of the locking-plunger strikes against the rear face of screw-box, forcing the plunger back into its recess in carrier plate and unlocking the plug for rotation.

Carrier latch and plunger.—The carrier latch (Fig. 5) is for the purpose of locking the carrier to the gun when the carrier and plug reach the proper position during breech-closure. It works in an athwartships groove on the front face of the carrier plate (dotted lines, Fig. 3), and its projecting *stud* moves in a groove cut in the rear face of the breech-plug (Fig. 2). Here also will be seen a small block of metal, the *carrier-latch stop*, and its screw, provided so the carrier latch and its spring may be removed without unscrewing the plug from its carrier. As the carrier strikes the rear face of the gun on breech-closure, the end of the latch plunger snaps into a recess cut into the inner face of the gun itself. This prevents a rebound and locks the carrier plate to the gun. As soon as the plug rotates and engages the threads of the screw-box, the *carrier-latch stud* travels up the cam surface of its groove (Fig. 2) and the latch is moved to the right and withdrawn from its recess in the gun.

In the proper place in the left rear face of screw-box there is a *carrier-latch plunger* (Fig. 6), which, as the plug is rotated on breech-closure and the latch is withdrawn, is forced by its spring into the *latch-plunger recess* (Fig. 5), thus holding the carrier plate unlocked from the gun until the breech is opened.

Caution.—*Do not take out this latch plunger and close the breech*, as the breech cannot then be opened without removing the hinge-plate from rear of gun. An *emergency hole* has been drilled in many guns to provide for this contingency or the sticking of the carrier-latch plunger in its bushing. This hole goes through carrier plate (Fig. 3) and into rear face of latch plunger. By entering a pin in this hole when the breech is closed the latch

cannot move to the left, even if its plunger fails to work, and the breech may be opened.

Extractor.—The *extractor* engages the cartridge rim and ejects the cartridge-case when the cam surface of operating-lever strikes the right-hand end of the extractor. A spring presses against the rear face of the extractor, making its action regular and certain.

Firing-mechanism (Fig. 1).—The mechanism is cocked by means of a *cocking-bar*, which moves fore and aft with regard to the breech-block, being restrained by its arms, which work in a slot cut longitudinally in the rear end of the *firing-mechanism stem* (Figs. 1 and 2).

The *firing-mechanism stem* is practically a part of the breech-block. In addition, the ends of the cocking-bar arms project into *cocking-bar grooves* cut on the inner surface of the boss of the carrier plate (Fig. 3). Consequently the cocking-bar rotates with the plug and at the same time has a fore-and-aft motion in it.

When the plug is rotated for opening, the *firing-pin* is drawn to the rear and retained there by the *sear*. Then, when the plug is rotated again on breech-closure the cocking-bar moves forward and further compresses the *main spring*.

The *sear* moves athwartships in a slot cut in the rear face of carrier plate and has a *safety-stud* which projects through a cut into the recess in rear face of breech-plug. This recess has two radial cuts which allow the sear to move only when the plug is rotated to the two positions; one is to allow the gun to be fired when the breech is entirely closed, and the other to allow the sear to engage its notch when the firing-pin is brought to the rear by the cocking-bar.

The *trigger* is pulled and the sear is released by a system of rods and levers leading to the *pistol-grip* on left side of gun (not shown), which is easily understood when seen.

Precautions.—To avoid jams and breakdowns while firing:

- (1) See that cocking-grooves are not burred.
- (2) File off burrs at ends of screw-threads of plug and screw-box.
- (3) File knife-edges off extractor nibs.
- (4) See that firing-pin point is not broken.
- (5) Adjust and lash turn-buckles of trigger-pull rods on left side of gun.



(6) See that carrier latch and its plunger move freely in their recesses.

A short wire lanyard with wooden toggle should be lashed to the cocking-handle of firing-pin for recocking in case of misfires.

3-Inch Semi-Automatic Breech-Mechanism, Mark V.

At present this is the only S. A. 3-inch in use in the service, and there have been several modifications of the original design to remedy certain defects which developed.

The gun is manufactured at the Washington Gun Factory, and it has been sometimes designated the "Driggs-Seabury S. A. 3-inch."

Opening and closing the breech.—The wedge-shaped *block*, similar to that of the Hotchkiss gun, is dropped by rotation of the *crank-shaft* (designated on official drawings "operating-lever").

The *hand lever* (Fig. 1) may be disconnected from the crank-shaft, and it will then be held in a vertical position during S. A. firing by its *latch* on the side of the gun, or it may be connected up and the gun be used as a R. F. gun.

The *crank-shaft* (Fig. 2) rests in a cradle projection under the gun which is a part of the gun itself. The *lock-plate* (Fig. 4) which holds the crank-shaft in its cradle is a flat U-shaped plate, held under the gun by dovetailed recesses, with jaws at the ends of its arms which embrace the shaft and retain it in place. A *lock-bolt* locks the lock-plate when in its proper position.

As the crank-shaft is rotated, the studded end of its *breech-block crank* moves along a sloping cam surface on the under side of the block, raising or lowering it. The *tumbler crank* on the left side of the gun opens the breech on counter-recoil.

Operating-lever clutch-mechanism (Fig. 3).—This mechanism is for the purpose of preventing rotation of the operating-lever when the gun works semi-automatically.

Where the operating-lever is hollowed out to receive the end of the crank-shaft, there is left a projecting sector of metal about $\frac{1}{4}$ inch thick. When the breech is closed and the operating-lever is upright, the upper, vertical face of this sector is against the corresponding face of the sector on the end of the crank-shaft (Fig. 2). Consequently rotation of the operating-lever, when the breech is closed, will rotate the shaft, but rotation of the shaft will

not rotate the lever, since the shaft sector will move in a blank space.

By screwing in the *clutch-lock* the *clutch* is carried to the left against its spring, and the sector on the left end of the clutch-lock fills the space between the other two sectors, thus locking the shaft and operating-lever together.

If the gun is to work semi-automatically, screw the clutch-lock all the way out.

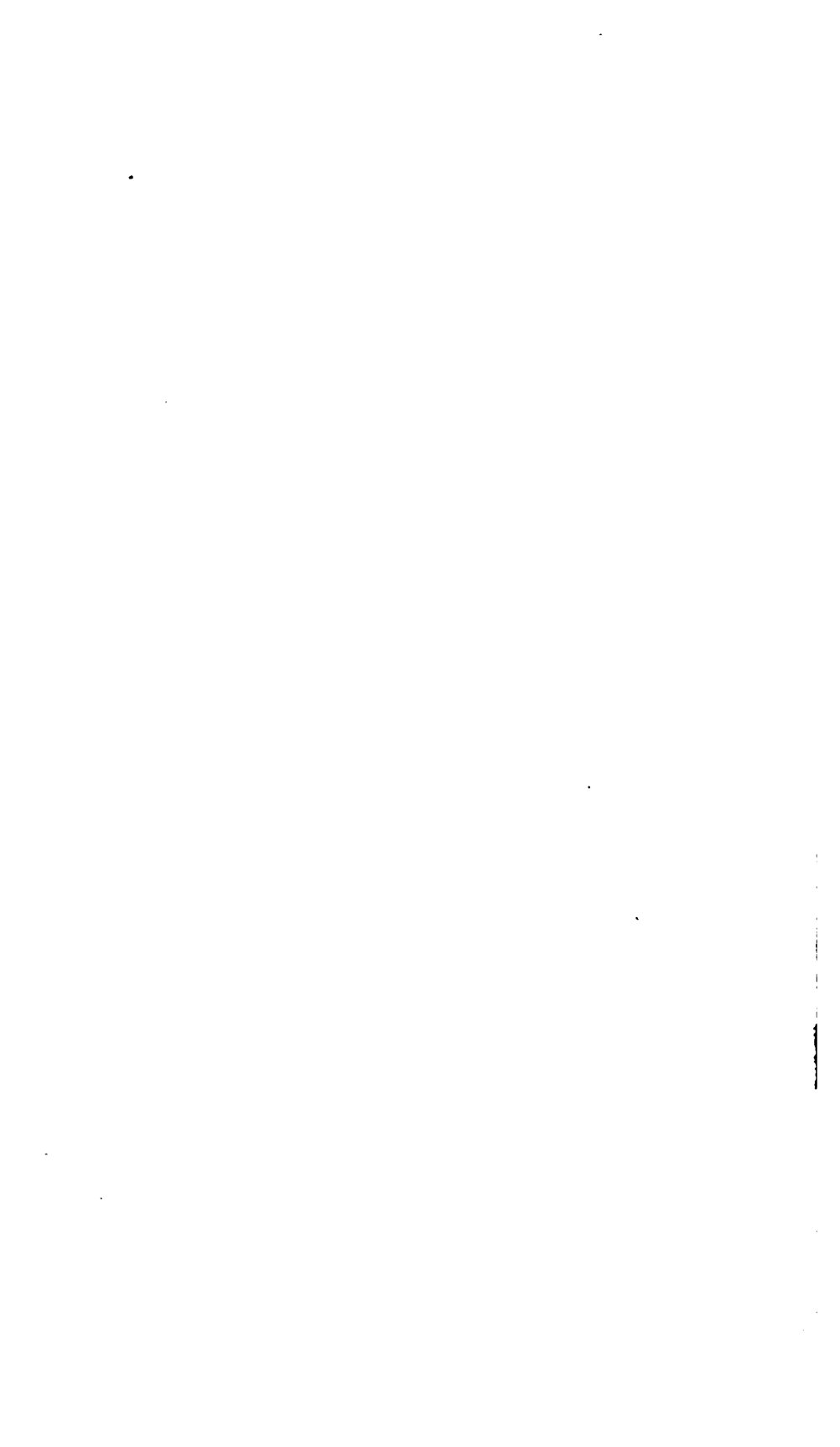
The *retaining-ring* on the hub of the operating-lever holds the lever in place longitudinally on the shaft. At its left end there is an inside ring of metal with two cuts in it. This narrow ring of metal bears against two small projecting feathers on the crank-shaft (Fig. 2), preventing removal of the operating-lever until the retaining-ring lock-screw (not shown) is taken out and the retaining-ring is rotated so that the cuts in the inner ring are opposite the crank-shaft feathers.

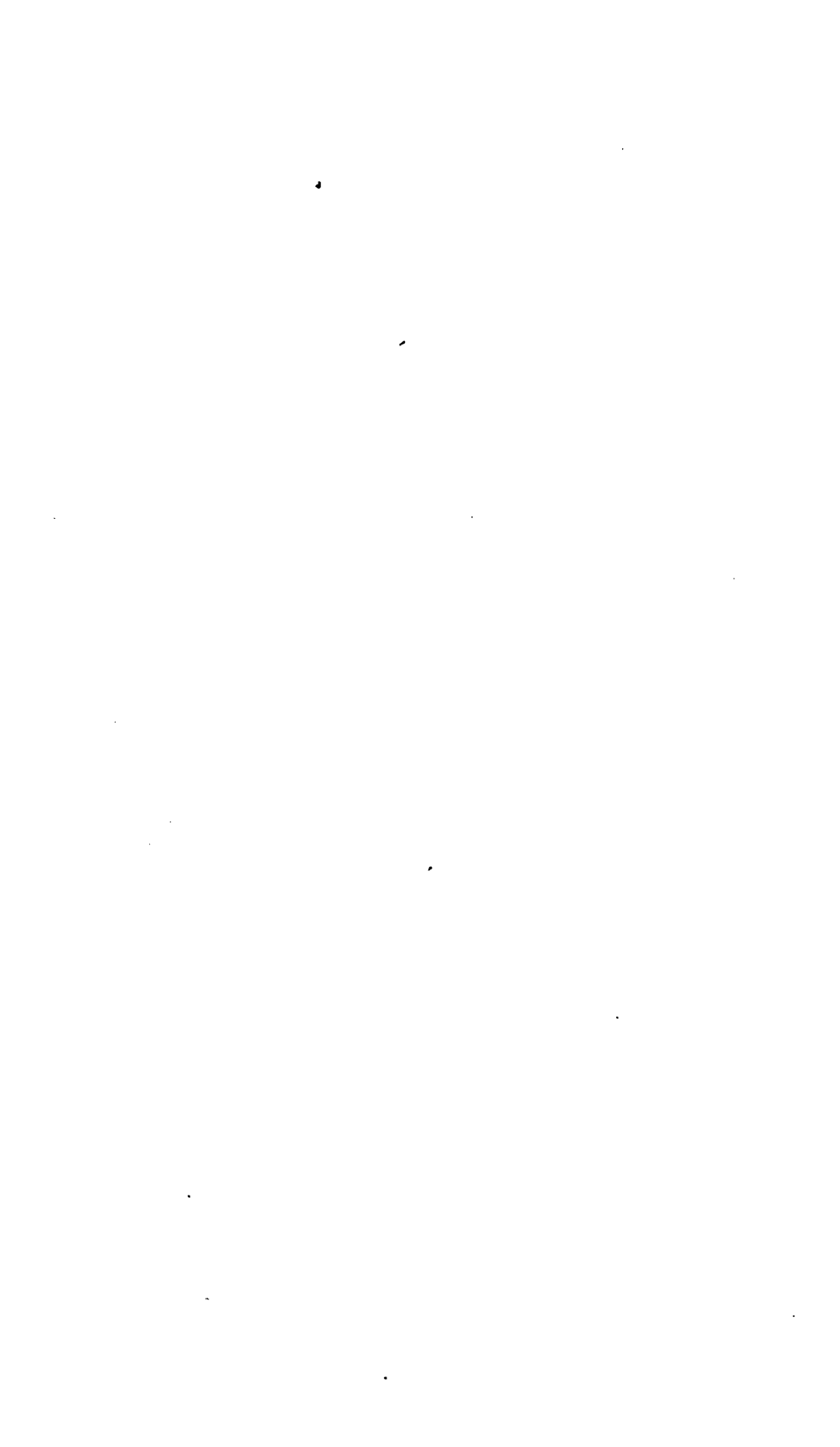
Firing-mechanism (Figs. 4 and 5).—The upper arm of the *cocking-lever* works in a slot in the rear end of the *firing-pin*, and the end of its other arm engages a short arm of the *sear* (Fig. 6). The *sear-spring piston* (dotted lines, Fig. 4), in the form of a rod connecting two small cylinders of metal, seats in a notch cut in the rim of the boss on the left end of the sear. The *sear spring* keeps the sear engaged with the cocking-lever.

Upon breech-closure the *sear arm* cocks the mechanism and retains same cocked until the sear is rotated. On the left side of the gun is the *trigger arm* of the sear, which is moved by the non-recoiling trigger mechanism (Fig. 5).

By pressing the *trigger* against the *pistol-grip* the trigger rotates its shaft; and the *trigger lever* on the end of this shaft, working in a slot in the *trigger rod*, moves the rod to the rear, when its arm presses against the sear arm, rotates the sear shaft, and the gun fires.

The extractors (Figs. 4 and 5).—As will be seen from Fig. 5, each extractor has at its lower end two projecting circular *guide-studs* on opposite sides of the body of the extractor. The outer one of these studs works in a short slotted arc cut in the inside cheek of the gun (Fig. 4). Thus the movement of the extractor is limited. The other stud works in a vertical slot, curving forward at its upper end and cut in the outside of the breech-block.





When the breech is opened and the plug descends, the inner stud is struck by the curved part of the slot in the plug, forcing the lower end of extractor forward. At the same time, since the front face of the extractor is a curved surface bearing against the rear of the gun-tube, the upper end of the extractor moves to the rear and extracts the empty cartridge-case.

The *extractor-plunger spring* forces its *plunger* against the outer stud of the extractor and tends to keep the lower end of the extractor in its forward position. When the plug is down, the inner stud of the extractor bears against the lower face of the curved slot on the side of the plug, and is kept there by the extractor plunger, holding the plug down until a cartridge is loaded.

Semi-automatic mechanism.—Bolted to the non-recoiling gun slide there is a *shield* (called "*cam-slide*" on official drawings) which projects to the rear on the left side of the gun (Fig. 5). A guide-rail on the gun slides in a T-shaped slot cut in this shield, and maintains accurately the relative position of the gun and shield.

A part of the shield forms a bearing for the *tumbler* (or operating-cam), which consists of a short shaft and arm. Around this shaft is a spring which tends to keep the arm of the tumbler upright and its front face against its stop.

As the gun recoils, the tumbler crank of the crank-shaft (Fig. 5) moves to the rear, and its stud strikes the tumbler arm, rotates same on its shaft, slides over the top of it, and on counter-recoil strikes the rear face of the tumbler (its spring having returned it to the original position). This rotates the crank-shaft and opens the breech, and the stud of the crank-shaft passes underneath the tumbler.

On the left end of the tumbler shaft is the *tumbler cover* and its *latch*, by means of which the tumbler may be rotated and locked with its arm held down, thus throwing out the S. A. action of the gun.

When a cartridge is loaded, the extractor releases the plug and the operating-spring closes the breech.

Disassembling the breech-mechanism.—(1) Take out retaining-ring lock-screw, unscrew retaining-ring and take off operating-lever after rotating to proper position.

(2) Remove operating-spring, piston, piston-rod and chain after unscrewing nuts on end of piston-rod.

(3) Turn lock-bolt a quarter turn and pull lock-plate to the rear.

(4) Screw breech-block dismounting-tool in top of block, holding top flush with top of gun. Rotate crank-shaft slightly and lift same from its cradle. Drop block out of gun.

(5) Remove extractor plungers, springs and extractors.

(6) Push sear piston forward beyond rear face of gun and pull sear out to the left with dismounting-tool. Take out sear piston and spring.

Disassembling the plug-mechanism.—(1) With dismounting-tool in hole on left side of plug, disengage spring catch of cocking-lever pin and pull out pin.

(2) Remove cocking-lever.

(3) Unscrew firing-pin bushing with dismounting-tool; remove bushing, spring, washer and firing-pin.

Precautions.—(1) Using ammunition with projectiles loose in cartridge-case usually causes a jam in loading. A jam is also caused by bent extractors and burrs in the chamber of the gun.

(2) Sometimes the gun fails to entirely return to battery, which may be caused by dirt or burrs where recoiling parts bear against non-recoiling parts; for example, the guide-rail on the gun and its slot in the cam-slide. By not filling the recoil cylinders too full the gun will more surely return all the way to battery.

(3) See that nuts on operating-spring piston-rod are set up tight before firing.

(4) Be prepared to tap breech-block underneath with a mallet in case it does not come all the way up after loading.

(5) Run gun in and be sure it will not stick in its slide.

3-Inch Breech-Mechanism, Mark VI. (Plates IV and V.)

This plug is of the type known as an "*eccentric plug*"; that is, the center of the plug is not in the axis of the gun. The eccentric plug is now considered the safest for guns using cartridge-cases. The firing-pin is at all times in the center line of the gun; the carrier hub, however, is eccentric on the carrier with respect to the axis of the gun, to an amount of .3 inch measured on a 45° radius to the left and up from the center line of the gun. The firing-pin

hole in the carrier is therefore eccentric on the front face of the carrier hub. The firing-pin hole on the front face of the plug is also eccentric. The eccentricity is so designed that, as the plug rotates on the carrier hub, these two firing-pin holes do not come in line until the plug is rotated fully closed. It is therefore an impossibility for the firing-pin to come in contact with the primer until the plug is rotated fully closed.

The metal parts are made of forged steel, except the carrier, which is cast steel. The mechanism consists essentially of the following parts: (1) *Plug*, (2) *carrier*, (3) *operating-lever* and *plug-rotating link*, (4) *firing-mechanism*, (5) *plug-rotating cam* and *rotating-cam follower*, (6) *salvo-latch*, (7) *extractor*, (8) *hinge-plate* and *hinge-pin*, (9) *screw-box liner*.

General operation and description of the plug.—Starting with the plug closed, shove operating-lever *latch-trip* (*S-1*) forward by hand and, grasping operating-lever handle (*L-1*), pull same to the rear. The operating-lever, coming to the rear, pivots on the *hinge-pin* (*H-1*) and transmits a transverse motion to the right to the *plug-rotating link* (*L-5*). This motion is transmitted to the plug-rotating link (*L-5*) by the *rotating-link pin* (*L-2*) sliding in a *slot* in the plug-rotating link (*L-7*). The plug-rotating link (*L-5*), sliding to the right, rotates the plug on the *carrier hub* (*C-1*). This rotation is attained by the *plug-rotating stud* (*P-2*) engaging in a recess in the left end of the plug-rotating link (*L-8*). The same instant the plug starts rotating, the plug-rotating link (*L-5*) starts cocking the *firing-pin* (*F-1*), by means of a *cam surface* (*L-6*) on the left-hand top side of the plug-rotating link (*L-5*) engaging a *lug* on the firing-pin sleeve (*F-10*).

Simultaneously with the ending of the revolution of the plug by the plug-cam follower, the rotating-link pin takes against the inner rear face of the carrier, thereby preventing further longitudinal motion of the rotating link and rotation of the plug. The rotating-link pin of the operating-lever being still in engagement with the rotating-link cam surface, further motion of the operating-lever causes the plug, carrier and operating-lever to swing as one piece about the hinge-pin as a center. As soon as the carrier starts to swing to the rear, the *plug-locking plunger* is forced forward by its spring and enters the plug-locking plunger *recess*, thereby preventing further rotation of the plug. This prevents any accidental

turning of the plug while open, and maintains the correct relation between plug and operating-lever.

When the firing-pin (*F-1*) has been cocked by the plug-rotating link (*L-5*), the *sear* (*F-12*) actuated by its spiral spring engages a *lug* on the firing-pin sleeve (*F-11*), and holds the firing-pin (*F-1*) in a cocked position.

The plug now being locked to the carrier (*C*) by the plug-locking plunger, the continuation of swinging the operating-lever swings the plug open. The *plug-flange* (*P-1*) is screwed to the rear end of the plug. To this flange is screwed the *plug-rotating cam follower* (*P-3*), which engages the *plug-rotating cam* (*S-2*) screwed to the *hinge-plate*. When closing the plug, the plug-rotating cam (*S-2*) controls the rotation of the plug after it is released from the plug-locking plunger, and also prevents rebound. A hole is drilled from the firing-pin bushing to the bottom of the plug, then through the screw-box liner and the bottom of the gun, to act as a vent in case of a blow-back. The *extractor* (*H-3*) works on a pin which is forged solid with it. This pin fits in a recess in the hinge-plate. The extractor is actuated by the right side of the carrier (*C*) taking against the *extractor toe* (*H-10*).

This extractor is of the type known as the "Tasker extractor," and is patented. It provides for great power when first opening the plug, and then great rapidity in extracting during the last part of opening the plug. This can be understood by inspecting the general-arrangement print. When the plug is opening, the extractor pin slides in the groove in the hinge-plate; this causes the pivot to shift, with the result as above stated.

General operation and description of firing-mechanism.—This firing-mechanism provides for percussion firing only.

When the plug begins to open, the cocking of the *firing-pin* (*F-1*) begins, as previously described; therefore the plug is closed with a cocked firing-pin (*F-1*), and this makes the firing interval very small, as upon the instant release of the *sear* (*F-12*) from the *firing-pin sleeve* (*F-11*), the firing-pin (*F-1*) moves instantaneously forward. The firing-pin (*F-1*) hits the *primer* with a force of 24 inch-pounds, which is the tension of the *firing-pin spring* (*F-3*) when compressed ready for firing. The mechanism is so designed that it is impossible to fire until the plug is fully rotated closed. If the *sear shaft* (*F-13*) were tripped with the

plug open, the *plug-rotating link* (L-5) would still hold the firing-pin (F-1) in a cocked position. It is impossible for the *trigger-bar toe* (F-17) to shove the sear shaft (F-13) to the rear till the plug is fully rotated closed, on account of a safety notch on the *plug-flange* (P-1), which allows the trigger-bar toe (F-17) motion to the rear only when the plug is fully closed.

The eccentricity of the plug provides an additional safety to the mechanism, by not allowing the *firing-pin hole* on the plug face (P-7) to come in line with the primer till the plug is fully rotated closed. The firing-pin (F-1) is also completely housed at all times, except when it is tripped and allowed to fly forward to fire the primer. This obviates the danger of a broken firing-pin by careless loading.

Cocking of the firing-pin (F-1) is obtained by the plug-rotating link (L-5) shoving the firing-pin sleeve (F-10) to the rear till the sear (F-12) holds it. When the pointer pulls the trigger in the *pistol-grip*, this motion shoves the *trigger-bar* (F-16) to the rear against the tension of the *trigger-bar spring* (F-18). The trigger-bar toe (F-17) then shoves the sear shaft (F-13) to the rear and allows the sear (F-12) to release the firing-pin sleeve (F-10). The motion of the trigger-bar toe (F-17) is controlled by the *trigger-bar toe-guide* (F-21), which is held in place on the *hinge-plate* by the *trigger-bar toe-guide detent* (F-22). The trigger-bar toe-guide detent (F-22) is held forward by the compression of the *trigger-bar toe-guide detent-spring* (F-23).

General operation and description of salvo-latch.—This device prevents the plug from being opened unless the gun has been fired; but if the plug is to be opened without firing the gun, this can be accomplished by shoving the *operating-lever latch-trip* (S-1) forward by hand. Ordinarily the operating-lever latch-trip (S-1) is held to the rear by the *lever latch-spring* pushing the *operating-lever latchspring sleeve* (S-8) against the *operating-lever latch* (S-3). The operating-lever is locked to the gun by the *operating-lever catch* (L-3) engaging with the operating-lever latch (S-3). When the gun is fired, recoil forces the operating-lever latch-trip (S-1) forward against the pressure of the operating-lever latch-spring, disengaging the operating-lever catch (L-3) from the operating-lever latch (S-3) at the same time the *operating-lever*

latch-locking plunger (*L-9*) flies forward and holds the operating-lever latch (*S-3*) in an unlocked position.

General description of hinge-plate.—The hinge-plate is fitted to the rear end of the gun and held in position by the screw-box collar being screwed home, and by the four hinge-plate screws.

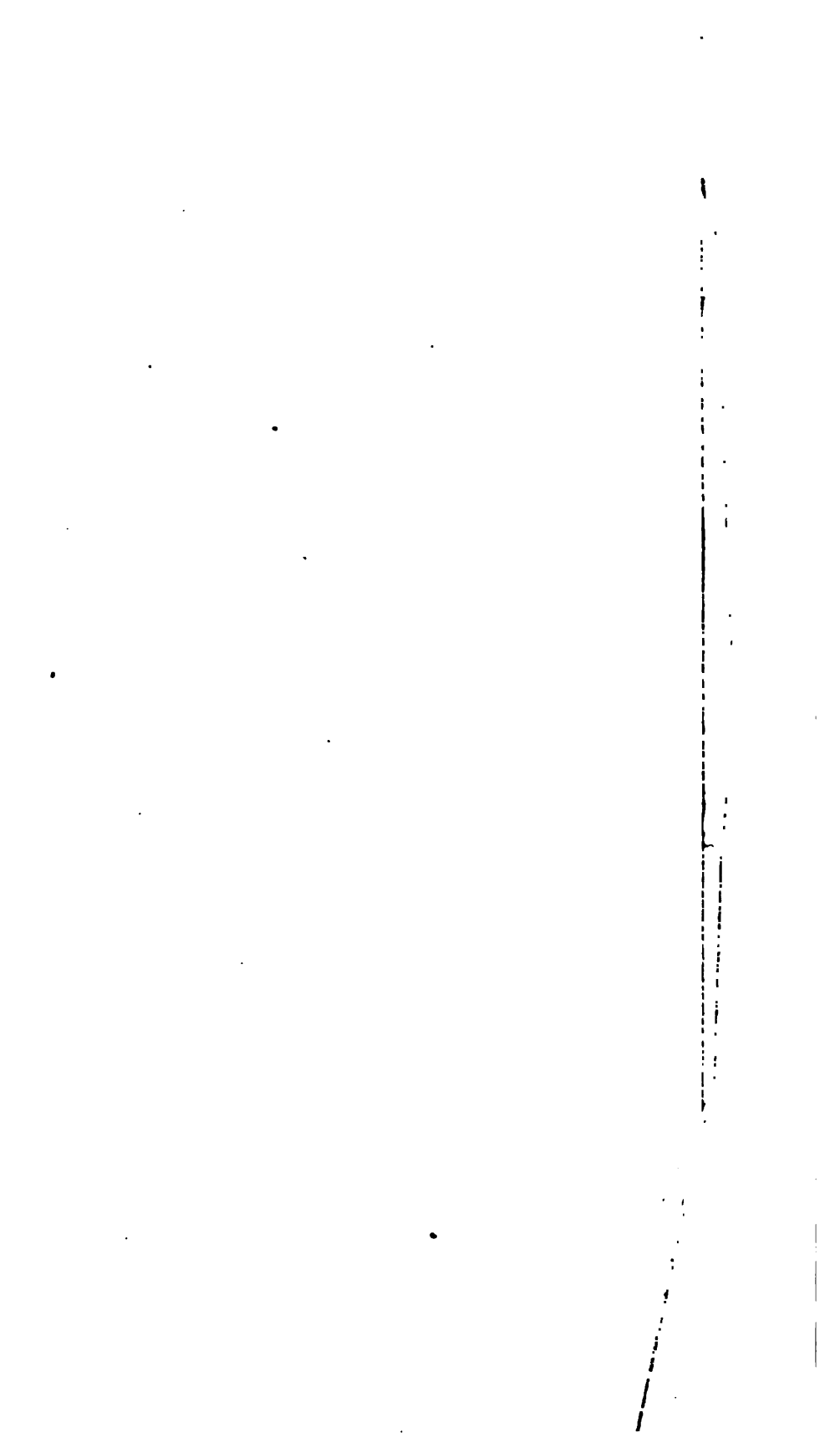
Disassembling the mechanism.—Starting with the breech closed:

- (1) Open the plug.
- (2) Take out plug-locking plunger by rotating plug on the carrier hub (*C-1*) to a closed position.
- (3) Release firing-pin (*F-1*) by pulling sear shaft (*F-13*) to the rear.
- (4) Take out sear shaft (*F-13*) by pulling same to the rear till bayonet-joint (*F-14*) will disengage, and then drive sear shaft (*F-13*) out to the left.
- (5) Rotate firing-pin case (*F-4*) to the left till released by turning knurled head by hand.
- (6) Pull firing-pin case (*F-4*) out to the rear.
- (7) To disassemble firing-mechanism, take out recocking-hook pin (*F-9*) on rear end of firing-pin (*F-1*), and unscrew recocking-hook (*F-8*), when the firing-mechanism can be easily disassembled.
- (8) Remove hinge-pin (*H-1*) by driving the same up from the bottom.
- (9) Take out plug and carrier (*C*) and lay on deck (plug face down).
- (10) Remove operating-lever.
- (11) Then swing carrier (*C*) on the plug toward the top till the arrow on top face of carrier (*C*) meets arrow on top face of plug-flange (*P-1*), and withdraw carrier (*C*) from the plug.
- (12) Pull out plug-rotating link (*L-5*).
- (13) Take off trigger-bar toe-guide (*F-21*), pull out on the trigger-bar toe-guide detent (*F-22*), and pull the trigger-bar toe-guide (*F-21*) off to the left.
- (14) To take off plug-rotating cam (*S-2*), remove operating-lever latch-pin, then operating-lever latch-spring sleeve (*S-8*), and unscrew plug-rotating cam screw. The rotating-cam can then be driven off to the left.
- (15) Take out extractor (*H-3*).









CHAPTER VI.

BREECH-MECHANISMS OF SECONDARY-BATTERY GUNS.

4-Inch Breech-Mechanism, Mark VIII.

General design.—The 4-inch breech-mechanism, Mark VIII, is designed to fit Mark IX guns, for which fixed ammunition is used. The mechanism is of the carrier type, with an “eccentric plug.” (See 3-inch, Mark VI, Chap. V.)

The carrier is journaled on a vertical hinge-pin, in hinge-lugs on the right-hand side of the gun. It extends across the breech face and has a hub which carries the breech-plug. The operating-lever is attached to the outer end of the plug-rotating shaft, which is journaled in a sleeve screwed into the carrier in a horizontal position near the center line of the gun. The inner end of this shaft carries an overhanging crank, the pin of which engages the plug-rotating shaft plunger. This plunger works in a recess bored at the right edge of the rear face of the breech-plug. (See figure, page 97, this chapter.)

To open the mechanism, the operating-lever is swung to the rear in a vertical plane. This rotates the plug-rotating shaft, which, by means of the plug-rotating shaft plunger, rotates and unlocks the plug. The operating-lever is then thrown to the right horizontally, which swings the carrier and plug clear of the breech.

Reverse motions close the breech. The operating-lever is locked in the closed position by the salvo-latch, and is unlocked by the recoil of the gun or by releasing the salvo-latch by hand.

The cartridge-case is automatically ejected, and the firing-pin is cocked, in opening the breech-mechanism.

Screw-box liner and breech-plug.—The rear end of the gun-jacket is bored out, recessed, and threaded to receive the *screw-box liner*. The screw-box liner is bored eccentrically, so that the center of the plug and carrier hub is to the right and above the center of

the gun. The firing-pin hole and firing-pin are eccentric in the plug an equal amount, and are so located in the plug that, as the plug rotates in the carrier hub, they do not come in line with the primer until the plug is rotated fully closed.

The *breech-plug* is of the Welin or stepped-screw type, having left-hand abutment threads, with the pressure side the steeper. The plug and the interior of the screw-box liner are slotted to form nine sections—three blanks and six threaded steps—in three groups, the blanks being wider to permit the action of the plug-rotating cam. The plug extends to the rear, and is screwed into the carrier hub with threads of the same pitch as those on the steps.

Operating-mechanism.—The *plug-rotating shaft* is journaled in a plug-rotating shaft sleeve of phosphor-bronze, which is screwed into the carrier and locked in position by the sleeve-locking plunger. On the inner end of the plug-rotating shaft, which is made of special crucible chrome-vanadium steel, the crank and crank-pin are forged in one piece with the shaft. The crank-pin works in a hole in the side of the *plug-rotating shaft plunger*. This plunger is a cylindrical member of phosphor-bronze which moves in a hole bored longitudinally at the right side of the rear face of the breech-plug, 22° above the horizontal center line, when the breech-mechanism is closed. A slot is cut in the edge of the plug to permit the crank-pin to enter the hole in the plunger.

The *operating-lever* is secured on the outer end of the plug-rotating shaft by a nut, and is prevented from twisting on the shaft by five flat surfaces milled on the shaft. The hub of the operating-lever extends for some distance into a counterbore of the plug-rotating shaft sleeve.

When the plug is closed and locked, the operating-lever extends upward and forward toward the muzzle. The plug-rotating shaft plunger is above the horizontal center line at an angular distance of 22° , and the crank of the plug-rotating shaft is in the "dead-center" position in relation to the movement of the plug, thus positively locking the same.

To open the breech, the operating-lever is swung to the rear until it reaches the horizontal position, turning the plug-rotating shaft through an angle of 120° . The corresponding circular motion of the crank-pin gives to the plug-rotating shaft plunger a movement

to the rear within the bore in the breech-plug, and an upward movement causing the plug to revolve to the right and disengage the threaded steps.

Plug-rotating cam.—The total angular movement of the plug, produced by the rotation of the plug-rotating shaft, is 44° , of which movement only 38° are required to disengage the threads. During the remainder of the rotation, an increasing rearward motion is given to the plug by means of the *plug-rotating cam follower*, which is driven into a hole in the breech-plug, and works in a cam fitted in a dovetail in the blank between the threaded sections at the bottom of the screw-box liner. The energy which the plug acquires in its rotation is thus utilized to start the swinging-out of the plug and carrier.

The advantages derived from the use of the plug-rotating cam are particularly marked during the operation of closing the breech-mechanism, when, by gradually absorbing and utilizing the energy of the swinging parts to impart a rotary motion to the plug and operating-lever, it serves to prevent the objectionable slamming and rebounding of the carrier.

Operating-lever guide and stops.—The rearward swing of the carrier about the hinge-pin, commenced by the plug-rotating cam, is continued by throwing the operating-lever outward until the mechanism has swung open, when further swing is limited by a projection on the lever hub coming up against the hinge-lug. While the mechanism is open, the plug is prevented from rotating and is maintained in the unlocked position by the above-mentioned projection on the lever hub, which, as the outward movement of the mechanism commences, is caught between a stop on the carrier hub and the operating-lever guide on the hinge-lug, on which it slides.

Extractor.—The *extractor* is held in the carrier-hinge lug by the extractor pin, and is actuated by the right-hand side of the carrier hub. This extractor provides for great power when first opening the plug, and then great rapidity in extracting during the later part of opening. When the plug is opening, the extractor, by reason of the oblong hole through it, slides on the extractor pin; this causes the lever arm to change, with the result above stated.

Salvo-latch.—The *salvo-latch* is pivoted on a pin screwed and doweled into the right-hand side of the carrier, below the plug-

rotating shaft, and consists substantially of the salvo-latch proper, the salvo-latch catch, the salvo-latch spring, and a set-screw for holding the salvo-latch on its pin and the salvo-latch catch in place. When the breech-mechanism is closed and the salvo-latch is "set," a hook on the operating-lever hub bears against the salvo-latch, which is held in position by the catch, thus preventing the mechanism from being opened. During recoil, the inertia of the salvo-latch gives to it a pendulum motion around its pin, swinging the salvo-latch clear of the hook on the lever hub. The salvo-latch carries the catch with it to the rear, and the catch spring moves the catch up behind the lever stop, keeping the salvo-latch in this released position. The breech-mechanism can now be opened.

When the breech-mechanism is being opened, the hook on the lever hub forces the catch back below the lever stop, and the salvo-latch is free to return to the "set" position and lock the operating-lever when the breech-mechanism is again closed.

As the salvo-latch is not disengaged automatically, except upon the discharge and recoil of the gun, it gives warning of misfires and hangfires which might pass unnoticed when a number of guns are fired in salvo. In such a case the breech-mechanism can be opened only after releasing the salvo-latch by hand.

Firing-mechanism.—This mechanism provides for percussion firing only.

The breech-plug is bored out eccentrically, as previously mentioned, for the firing-mechanism lock and firing-pin, the center of the bore being so located that the firing-pin comes in line with the primer in the center of the gun only when the breech-plug is rotated fully closed.

The firing-pin is mounted in the firing-mechanism lock, which is inserted in the rear end of the breech-plug and held in position by a bayonet-joint. The firing-pin is kept from rotating in the lock by the firing-pin cocking-toe, which slides in a slot in the lock. The sear is located in a hole in the plug.

When the breech-mechanism is opened, the firing-pin is automatically cocked by the plug-rotating shaft plunger, which catches under an arm projecting from the firing-pin and forces it rearward, compressing the firing-spring.

The firing-lever is journaled on a fulcrum-pin screwed into the carrier. When the plug is fully closed, the outer end of the sear comes opposite the end of the firing-lever, and the gun is ready for firing.

Carrier hinge-lugs.—The *carrier hinge-lugs* consist of a single steel forging, and are bolted to the gun by means of four screws which are locked by lock-screws. A dowel locates the hinge-lugs on the gun.

Method of assembling and disassembling.—(1) Bolt carrier hinge-lugs on gun and secure bolts by locking-screws.

(2) Attach carrier to hinge-lugs by its pin.

(3) Assemble sear and sear spring in breech-plug, and hold in position while screwing plug into carrier hub.

(4) Place the plug-rotating shaft plunger in position in the plug.

(5) Insert plug-rotating shaft into carrier from the right-hand side, and enter the crank-pin into its hole in the plug-rotating shaft plunger.

(6) Place the sleeve-locking plunger and its spring in its hole in the carrier, and hold it back by means of the cotter-pin at the inner end, while screwing the plug-rotating shaft sleeve into the carrier.

(7) Insert extractor into its recess between the hinge-lugs and secure with its pin.

(8) Slide the operating-lever on the end of the plug-rotating shaft, into the plug-rotating shaft sleeve. Secure by the nut and lock nut with the cotter-pin.

(9) Screw salvo-latch pin into the carrier and secure it with dowel. Assemble salvo-latch spring and catch in salvo-latch and slide the latter in place on the pin. Screw set-screw into salvo-latch for holding it and the catch in place.

(10) Place the firing-lever in position on carrier, and secure with the firing-lever fulcrum-pin.

(11) Assemble the following parts, in the order given, on the firing-pin: Firing-mechanism lock, firing-spring washer, firing-spring, and firing-pin washer. Compress the firing-spring and insert the firing-pin point, locking it with the firing-pin washer pin. Turn firing-pin washer round until it snaps over the washer pin. Put the safety-latch in place on the firing-mechanism lock. Take

the firing-mechanism as assembled and, partly cocking it, push the safety-latch in between the firing-mechanism lock and the collar on the firing-pin.

(12) Close the breech-mechanism.

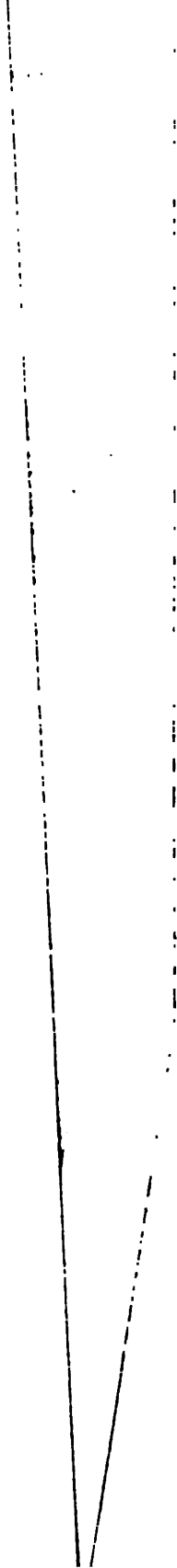
(13) Push back the sear by means of the firing-lever, and insert the firing-mechanism in the breech-plug; turn it to the right until the lug on the firing-mechanism lock strikes the stop-pin; let go of the firing-lever and cock the firing-pin by hand, thus releasing the safety-latch.

The plug-rotating cam is fitted into a dovetail in the screw-box liner and secured by two screws. The cam-follower is driven into a tapered hole in the plug and secured by a $\frac{5}{8}$ -inch driven pin. These parts are permanently assembled, and need not be taken down except in case of breakage. Should it be necessary to remove the cam-follower, it may be driven out by a small rod inserted in the $\frac{3}{8}$ -inch hole which extends through the plug, after the $\frac{5}{8}$ -inch securing-pin has been driven out.

All screw-bolts should be set up firmly and secured by lock-screws, where these are provided. In assembling, it is necessary that all screw-bolts be replaced in the same holes from which they were removed, since, owing to the lock-screws, they cannot be made interchangeable.

To disassemble the mechanism, the order of assembling is reversed.

Care of mechanism.—All metal parts should be kept clean and free from corrosion; working parts should be kept well lubricated. Oil-holes are provided in the plug-rotating shaft sleeve, hinge-pin, and salvo-latch, and other working parts may be lubricated by dripping oil between the working surfaces.



5-Inch Breech-Mechanism, Mark V (Bethlehem).

This mechanism (Plate II) was designed by the Bethlehem Steel Company, and is fitted to the latest type of 5-inch guns using cartridge-cases. It embodies the following characteristics:

(1) The Bethlehem breech-closure.

(2) The plug is carried on the *carrier hub*, over which it screws, the latter screwing through the *carrier* and being made fast to it by the *hub locking-screw*. The carrier pivots about a hinge-pin on the right of the breech. The threads of the screw-box are so cut away as to allow the plug, when unlocked, to swing clear of the screw-box without any movement of translation.

(3) The firing-mechanism is designed for firing combination primers by electricity or by percussion. In firing by percussion the operation of cocking and firing is accomplished in one motion.

(4) The screw-box is cut in a screw-box liner which screws into the jacket and abuts against the tube.

The **breech-plug** is divided into three sections, two-thirds of each section being threaded and one-third blank. The blank portions of plug and screw-box are cylindrical, while the threaded portions are involutes of circles, which insures a firm and even contact. The threads are simply collars having no pitch, and hence give no motion to the plug while rotating; this motion is obtained from the pitch of the thread on the carrier hub. This is possible because the collars begin to disengage as soon as they start to revolve, and may move to the rear slightly even when the unlocking has just begun; this feature eliminates much friction and makes rotation easy.

The **carrier** is hinged to the *hinge-lug*, which is secured to the right side of the breech by a vertical *hinge-pin*. Extending through the carrier vertically, and to the rear of the hinge-pin, is the *hand-lever pin*, about the lower part of which pivots the *operating-lever*.

The **operating-gear** includes the *operating-lever* and the *plug-rotating link*, the latter being joined by universal joints at one end to the pivot-stud on the rotating-link, and at the other to the rotating-lug which screws into an extension from the collar on the rear of the plug.

The **extractor** is a lever turning about the extractor-pin in the hinge-lug. It lies horizontally in a recess cut in the right side of

the breech, and the nib on its inner end fits under the rim of the cartridge-case.

The operation of the mechanism is as follows: In opening the breech, the first movement of the operating-lever turning about the lever-pin causes the plug to revolve to the left by the action of the plug-rotating link until the threads of the plug are disengaged from those of the screw-box, and further motion of the operating-lever causes the carrier to swing about the hinge-pin, carrying the plug with it. As soon as the carrier leaves the breech, the *plug latch*, under impulse of the *latch plunger*, springs into the recess of the *latch-guide plate* in the collar of the plug, where it locks the plug against rotary motion until the carrier is again swung to. At the end of the swinging motion, the extractor cam on the carrier strikes the cam-toe of the extractor and sharply ejects the cartridge-case.

The firing-mechanism is for firing both electrically and by percussion. The *insulated firing-pin*, in its sleeve, extends through the center of the carrier hub and breech-plug, as shown in the drawing. The point of the firing-pin rests against the primer of the cartridge-case when the plug is closed, but is housed by the action of the *firing-pin retracting-sleeve* when the plug is revolved on opening.

For firing *electrically*, a short firing-wire connects the binding-post on the end of the firing-pin to the binding-post on a bracket on the carrier which is insulated through the bracket to the contact-nut on the lower side of the bracket, as shown in drawing. The breech terminal from the firing battery connects at the *latch contact-pin*, which passes through the *lever-latch plunger*, being insulated from it. The latter passes through the *lever-latch bracket*.

The circuit through is completed when the breech is closed by an insulated *plunger contact-pin* extending through the operating-lever. The *lever-latch spring* serves to maintain firm contact.

The *percussion firing-mechanism* consists essentially of the *cocking-lever* and *sear*, on the carrier, and the *firing-lever* and *plunger*, which are on the breech. The sear is carried in the cocking-lever and engages in a shoulder in the firing-pin sleeve, and is held out by the sear spring, being limited by the sear pin. The cocking-lever is a bell-crank lever, and is worked by the firing-lever

and plunger, the firing-lever being also a bell-crank lever. A pull on the firing-lever causes the cocking-lever to draw the firing-pin sleeve and firing-pin to the rear, compressing the firing-pin spring. When it has been withdrawn a certain distance, the sear will be disengaged from the firing-pin sleeve, and the firing-pin and sleeve will fly forward, striking the primer.

The gun cannot be fired until the breech is closed, because neither the electric nor the percussion firing-mechanism is fully connected until the breech is closed.

Loading-trays.—Practically all guns using powder-bags use hand-loading trays. The 5-inch and 6-inch guns use a conical scoop, having slots to allow escape of air. A special loading-tray, carried by four men, is used in the 7-inch guns. The forward end of this tray is shaped to fit the screw-box, which it serves to protect. In loading, the shell and powder charge in two bags are all carried in the tray. As soon as the tray enters the screw-box, they are all rammed home by the rammer-man pushing on the rear powder-bag.

Turret guns use hand-loading trays, many of them designed and manufactured on board ship. They are generally short copper cylinders with a bell lip at the after end, a block of hard wood to fit in the lower screw-box blank as a guide, and lightening holes opposite the screw-box blanks and inlets of the gas-ejector.

All loading-trays are for the purpose of protecting the threads of the screw-box from the projectiles, and the powder-bags from the screw-box threads.

5-Inch Breech-Mechanism, Mark VII.

Introductory.—The description in detail of the 5-inch Mark VII breech-mechanism follows. Except for minor details which will be pointed out later, this description covers also the 8-inch Mark VI, 12-inch Mark IX and 14-inch Marks II and III breech-mechanisms.

In designing a carrier mechanism for turret guns, one of the most important difficulties to be overcome is to avoid slamming of the plug, which, due to its greater weight as compared with medium-caliber mechanism, would necessarily bring severe strains upon the carrier and the operating-mechanism. It is also desirable

to avoid the use of gearing as much as possible, to reduce the number of parts and to transmit the power by means which reduce the friction to a minimum.

In fitting the firing-mechanism, it is necessary, for safety, to prevent priming until the plug is locked, and to provide for easy repriming without danger to the personnel in the case of misfire.

For overcoming the ill effects of the slamming of the plug as it swings into the screw-box, it is possible to change the motion of the plug into one of rotation, thus cushioning the blow and utilizing the swinging energy of the plug to assist in locking it. To avoid the use of gears, and still obtain the necessary power for unlocking, a crank-shaft, with lever attached, is the most efficient device. To avoid the complication necessary to obtain a continuous motion of the operating-lever to both rotate and swing the plug, it is found that the cam action which changes the swinging motion into rotating motion of the plug also changes the direction of motion of the operating-lever and permits of quick and easy operation of the plug, with the lever arranged to swing in two planes instead of one. This movement of the lever in a vertical plane around the crank-shaft for rotating the plug, and in a horizontal plane around the hinge-pin for swinging it, results in several desirable features being obtained, as follows:

(1) It is more difficult for the plug-men to slam the plug unnecessarily hard, and it is impossible to operate it by a line attached to the lever and manned by several men.

(2) It eliminates the use of a carrier latch or a plug latch.

(3) The operator stands entirely clear of the recoil.

(4) When the plug is closed, the lever is in such position as to allow the plug-man to catch it as the gun returns to battery and, by holding on to it, to have the forward movement of the gun unlock the mechanism.

(5) It permits of a design of mechanism which does not require right- or left-hand parts.

The speed of the mechanism depends entirely upon the dexterity of the operator, but it has been found that the plug can be opened or closed by an unskilled operator in two seconds with the gun level. Any greater speed is not recommended. It has also been found possible for one man to close the plug with the gun elevated to an angle of 8° . With one man on the operating-lever and one



man pushing on the plug, it has been found practicable to close the mechanism at any angle of elevation.

This new design prevents the insertion of a primer in the mushroom stem, as it must be inserted in the magazine, which holds it clear of the vent until the plug is about seven-eighths locked. Safety orders in connection with this firing-mechanism are therefore unnecessary.

The magazine feature of the lock permits of an extra primer being available for repriming by movement of the lock-operator handle at the side of the gun. Although this extra primer need not be carried unless desired, it has been found that no ill effects result from the shock it receives when the gun is fired.

The introduction of the rotating-cam uses the energy stored up in the moving mass either to rotate the plug when closing or to swing out the mechanism when opening, and eliminates slamming and rebounding of the plug. It does away with the necessity of a closing buffer and the customary tray or carrier latch.

Inefficient forms of power-transmission, such as gears, racks and worms, have been eliminated, and bearings with large surfaces have been introduced instead. A ball-bearing on the upper hinge-lug carries the dead weight of all swinging parts.

The number of pieces has been greatly reduced.

General design.—This breech-mechanism is designed to fit the 5-inch Mark VIII powder-bag gun. The breech-mechanism is of the carrier type, with the Welin breech-plug, De Bange gas-check system, and a new type of operating-mechanism and firing-mechanism.

The carrier is journaled on a vertical hinge-pin on the right-hand side of the gun. The carrier extends across the breech face of the gun and has a projecting hub on which the breech-plug is journaled. The operating-lever is attached to a shaft journaled in the carrier. The other end of this shaft carries an overhung crank, the pin of which engages a cross-head which works in a cross-head bearing set into the rear face of the breech-plug.

To open the mechanism, the operating-lever is swung to the rear in a vertical plane. This rotates the crank-shaft, which, by means of the cross-head, rotates and unlocks the plug. The operating-lever is then swung to the side in a horizontal plane, which swings the carrier and plug clear of the breech. Reverse motions

close the breech. A salvo-latch locks the operating-lever in position so that it can only be unlocked by the recoil of the gun or by hand.

The firing-lock has a magazine for two primers. A primer is automatically pushed out of the magazine and inserted in the end of the mushroom stem when closing the breech-mechanism, and is ejected when opening the same. In case of misfire the faulty primer can be ejected, and the second primer in the magazine be inserted in its place, by pulling the lock-operator handle to the right as far as it will go and then pushing it back in place.

Screw-box liner and breech-plug.—The rear end of the gun-jacket is threaded to receive the *screw-box liner*. The gas-ejector valve is secured to the rear flange of the screw-box liner, and is opened when the breech-plug is started to the rear in opening the breech. Air from the valve passes to two channels turned on the outside of the screw-box liner, and from these through ducts to the inner side of the screw-box liner and to the bore of the gun.

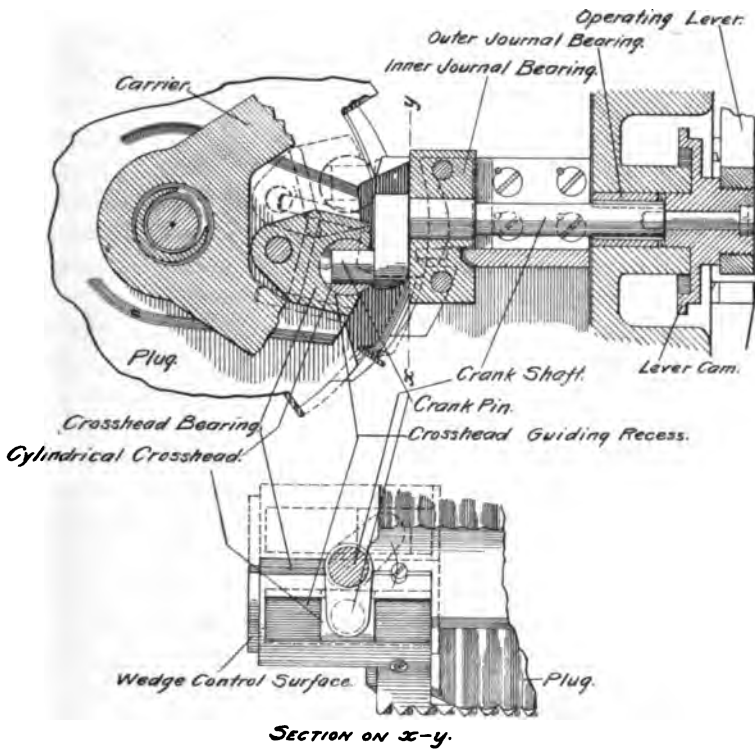
The screw-box liner and the breech-plug are slotted to form 12 sections—4 blanks, and 8 threaded steps in four groups, the blanks being wider than the threaded steps to permit the action of the rotating-cam.

The *breech-plug* is of the Welin or stepped-screw type, having abutment threads with the pressure side the steeper. The center of the plug is bored out to provide a bearing for the mushroom stem and to receive the threaded hub of the carrier. This thread has the same pitch as the external thread on the plug.

Mushroom and gas-check.—The gas-check system is of the De Bange type, consisting of a *mushroom*, *gas-check pad*, and *gas-check rings*.

The stem of the mushroom extends to the rear through the breech-plug and the hub on the carrier. The mushroom can move longitudinally, but is prevented from rotating by a key attached to the carrier. A helical spring located in a recess in the carrier and encircling the mushroom stem butts up against a nut on the same, and thus holds the mushroom in place. In rear of the nut, the mushroom stem has a bayonet-joint for attaching the firing-lock receiver. The vent extends from the face of the mushroom through the stem, the end of which is bored out for the primer seat.

Operating-mechanism.—A *crank-shaft*, which extends through the carrier, is provided with two bearings. The inboard bearing engages the portion of the crank-shaft adjacent to the overhung crank. This is a phosphor-bronze bearing set in a machined pocket in the carrier and secured by two screw-bolts. The outboard bear-



OPERATING-MECHANISM FOR 5-INCH BREECH-MECHANISM, MARK VII.

ing for the crank-shaft is machined in the shoulder of the carrier casting, which is bored out to fit a steel sleeve keyed to the crank-shaft. To this sleeve is attached the operating-lever and *firing-mechanism cam*, these parts being keyed to the outer portion of the sleeve and clamped in position against a collar on the sleeve by the circular flange of a nut threaded on the extremity of the crank-shaft and seated in a counterbore in the end of the cam.

In the rear face of the plug, and located near the right-hand edge, at an angular distance above the horizontal center line (unlocked position) equal to half the angle of rotation, is a counterbore into which is rigidly fitted a hollow cylindrical cross-head bearing. The *cross-head*, which is housed in the cross-head bearing, engages the crank-pin of the overhung crank, the parts being so arranged that the cross-head is capable of both a rotary and a sliding motion with respect to its bearing and crank-pin.

When the plug is closed and locked, as during firing, the operating-lever extends upward and toward the muzzle, making an angle of 43° with the vertical. The cross-head and bearing are below the horizontal center line at an angular distance of $16^\circ 42' 30''$ (equal to half the rotation of the plug), and the crank-shaft is in the dead-center position, with the crank-pin directly in line with the center of the shaft when viewed in the plane of rotation of the plug. The plug is thus securely locked against any rotary tendency produced by reason of the chamber pressure and the inclination of the plug threads.

To open the breech, the operating-lever is moved to the rear until it reaches the horizontal position, turning the crank-shaft through an angle of 133° . The corresponding circular motion of the crank-pin is resolved by the cross-head mechanism into a forward movement of the cross-head within its bearings and an upward movement of this bearing, which, being rigidly attached to the plug, causes a rotation of this member in the direction required to disengage the threaded steps. At the beginning of this motion, as the crank-pin leaves the dead-center position a large angular movement of the lever and crank-shaft will produce but a small rotation of the plug, with a corresponding increase in the force available to unseat the gas-check pad.

Plug-rotating cam.—The total angular movement of the plug produced by the rotation of the crank-shaft is $33^\circ 25'$, of which movement but $26^\circ 42' 5''$ is required to disengage the threads, the remainder of the rotation occurring as the carrier begins to swing away from the gun, thus affording an easy transition from the rotary motion of unlocking the plug to the translatory motion of swinging it out of the breech. This effect is accomplished by the *plug-rotating cam*, which is fitted in a dovetail in the blank between the threaded sections on the left side of the screw-box, and consists

of a hardened-steel plate into which is cut a curved *cam-slot* coinciding in its forward portion with the pitch of the screw-box threads, and running out at the breech face in the path of the parts swinging about the hinge-pin. This cam-slot engages a *stud* or *cam-follower* projecting from the side of the breech-plug, and guides it during the latter part of the motion of unlocking, so that, as soon as the threads of the plug are disengaged, the rearward motion of the plug and carrier, in swinging about the hinge-pin, is gradually started without the shock to the mechanism or to the operator which would result were the direction of motion changed suddenly. The advantages derived from the use of the plug-rotating cam are most marked during the act of closing the breech, when, by checking gradually the velocity of the swinging parts, it serves to avoid the objectionable slamming and rebounding of the carrier by utilizing and absorbing the energy of the swinging parts in imparting a rotary motion to the plug and operating-lever.

Operating-lever guide and stop.—The rearward swing of the carrier about the hinge-pin, commenced by the plug-rotating cam, is continued by the operating-lever until the mechanism has been swung through 90° , when further swing is limited by recessed stops on either side of the carrier hinge, which come up against corresponding abutments formed upon the hinge-lug forging. While the mechanism is open, the plug is prevented from rotating and is maintained in the unlocked position by the *operating-lever guide*, a projection from the hub of the operating-lever, which, as the outward movement of the mechanism about the hinge-pin commences, enters a *guide-slot* in the hinge-lug forging. This device and the rotating-cam prevent the plug from rotating while the threads of the plug and screw-box are disengaged.

To guard against the failure of the guide on the operating-lever hub to enter fairly the guide-slot, which might occur if lost motion should develop in the operating-gear, an *operating-lever stop* is provided to limit the rotation of the lever and crank-shaft. This stop consists of a pin driven through the hub of the operating-lever, and provided with a stud projecting inwardly to engage a slot milled in the outboard end of the carrier.

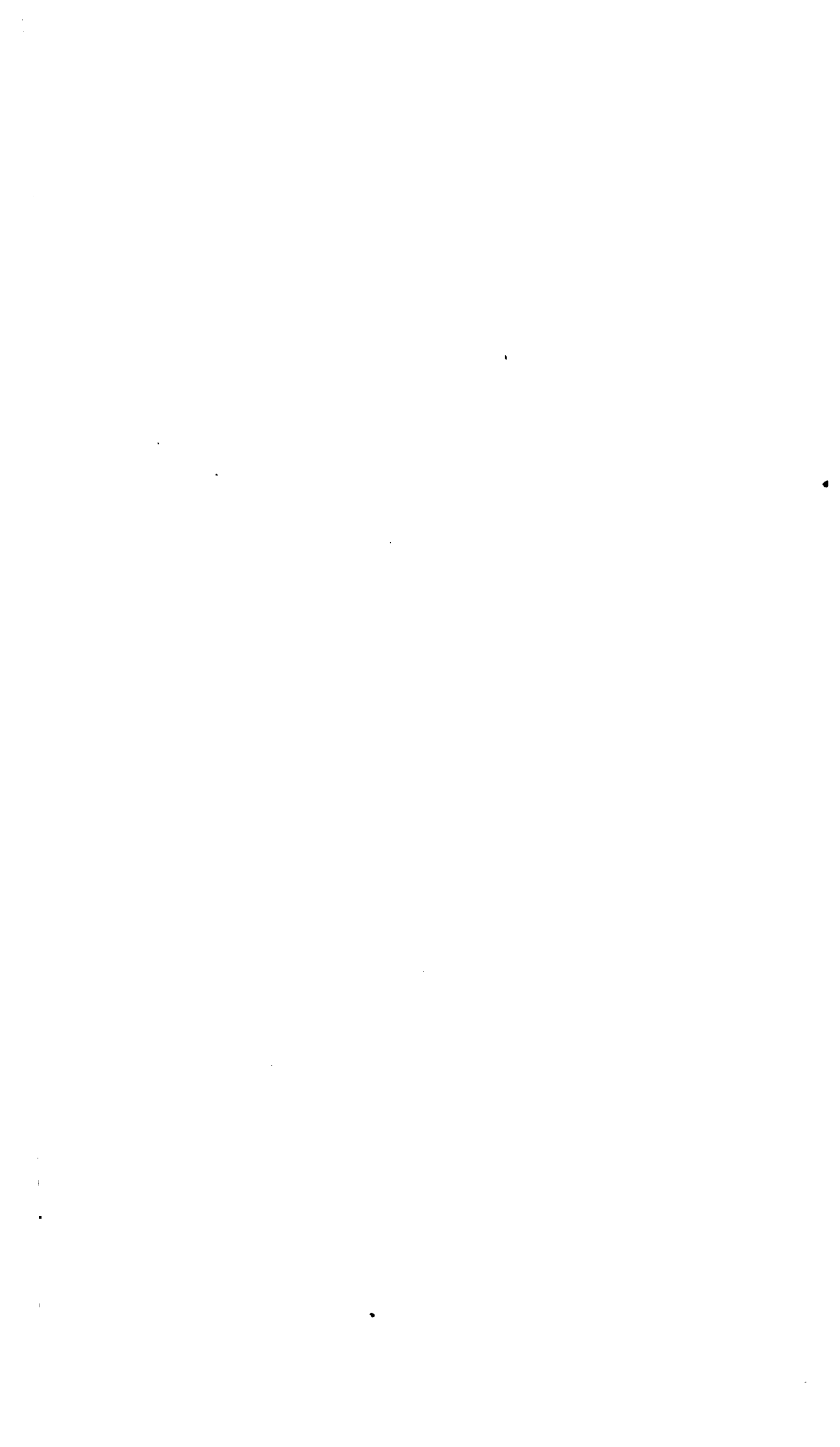
Operating-lever latch (salvo-latch).—The *lever-latch* consists of a latch member journaled on a screw-bolt attached to the for-

ward edge of the hinge-lug in line with the operating-lever guide-slot. A locking-plunger is mounted in a recess directly in the rear of the latch boss, and in such a position that the plunger is retained in place by an overlapping portion of the latch. The upper portion of the latch is broad and heavy, and is machined at its upper extremity to engage the hook or catch formed on and projecting from the under side of the operating-lever. The lower part of the latch is made as light as possible, and is bored out to provide a bearing for the latch-spring and plunger, which, by acting against the hinge-lug, throw the latch into proper position to engage the catch on the operating-lever.

During recoil, the inertia of the upper and heavier parts of the latch cause it to rotate on its pivot so that the lower portion moves to the rear toward the hinge-lug, compressing the latch-spring, and the upper portion moves forward and out of engagement with the catch on the operating-lever. The latch is held in this released position by the locking-plunger, which, under the impulse of the locking-plunger spring, moves out and engages a notch in the latch as soon as it is brought into line by the rotation of the latch. When the breech is opened, the lug on the operating-lever strikes the locking-plunger, compressing its spring, and moves the projecting stud out of engagement with the notch in the latch, which thereupon, under the action of the latch-spring and plunger, is returned to the "set" position ready to engage the catch on the operating-lever when the breech is closed. The top part of the latch serves as a stop which comes up against the hinge-lug and limits the rotation of the latch.

As the latch does not release automatically except upon the discharge and recoil of the gun, it gives warning of misfires, or hang-fires, which might pass unnoticed when a number of guns are being fired in salvo. In such case, the breech can only be opened after releasing the latch by hand.

Gas-ejector.—An eight-hole gas-ejector system is used in connection with the 5-inch Mark VII breech-mechanism and Mark VIII gun. The air is conducted by a $\frac{3}{4}$ -inch copper pipe leading from a bracket between the piston-rod lugs of the gun-yoke, to the rear and upward over the left-hand side of the breech, to the gas-ejector valve, which is of the Mark V type and is located on the upper part of the breech face 34° to the left of the vertical center



All screw-bolts should be set up firmly and secured by lock-screws where these are provided. In assembling, it is necessary that all screw-bolts be replaced in the same holes from which they were removed, since, owing to the lock-screws, they cannot be made interchangeable.

To disassemble the mechanism, the order of assembling is reversed. The gas-ejector valve trip must be removed from the plug before this piece can be unscrewed from the carrier hub.

The firing-mechanism is assembled in position after the mechanism has been set up; and in disassembling, the firing-mechanism should be first taken down, the parts being removed in the following order: (1) Firing-spring, (2) receiver, (3) operator bar.

Care of the mechanism.—The parts of the mechanism should be given the care usually required for the mechanisms of powder-bag guns. Particular attention should be given the gas-check pad and rings, to see that these are in proper alignment and free from cuts or bruises extending from front to rear. Before firing, the pad and rings should be slushed with a heavy mixture of white lead and tallow.

All metal parts should be kept clean and free from corrosion and grit; working parts should be kept well lubricated. Oil-holes are provided in the crank-shaft bearing and carrier for oiling the crank-shaft and sleeve. An oiler in the head of the hinge-pin communicates with an oil-groove extending around and along this piece, and serves to carry the lubricant to the carrier hinge. The cross-head and bearing may be lubricated through the opening in the side of this piece.

If, by reason of wear in the carrier hinge, the plug droops so that the threads do not engage those of the screw-box fairly when the mechanism is closed, the trouble may be remedied by using a carrier washer of greater thickness.

Firing-Mechanism for 5-Inch Mark VII, 8-Inch Mark VI, 12-Inch Mark IX, and 14-Inch Marks II and III Breech-Mechanisms.

General description.—The firing-mechanisms for the 5-inch Mark VII, 8-inch Mark VI, 12-inch Mark IX, and 14-inch Marks II and III breech-mechanisms are of the self-feeding automatic-lock type. Opening and closing the breech-mechanism actuates

the lock, causing it to eject the empty primer and to load a fresh one. Two primers are held in the magazine at a time; and all that is necessary, after the gun is fired, is to place a new primer in the magazine over the one ready to be loaded. The firing-mechanism is given its entire movement by means of the cam attached to the operating-lever of the breech-mechanism, the movements of the various parts being subsidiary ones. In case of misfire, the faulty primer can be ejected, and the second primer in the magazine be inserted in its place by hand, by pulling the lock-operator handle outward as far as it will go and then pushing it back in place, the breech-mechanism remaining closed.

Firing-Mechanism for 14-Inch Mark II Breech-Mechanism.

Receiver and magazine wedge.—The *receiver* is more or less rectangular in shape, and is milled out to receive the *magazine wedge*. It is secured to the gun by means of a bayonet-joint on the end of the mushroom stem, and is prevented from rotating by the *receiver latch*, which is fitted in the operator-bar bearing near the center of the carrier.

On the rear upper edge of the receiver, when fitted for right-hand guns, is a recess in which travels the operating-arm of the *hammer latch*. At the inner end of this recess is a cam which, when the operating-arm moves on it, releases the hammer and primer. On the center line of the gun is a vertical recess cut in the receiver for the *safety-arm* of the hammer. This cam prevents the firing-pin from coming in contact with the primer until the plug is completely closed. At the outer end of the receiver is the *loading-arm* along which the cam-follower on the hammer travels, keeping the hammer from moving across the face of the gun while pushing the primer into its seat. When the lock is fully closed, the cam-follower above referred to limits the amount of travel of the firing-pin in percussion firing. This is accomplished through grooves cut in the receiver. At the outer end of the receiver is a *hammer-operating lug*, which engages the hammer toe and causes the hammer to rotate around its pin. The receiver is bored for the trunnions of the extractor, which is operated by a cam cut on the wedge.

The wedge travels in the receiver and is drawn in and out by means of the *operator* and *operator bar*. At the inner end of the wedge are the magazine and hammer latch. The hammer latch is secured to the wedge by lugs and a pin, and is actuated by a small spring around the pin. At the same end and forward are the *loading-slope* and *bevel* for clearance of the extractor. Near the center is the *firing-point recess*. The hammer pivots at the outer end of the wedge. The magazine is in one piece with the wedge. The magazine bottom is a separate piece designed to hold the primer central, and to be reversed in case the mechanism is placed on a left-hand gun.

Lock-operator details.—The lock is operated by the *lock-operator* working in the *lever cam*. The operator is inserted in a slot in the operator bar and held in place by the *lock-operator pin*. The operator bar, which is inserted in a T-slot in the outer end of the carrier, is attached to the wedge by a hook engaging in a recess in the latter. The *firing-spring* is held in place by the *firing-spring sleeve* and the *firing-spring guide* which telescopes in the firing-spring sleeve as the spring is compressed and expanded. The firing-spring sleeve is attached to the lock-operator, and the firing-spring guide to the hammer, by means of ball-joints. The lock-operator handle, which disengages the lock-operator from the cam in repriming the lock by hand, straddles the lock-operator and is secured by the *lock-operator handle pin*.

Primer-feeding details.—When the mechanism is opened, the hammer is held in the loading position by a toe on the rear end of the hammer latch. The primer is inserted in the magazine and is held central by the magazine bottom. It is prevented from going forward until the magazine is over the primer seat in the center of the mushroom stem by a toe on the hammer latch which engages the head of the primer through a slot in the magazine. In closing the mechanism, the primer is loaded by the hammer, which is released, together with the primer, by the action of the *operating-cam* of the hammer latch. The primer is guided into the primer seat by the *primer-guide*, which is screwed into the forward face of the wedge.

Percussion and electric firing.—On the rear of the hammer is an arm to which is attached the ball that fits in the socket of the firing-spring guide. The end of this arm is gripped with the finger

and pulled outward, compressing the firing-spring until the cam-follower on the hammer comes to a stop against the side of the grooves in the receiver. This action makes the finger slip off, releasing the spring, which carries the hammer forward against the primer. Electric firing is accomplished by attaching the *firing-terminal* to the firing-pin *connecting-fork*, which piece is screwed on the firing-pin, holding it in place on the hammer.

Safety appliances.—The gun cannot be fired either electrically or by percussion until the mechanism is completely closed. The firing-pin is prevented from advancing beyond the face of the wedge, and making contact with the primer, by the *safety-arm* of the hammer riding on the rear face of the receiver until the firing-pin is directly over the center of the primer. The safety-arms then drop into the recess in the receiver and allow the firing-pin to make contact.

If, from any cause, the operating-details of the firing-mechanism, which are operated by the cam, should fail to function in opening the mechanism, the firing-pin is withdrawn from the center of the primer and housed within the wedge by a projection on the rear face of the cross-head bearing operating against a projection on the outer end of the wedge.

If the primer should jam or fail to seat itself in the primer seat, the transverse motion of the hammer will be stopped by the primer. The cam-follower on the hammer will come up against the cam on the receiver, and the wedge to which the hammer is attached will be prevented from advancing farther and damaging the primer. When the motion of the hammer is stopped, the firing-spring will be compressed as the lock-operator continues to advance in locking the breech-mechanism.

Operation.—*To open:* The salvo-latch having been disengaged from the operating-lever, either by hand or when the gun returns to battery after firing, the operating-lever is rotated to the rear. The stud of the operator is thereby caused to travel in the first inclined part of the lever cam. During this travel of the stud, the operator, acting through its pivot-pin, withdraws the operator bar and the wedge, since the two are hooked together, thereby carrying the firing-pin out of engagement with the primer and bringing the magazine into alignment therewith. As the operator stud travels through the straight portion of the lever cam, the operator

bar, wedge, magazine and hammer, and associated parts, remain stationary. During the movement of the operator stud through the second inclined part of the lever cam, the operator, the operator bar, wedge and magazine are further withdrawn. The hammer, during this period of movement of the wedge, is rotated on its pivot-pin to a raised position, thereby compressing the firing-spring. This movement of the hammer is caused by the engagement of the hammer-cam finger with the hammer-lifting cam in the receiver. The latter being stationary and the cam finger being drawn to the right, the hammer is caused to rotate until the cam finger clears the shoulder. The hammer is then maintained in a raised position by the cam finger riding on the surface of the receiver.

During the period of rotation of the operating-lever corresponding to the travel of the operator stud in the straight portion of the lever cam, the firing-lock members remain at rest, but the crank-shaft by which the plug is rotated continues to revolve to complete the unlocking of the plug, which operation is not completely effected until the firing-mechanism is in the unlocked or open position. When the unlocking of the plug is completed, it may be swung to open position by pulling outwardly upon the operating-lever.

To close: The breech can be closed by first pressing on the operating-lever to rotate the carrier on its hinge-pin until the plug-rotating cam follower on the breech-plug engages its cam in the screw-box, thereby changing the swinging of the plug into a rotating motion, and the movement of the operating-lever from the horizontal to the vertical plane. By continuing the motion of the operating-lever in the vertical plane, the plug is rotated into a locked position. During the first part of the rotation of the plug, the operator stud travels in one of the inclined portions of the operating-lever cam, thereby forcing in the operator, the operator bar and the wedge. The hammer is still raised, with the firing-spring under compression.

This movement continues until the magazine is in exact position for forcing a primer from the magazine into the primer seat. The instant this position of the magazine is obtained, the cam finger of the hammer latch engages the inclined surface of the groove in which it works, thereby causing the hammer latch to

rotate about its pin and thus withdrawing its control lugs from in front of the primer and the feeder prong of the hammer. The latter is at this instant free to rotate about its pivot upon the wedge, and, under the impulse of the firing-spring, feeds a primer into the primer seat.

During the primer-feeding operation, the operator lug is traveling in the straight portion of the lever cam, and all the parts of the firing-mechanism except the hammer are at rest ; but the plug continues to rotate, and is almost completely locked when the primer is finally inserted.

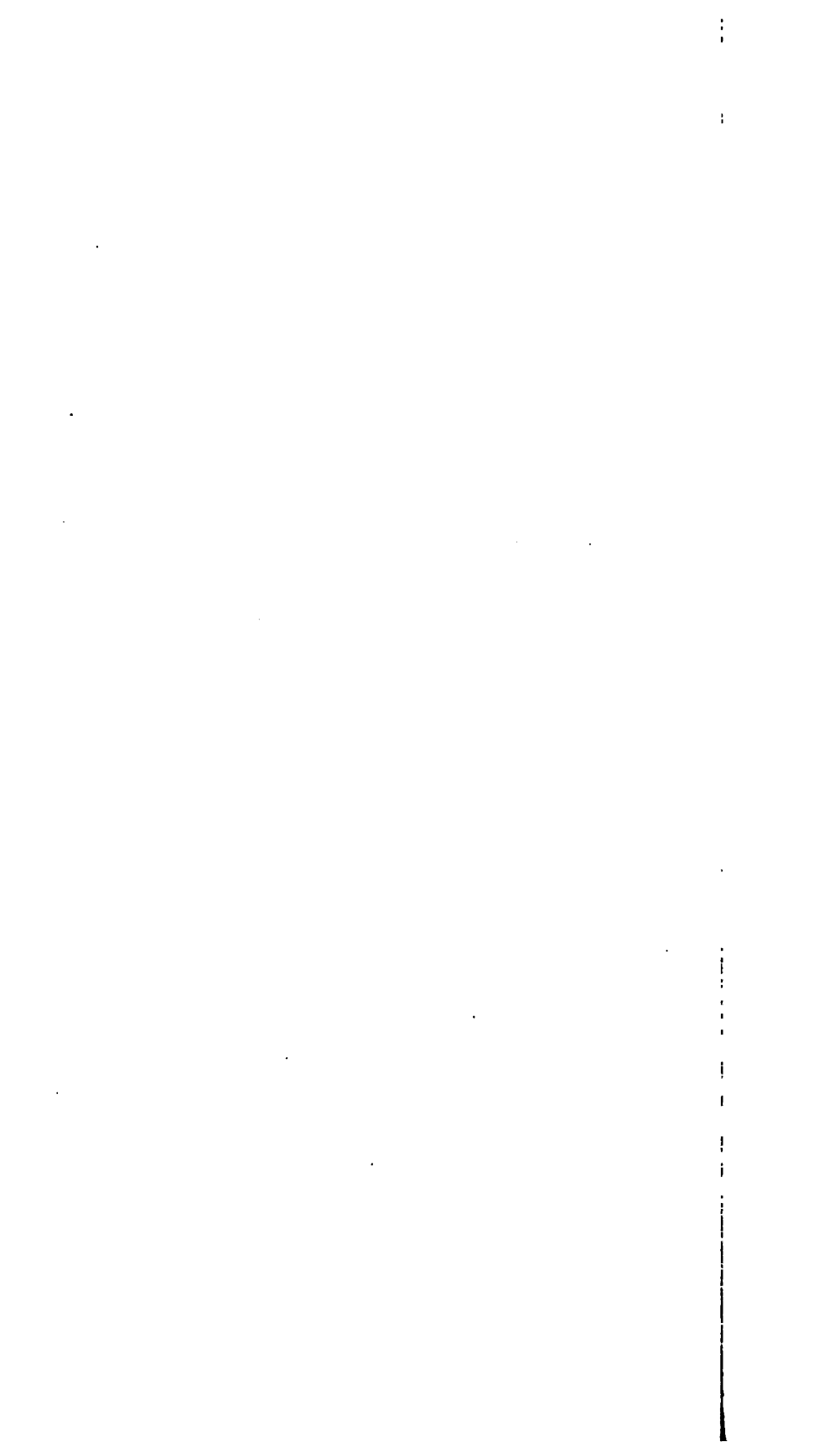
The operator lug next travels in the second inclined portion of the lever cam, thereby moving in the operator, operator bar, wedge and its attached hammer until the firing-pin is in the rear of the primer. Not until this movement is completed is the hammer finally in contact with the primer, because its safety-lugs ride upon the rear face of the receiver, thereby maintaining it in a slightly raised position until these lugs fall into a cam-slot on the receiver, this slot being in line with the axis of the gun.

The final motion of the wedge cannot take place until the plug is locked, because the cam projection on the cross-head bearing prevents such a movement until it is moved clear of the wedge by the rotation of the plug.

Assembling and disassembling.—The magazine bottom is placed in the magazine and held in place by a pin. The hammer latch and hammer-latch spring are next assembled ; they are held in place by the hammer-latch pin through the lugs on the wedge, which pin is secured by a split-pin. The firing-pin and details are then assembled in the hammer and are held in place with the connecting-fork, which is screwed on the pin and prevented from unscrewing by a split-pin. The hammer is held in place in the wedge by the hammer-bearing pin with a split-pin through them. The extractor is placed in the receiver, and then the assembled wedge.

The receiver latch is assembled in the operator-bar bearing, which is then bolted in place on the carrier.

The lock-operator and handle are fastened together by the handle pin, which is peened on the ends. They are then attached to the lock-operator bar by the lock-operator pin, which should be held in place while the lock-operator bar is slid into the T-slot in the



carrier. The lever cam has to be removed before the lock-operator bar can be put in place.

To assemble the firing-spring, guide, and sleeve, place the spring over the guide and the end of the guide in the sleeve. Then compress the spring until the oblong slot in the sleeve matches with the end of the slot in the guide, and then secure them with a split-pin.

To assemble the mechanism on the gun, take the receiver, withdraw the wedge until the extractor will clear the end of the mushroom, and, holding it in a vertical position with the body downward, place it on the mushroom stem. Next revolve it to the left until the lock on the outer end of the receiver takes into the receiver latch. The firing-spring is put in place by inserting the ball on the firing-pin sleeve into the socket in the lock-operator, and the socket on the firing-spring guide over the ball on the hammer, while compressing the spring. Finally, remove the split-pin from the oblong slot and place it in the hole behind the shoulder of the firing-pin sleeve.

The firing-mechanisms for the 5-inch Mark VII, 8-inch Mark VI, 12-inch Marks IX and IX, Mod. I, and 14-inch Mark III breech-mechanisms are substantially the same in their details and operation as that for the 14-inch Mark II breech-mechanism, with the following exceptions:

The receiver on the 5-inch Mark VII mechanism is locked against rotation by a *locking-plunger*, the slotted end of which, under the action of its spring, projects from the rear face of the carrier and engages the outer end of the receiver. This plunger has to be placed in the carrier before the crank-shaft bearing is bolted in place.

On the 8-inch Mark VI mechanism the latch handle extends outward, instead of downward as on the 14-inch Mark II.

The 14-inch Mark III firing-mechanism is the Mark II mechanism turned through an angle of 90° to suit the breech-mechanism. On this mechanism there is a *primer feed-spring* attached to the magazine to push the reserve primer in place when repriming, as the position of the magazine is such that the primer will not fall in place by gravity. A special *repriming-rod* is also used to facilitate repriming by hand in case of misfire.

7-Inch Breech-Mechanism, Mark I.

The 7-inch Mark I breech-mechanism (Fig. 1) is a modified Vickers mechanism of the Welin or stepped type. It is fitted to 7-inch guns, Mark II.

The breech-plug (P, Fig. 2) has its circumference divided into 12 sections—8 threaded and 4 blanks. The plug is cut away about the hinge-pin as a center, to allow it to clear the gun when swinging in or out. The mushroom-stem hole enlarges in the rear half of the plug to form two recesses, the smaller of which is threaded with a square thread to engage the thread of the carrier hub by means of which the plug is secured to the carrier. The *plug-locking plunger seat* on the circumference of the plug-flange is a hardened piece of steel dovetailed into the flange to form a seat for the plug-locking plunger when the plug is locked to the carrier. In the rear face of the plug is a recess to take the boss of the plug-rotating link. Near the circumference of the plug-flange is bored a hole to take the wedge safety-bracket *safety-screw* when the plug is fully locked in the gun. In the rear face of the plug is milled a cam-slot in which works the *carrier-latch guide-stud*.

Gas-check and details.—The De Bange gas-check (Fig. 2) is of the usual design, consisting of the *gas-check pad*, *gas-check rings* (front, rear, and inner), and the *mushroom*.

The gas-check is adjusted by means of the *mushroom nut*, fitted with four spanner-wrench holes, by means of which it is set up against the *mushroom spring*, drawing the mushroom to the rear and pressing the pad out against the gas-check seat. The mushroom is prevented from turning by the *mushroom key* fitted to the carrier hub and sliding in a keyway in the mushroom stem. On the end of the mushroom stem are cut square interrupted bayonet-joint lugs by means of which the receiver of the lock is secured to the gun. An axial vent passes through the mushroom stem, enlarging at the after end to form the *primer seat*. On the lower side of the rear end of the stem is cut a clearance for the extractor, which fits in two grooves milled in the end of the stem on either side of the primer seat.

Carrier and details.—The *carrier* (Figs. 3 and 4) is made of bronze, shaped as shown in the plates. The *carrier hub* is made of steel, screwed and riveted to the carrier. The function of the

carrier is to support the plug (which screws to the hub) and the operating-mechanism for turning and swinging the plug. Through the hinge of the carrier are bored two holes, the forward one for the *hinge-pin* and the after one for the *operating-lever pin*. The carrier hub is recessed axially, enlarging at the rear end to form a recess for the boss of the *receiver* of the lock (Fig. 2). In the recess in the carrier is cut a keyway for the mushroom key. The *hinge-pin hole* has a keyway cut in it to take the *hinge-pin key*, causing the pin to turn with the carrier, which is not necessary now that the automatic loading-tray is done away with. The lower end of the *operating-lever pin hole* is enlarged for the *operating-lever pinion*, and to the left of this is a space in which works the *plug-rotating link pinion*, held in place by its pin passing through the carrier. In the forward face of the carrier, at its left end, is bored a hole for the *plug-locking plunger* and its spring, shown on Fig. 4.

On the under side of the carrier, to the right of the operating-lever pin hole, is the *carrier operating-lever stop*, against which hits the operating-lever stop when the plug is unlocked, causing the center of motion to shift to the hinge-pin. On the left under side of the carrier is screwed the *latch-box*, in which slides the *carrier latch* against its spring. In the right end of the latch is a short recess into which fits one end of the *latch spring*, the other fitting into a recess in the carrier. At right angles to the axis of the latch, at its right end, is tapped out a hole into which screws the *carrier-latch guide-stud*, one end of which works in the cam-slot in the rear face of the plug, causing the retraction of the latch against its spring when the plug rotates during breech-closure. The latch, when retracted, is held until the breech is opened by the *carrier-latch plunger*, which projects from its recess in the screw-box, due to the pressure of its spring. This plunger is kept compressed by the latch until the latter is pulled to the right, clear of the *latch catch*, when the plunger slips into its recess in the latch. The carrier-latch catch is screwed into the gun and held by a set-screw.

On the left end of the carrier is screwed the *buffer*. Its function is to absorb the shock of breech-closure. The cushioning effect of the buffer can be regulated by a small air-valve with pointer on the rear face of the buffer.

Operating-gear.—The operating-gear consists of the *operating-lever*, *plug-rotating link*, *plug-rotating link pinion*, *operating-lever pinion*, *hinge-pin*, and *operating-lever pin*, with nuts and pins.

The operating-lever is fitted with a handle. At the right end of the lever is a vertical boss, the lower part round and the upper part hexagonal, to take the operating-lever pinion. This boss is bored axially to fit the operating-lever pin, the lower end of which is fitted with a nut to secure the operating-lever. Near the center of the operating-lever is screwed the *wedge safety-bracket*.

The operating-lever pinion fits over the hexagonal boss of the operating-lever. Over part of its circumference are cut 45° teeth, which gear with similar teeth on the plug-rotating link pinion, causing the latter to turn in a vertical plane and rotate the plug through the plug-rotating link.

The plug-rotating link pinion in the vertical plane is secured to the carrier by its pin, on which it rotates. On its right side are cut 45° teeth, engaging those of the operating-lever pinion. The left end of the rotating-link pinion forms a jaw through which is a hole to take the plug-rotating link pin, which secures it to the plug-rotating link.

The plug-rotating link has a forward-projecting boss on its left end which fits in its recess in the plug. The rear face of the left end of the link is milled to form a cam-groove in which fits the wedge-operating cam pin of the lock, which raises and lowers the wedge as the plug is closed and opened.

The hinge-pin, fitted with oil-groove and keyway, as shown, serves to secure the carrier to the gun, and is secured on its lever end by a nut.

The operating-lever pin, fitted with oil-groove and nut as shown, fits in its vertical hole in the carrier and acts as a pivot for the operating-lever.

Action of the mechanism.—*To open the breech:* By pulling the handle (first giving it a twist to the right) of the operating-lever to the rear and right, the breech will be open and the following will take place:

(1) The operating-lever latch will be disengaged from its catch on the latch-box.

(2) During the first small movement of the operating-lever, the right end of the plug-rotating link moves down so that the link is

horizontal. This is accomplished by the plug-rotating link pinion turning counter-clockwise, due to the engagement of its teeth with those of the operating-lever pinion, which latter is turned in a counter-clockwise direction in the horizontal plane by the operating-lever. This movement of the link causes the wedge of the lock to descend, due to the engagement of the wedge-operating cam pin in the cam groove in the link.

(3) The further movement of the operating-lever will now result in further movement downward of the link-pinion pin, pulling the right end of the link down and to the right, causing the plug to rotate counter-clockwise until it has rotated through 30° , when it is unlocked. The operating-lever has now swung through 90° about its pin, and the plug-locking plunger is fair to jump into its seat in the plug-flange. The stop-lug on the operating-lever has taken against the stop-lug on the carrier, causing the carrier to swing out on the hinge-pin and preventing further rotation of the plug.

(4) While the plug is unlocking, the cam-groove on the plug-rotating link lowers the wedge. As it descends, the toe of the extractor cam is struck by the trip on the wedge, causing the extractor to swing to the rear about its pin and extract the fired primer.

(5) As soon as the revolution of the plug is stopped, the carrier and plug swing out on the hinge-pin as a center. When the carrier leaves the face of the breech, the plug-locking plunger, actuated by its spring and being no longer pressed in by the contact of the carrier with the gun, jumps into its seat in the plug-flange and locks the plug from rotation on the carrier hub.

(6) As the carrier leaves the face of the breech, the latch is housed in the latch-box and held there by the latch plunger; but as soon as the latch is clear of the catch and the plunger, it moves to the left and is ready for latching when the plug is closed.

To close the breech: In closing the breech the movements are the reverse of the above. When the projecting toe of the plug-locking plunger strikes the face of the breech, it is forced back against its spring, unlocking the plug from the carrier and allowing it to rotate clockwise. At the same time the plug is unlocked, the center of motion of the operating-lever is shifted to the operating-lever pin. The operating-lever pinion turns clockwise with the

lever, resulting in a clockwise motion of the link pinion, moving the link to the left and rotating the plug clockwise until it is locked in the gun. As the plug-rotating link moves to the left, its cam-groove, by means of the operating-cam pin of the lock-wedge, moves the latter up until it is nearly closed.

At the same time the plug is being unlocked, the latch strikes the latch catch, which forces the former to the right against its spring; and then, as the plug strikes the gun and is ready to lock, the latch springs out and catches in the latch catch, preventing the plug from rebounding. As the plug is rotated in locking, the latch-guide stud, working in the cam-slot in the plug, forces the latch to the right until the latch plunger springs into its recess in the latch and holds it.

The last motion of the operating-lever in closing results in the following:

(1) The wedge safety-bracket strikes the operating-lever guide on the carrier and forces the lever into its proper position, allowing the operating-lever latch to engage in its catch.

(2) As the rotating-link passes above the center, the ribs of the wedge safety-bracket ride under the link, locking it from any tendency to move on firing, and preventing any tendency of the plug to unlock.

(3) The cam-groove in the wedge safety-bracket, by means of the wedge safety guide-pin, fully raises the wedge, bringing the firing-pin in line with the primer. This is only accomplished when the plug is fully closed and locked and the operating-lever is closed and caught. If the plug were not fully locked, then the wedge safety-bracket safety-screw would not enter its hole in the plug-flange, and the lever and lock-wedge could not be fully closed.

As a safety precaution from firing the gun electrically before the plug is fully locked, there is screwed on the plug-flange, at 1 o'clock, the *plug safety contact-piece*, connected by a cable to the lock. To the right, but touching this when the plug is locked, is the *gun safety contact-piece*, screwed to the gun and connected by a cable to the firing-key. These two contacts complete the circuit only when the plug is closed and locked.

The Vickers system has also been used on 5-inch and 6-inch guns. On these calibers the number of threaded sections on the plug is reduced to six, and the blanks to three. The carriers do

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not extend entirely across the face of the breech as in the 7-inch guns, and the carrier buffers and latches are omitted. Automatic loading-trays are also fitted, but they are not generally used. Except in minor details, the 5-inch and 6-inch mechanisms are the same as the 7-inch.

The firing-lock.—The *lock*, known as the Mark X lock, is adapted for percussion primers to be fired by either electricity or percussion; it is intended that, as far as possible, all firing be done by electricity, and that percussion firing be regarded as an alternative. This lock is similar in appearance to the Mark IX lock, which it supersedes, but differs greatly from it in its mechanism.

The *receiver* is of forged steel, and secures to the mushroom stem by interrupted collars. The wedge travels vertically between the *wedge-guides* in the receiver, its motion being limited by a *guide-stud*. It extends well below the center of the breech-block, and has in its lower portion a *wedge-guide pin*, extending forward, which engages the cam-groove of the rotating-link, and a *wedge-guide safety-pin*, extending to the right, which engages the groove of the operating-lever. The latter pin holds the wedge in position when the breech is closed, and is held against its cammed surface by a spiral spring; it may be retracted and disengaged by means of a handle, and the lock can then be opened by hand, as the cam-groove of the rotating-link allows free motion downward when the breech is fully closed. The lock can be opened by hand by the operating-lever, which pivots about a pin extending through from the front face of the right wedge-guide, and which has a circular arc of teeth engaging a rack on the side of the wedge.

The *extractor* is normally held against the stem by its spring; when the wedge moves downward, a small lug on the right side of the wedge strikes the *extractor pawl* and ejects the empty primer-case, after which the lug slips by and the extractor is snapped back in place by its spring. When the primer is inserted, it is held in place by the *primer-retaining catch*, which is held down by a spring; to disengage this catch and allow the primer to be extracted when the wedge is thrown down, one nib of the extractor engages a cam surface on the side of the catch and shoves it upward.

In a recess in the wedge is placed the insulated *firing-pin*, with its point resting against the primer when the lock is closed, and affording at its rear end a contact-point for the hammer; the spring

exerts its force to keep the pin away from the primer. The *hammer* and *cocking-lever* are pivoted, one behind the other, on pins between lugs extending to the rear on each side of the lower half of the wedge. The hammer carries, extending through its upper end, an insulated *firing-point* which is held against the firing-pin by the *hammer-thrust pin* and *hammer spring* at its lower end; the firing-point is threaded at its rear end for the clamp-nuts of the terminals of the *firing-conductor*, and its forward end terminates in a truncated conical-shaped piece which makes contact with the insulated firing-pin.

For firing by percussion, the cocking-lever has at its upper end an eye for the *firing-lanyard*, and at about the middle of its length, on the right side, a hook-shaped extension engaging over the *hammer catch* on the hammer. When the cocking-lever is drawn back, the hammer is carried back with it and, at its lower end, shoves in the *hammer-thrust pin* and compresses the *hammer spring*, until the hook slips over the *hammer catch* and releases the hammer, which then flies forward under the impulse from the hammer spring and strikes the firing-pin. When the lanyard is released, the cocking-lever flies forward under the impulse of the *cocking-lever spring* and once more engages over the hammer catch. As a precaution, while firing by electricity, the cocking-lever is locked to the hammer by the *safety-bolt* and *nut*. To unlock, turn safety-bolt nut down.

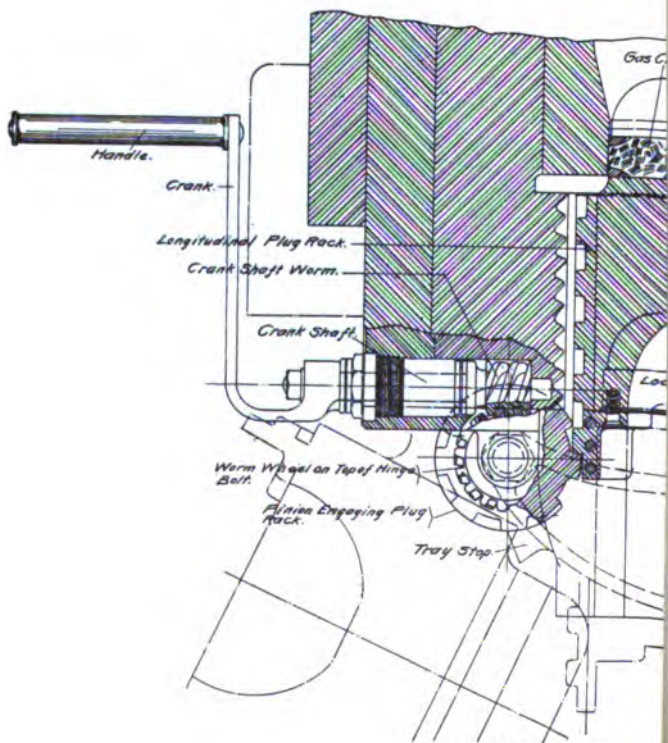
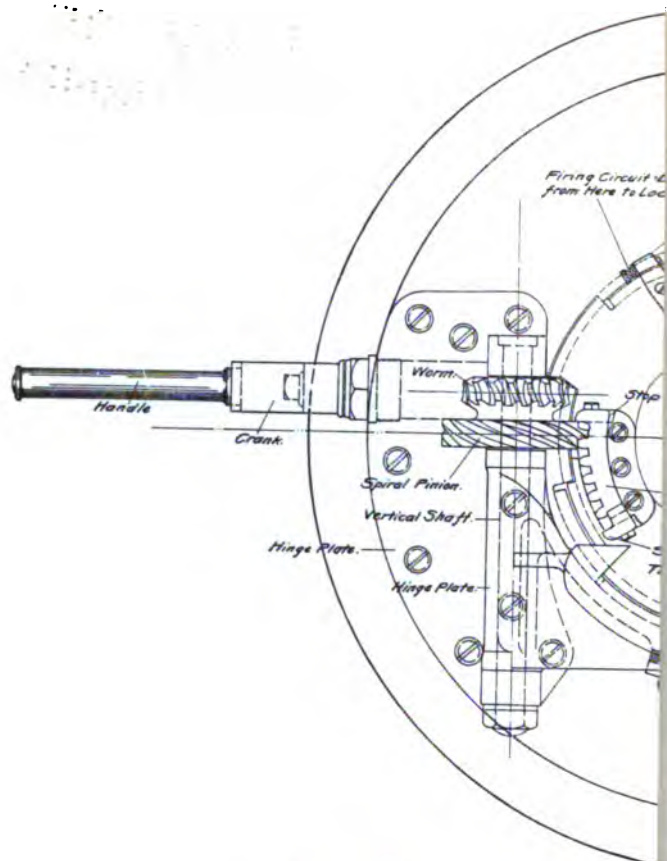
Safety.—The breech-block will not open when the gun is fired, nor at extreme elevation, because:

(1) No external force can so act on the block as to make the operating-gear work backward.

(2) The lever-lock prevents the operating-lever from swinging open.

The gun cannot be fired prematurely, because: (1) The firing-point is not in contact with the primer—nor (2) the hammer with the firing-pin—until the breech-block is locked.

The 5-inch and 6-inch breech-mechanisms are similar to the above, differing only in minor details.



CHAPTER VII.

BREECH-MECHANISMS OF MAIN-BATTERY GUNS.

The **Smith-Asbury** type of breech-mechanism, known as the "Naval Gun Factory design," is the latest type in use on naval guns. This design, with slight modifications to adapt it to plugs of different weights and to guns variously located on board ship, is now installed on all new guns from 5-inch to 14-inch inclusive.

The **Improved Farçot** breech-mechanism is still in general use on 8-inch, 10-inch and 12-inch guns on many of our modern ships. This type will be described first.

12-Inch Breech-Mechanism, Mark VI.

Marks VII and VIII differ from Mark VI only in minor details. 10-inch and 8-inch mechanisms resemble Mark VI.

The **breech-block** (see Plate I) is of the "Welin" type; and for the 12-inch mechanism, which is the size shown in the plates, the screw-box and block are each divided into three sections. Each section is divided into four steps, three of which are threaded cylindrical surfaces and the fourth a blank, thus giving the block a holding surface comprising three-fourths of its circumference. By using this, the Welin patent, a much shorter block may be used, giving greater ease of manipulation and requiring less weight both of gun and of breech-mechanism.

The De Bange gas-check, with front and rear split-rings, is used as previously described. The primer seat is in the rear end of the mushroom stem, on which is screwed the firing-lock. The vent, or orifice through which the flame of the primer discharge reaches the powder, is through an axial hole in the mushroom stem. The mushroom, with gas-checking pad and rings, is secured to the block by the locking-nuts screwed on the mushroom stem. During the process of locking and unlocking, the block is revolved about the mushroom stem, and for this reason a ball-bearing washer is inserted to reduce friction. Plate I shows the block (in

its unlocked position) in rear elevation and in horizontal cross-section.

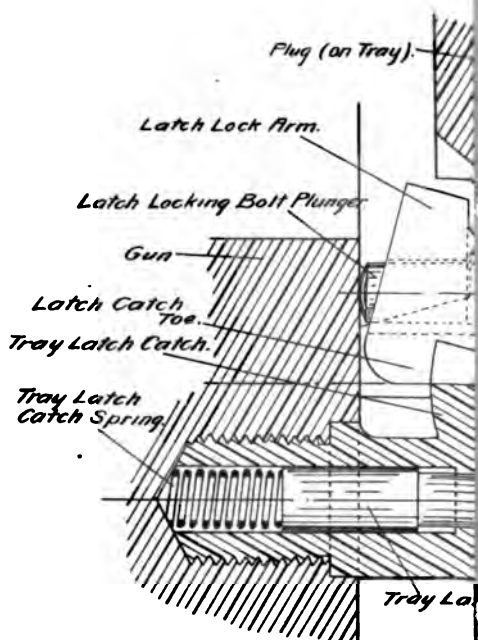
The operating-gear is of the system known as the "Improved Farçot Gear," which is in all the essentials the same as the "Modified Farçot"; the latter differs principally in having its hinge-pin turn *with* the spiral pinion. The name "Farçot" is from the inventor. Lieutenant Commander F. F. Fletcher improved it and adapted it to the U. S. naval guns, and it is sometimes called the "Fletcher system."

There are three steps in the operation while closing or while opening: (1) *Rotation* about the axis, which locks or unlocks the threads of the block and the threads of the screw-box; (2) *translation* along the axis of the bore of the gun between the positions of locking and of swinging; (3) *swinging*, by which the block is swung on a vertical hinge into or out of the line of the bore. In this system of operating-gear, the three steps are accomplished in either direction by the continuous rotation of one crank, other movements being automatic; seven turns of the crank suffice to operate a 12-inch mechanism, which is a near approach to "quick acting."

Description and operation.—The operation of *opening* the breech is as follows: A vertical *shaft* (see Plate I), also acting as a *plug-tray hinge-pin*, is journaled in a lug on a *hinge-plate* bolted to one side of the gun's breech face; the shaft itself carries on its upper end a *worm-wheel*, and, on its central part, in a horizontal plane through the gun's axis, a *spiral pinion* with teeth inclined 20° degrees to the horizontal. A horizontal *crank-shaft* is journaled in the upper end of the hinge-plate, or partly in the gun, or entirely in the gun if there is no hinge-plate. It has a *worm* that engages the worm-wheel, and is actuated by a crank on the outer end. Turning the crank will thus turn the vertical shaft and the spiral pinion.

There is a system of *spiral teeth*, also inclined 20° , cut on a rack, part of which is longitudinal, dovetailed and recessed lengthwise into the plug, and part circumferential, or "fan-shaped," generally extending to the rear of the plug and secured to the rear face thereof. The spiral pinion engages this rack helix. On turning the crank, if the plug be locked, the spiral pinion engag-

CHAPTER VII. PLATE II.



PLUG TRAY-LATCH DETAILS.

ing the circumferential or segmental rack will revolve the plug to unlock the threaded sections; and when this is accomplished, the rotation is stopped by a suitable *stop-plate* secured to the segment, taking against the upper face of the pinion.

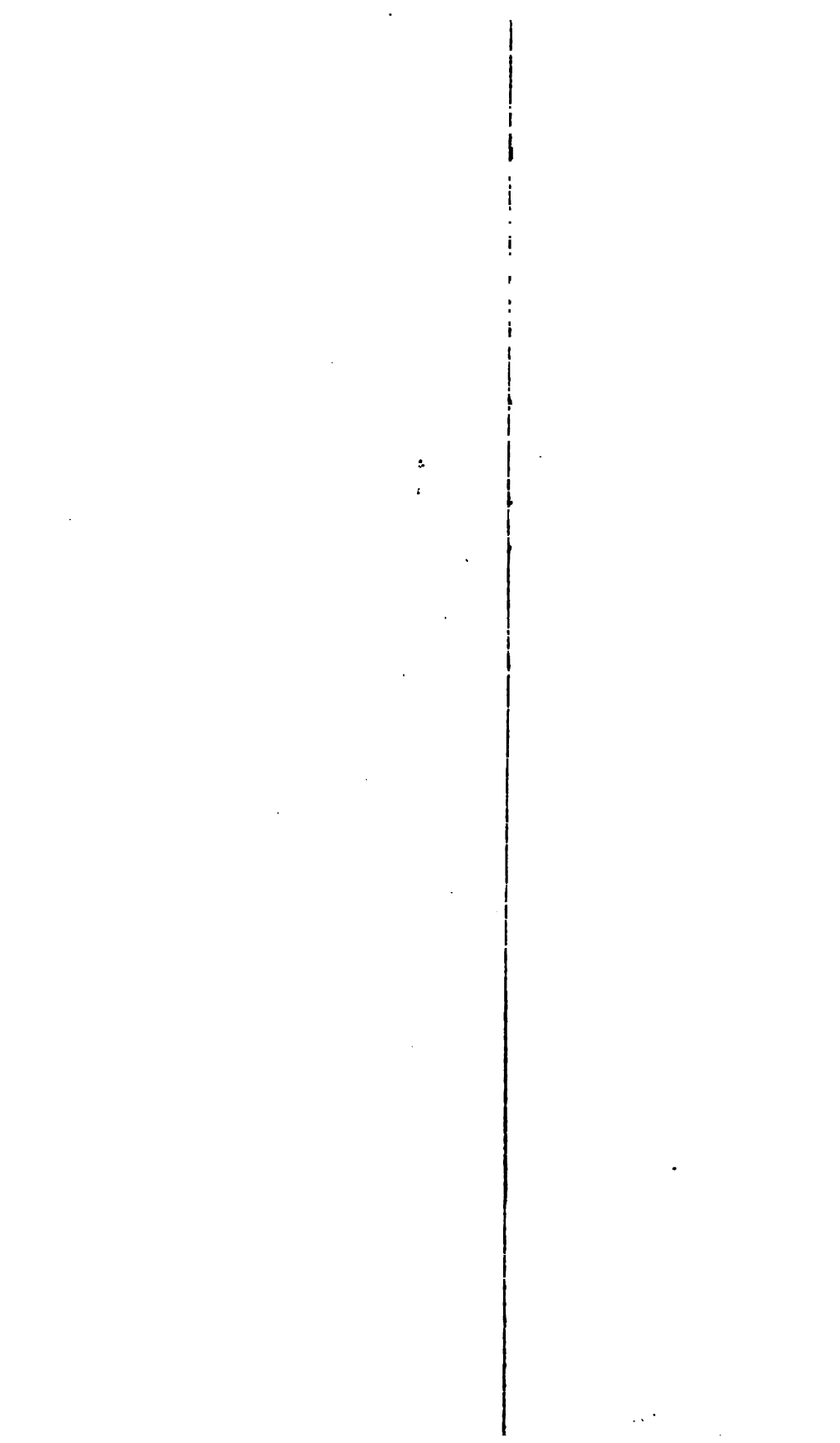
The continued movement of the crank will now cause the pinion to act on the longitudinal part of the rack (rotation being prevented by the stop-plate, which also acts as a guide in contact with the upper face of the pinion) and withdraw the plug to the tray. When the plug is completely withdrawn, the *tray-latch* is automatically released, at the same time locking the plug on the tray; the movement of translation is changed to swinging, since the pinion continues to rotate by the action of the *crank-worm*, and at the same time continues in engagement with the plug, thereby causing pinion, plug and tray to rotate as one piece. The plug and tray swing out clear of the breech about the vertical shaft, until brought up by the *stop*.

During the movement of the plug to the rear, the longitudinal *groove* in the surface of the plug permits the *trip-toe* on the *tray-latch* to remain up, and the *latch-toe* on the front underside of the latch remains hooked in the *tray-latch catch* in the gun. This condition continues until the shoulder at the inner end of the groove in the plug reaches the trip-toe, forcing it back and downward, tripping up the latch-catch toe and releasing the tray, and the continuance of the rotation of the crank handle swings the tray with plug clear of the breech face of the gun.

At the moment that the trip-toe of the latch is forced back and down, the *latch-lock arm* enters a slot cut in the front tooth of the plug; and immediately on the tray leaving the breech face, the plunger of the *latch-locking bolt* in the pocket in the front edge of the tray is forced out by action of its *spring*, the arm of the locking-bolt retaining the latch-lock arm in the slot in the plug, preventing any longitudinal movement of the plug while it is on the tray.

In *closing* the breech, the reverse action of the mechanism takes place, the guide-plate at the rear underside of the longitudinal section of the plug-rack, by bringing up against the underside of the pinion, acts as a guide for the teeth in changing longitudinal to rotary movement of the plug in locking; it also prevents rotation until the proper moment.

The action of the tray-latch and catch in closing the breech is as follows: As the tray meets the face of the gun, the plunger of the *latch-locking bolt* is forced to the rear, the *plug-tray latch-spring* being compressed and the *latch-lock arm* being rendered free to drop. The front face of the *keeper toe* simultaneously meets the *plunger* of the tray-latch catch in the gun, forcing it to the front and compressing the *tray-latch catch-spring*. The next instant the plug starts to enter the screw-box, the shoulder at the end of the groove in the plug moves clear of the *trip-toe*, the *tray-latch catch-spring* exerts its power, forces out the plunger of the catch against the *keeper toe* of the latch, rotates the latch about its pin, releasing the *latch-lock arm* from its notch in the plug, and forcing the *latch-catch toe* down into engagement with the *catch*. Thus the plug is free to travel on the tray, and the tray is securely latched to the gun, so that there is no danger of its flying open on discharge, the pressure of tray-latch catch-spring against the keeper toe tending to keep the latch-catch toe down in position.



The **firing-mechanism** (Plate III, 12-Inch Breech-Mechanism, Mark VIII) is adapted to electric or percussion firing, and consists of the following principal parts: *receiver*, *wedge*, *wedge extension*, *wedge-extension guide*, *cam-plate*, attachments for electric firing and device for percussion firing.

The *wedge-extension guide* is so shaped that one end of it fits over the mushroom stem and keeps it from revolving by means of two keyways; while the other end secures to the breech face of the plug, where it forms a guide for the wedge extension. The *receiver* is screwed on the rear end of the mushroom stem; it is elongated and slotted to form a guide for the *wedge*, which carries the insulated *firing-pin* and recocking device for percussion firing. The receiver carries the *extractor* and *primer lock*, which are operated by the wedge. Attached by a pin to the wedge and fitting through the wedge-extension guide, is the *wedge extension* terminating in a *guide-stud* which works in the cam-groove of the cam-plate on the face of the breech. This guide-stud can be withdrawn from the cam-groove, and the wedge can be operated while the breech is closed, by means of the *wedge-operating lever*.

When the plug revolves, the whole mechanism turns with it, and motion of the guide-stud in the cam-plate causes the wedge to be drawn over. A *cam-trip* on the wedge throws back the extractor. On closing the plug, the operation is reversed. A short wire makes the connection between the binding-post of the firing-pin and the contact-lug. To the other lug is connected the electric firing-wire; the two lugs touch and complete the circuit only when the plug is fully closed. Premature firing is therefore impossible, as the firing-pin is not in contact with the primer until the wedge is closed.

The percussion firing is designed so that the pointer may cock and fire in one movement. The action of the pointer turns the upper crank on the breech, and this motion is transmitted through the *crank-shaft* to the *lower crank*, which shoves the *sear* in. This sear is in contact with the *plug contact-piece* when the breech is closed. The motion of the plug contact-piece is carried by a connecting-rod to the *firing-lever* crank, which compresses the firing-spring in its barrel until the continued rotation of the crank releases the hammer, which then flies forward and strikes the firing-pin.

It will be seen that it is impossible to fire either by electricity or by percussion until the breech is closed, so the primer may with safety be inserted while the breech is open.

12-Inch Breech-Mechanism, Mark IX.

General design.—This mechanism, designated to fit the 12-inch Mark V, Mod. III gun, is of the Smith-Asbury type (Naval Gun Factory design). In general, it is the same as the 5-inch Mark VII which has been described in detail in the previous chapter. The principal points in which the 12-inch differs from the 5-inch design follow:

Hinge-pins.—The carrier is provided with two hinge-pins.

Screw-box liner and breech-plug.—The rear end of the gun-jacket is bored out, recessed and threaded to receive the *screw-box liner*. The gas-ejector valve is secured to the upper part of the flange of the screw-box liner, and is opened automatically, when the breech-plug is started to the rear in opening the breech. Air is admitted through the valve to a circular channel formed partly by a groove turned on the outside of the screw-box liner under the flange, and partly by a recess bored in the rear end of the gun-jacket. From this channel the air passes through four ducts to the inner side of the screw-box liner and to the bore of the gun.

The screw-box liner and the breech-plug are slotted to form 16 sections—4 blanks and 12 threaded steps in 4 groups, the blanks being wider than the threaded steps, to permit the action of the rotating-cam.

Control-arc and stop.—The rearward swing of the carrier about the hinge-pins, commenced by the plug-rotating cam, is continued by throwing the operating-lever outward until the mechanism has swung through 90°, when further swing is limited by a *buffer* which receives the shock. This buffer is bolted to the yoke just forward and below the center line of the hinge and consists of a cylinder with a plunger which is surrounded by spiral springs in three sections.

While the mechanism is open, the plug is prevented from rotating in the closing direction by the *control-arc* engaging the adjacent high section of the plug. The control-arc is a circular steel

segment, concentric with the hinge-pin, and is bolted to the breech face of the gun near the horizontal center line. If the plug be rotated slightly while swinging or when open by means of the lever, the upper face of the control-arc acts as a friction-brake against the adjacent high section of the plug.

An *operating-lever stop* is provided to limit the rotation of the lever and crank-shaft. This stop consists of a ring, slid over the boss on the carrier, which forms the bearing in which the lever cam revolves. The lever stop is prevented from rotating by a *stop-pin*, and it has projections which catch against corresponding projections on the interior of the lever cam, thus limiting the rearward motion of the lever cam.

Salvo-latch.—The *salvo-latch* is pivoted on a pin driven into the right-hand side of the carrier, and is partly contained within the lever cam. The *plunger-spring*, acting on the *plunger* which rests in a recess in the latch and butts up against a lug on the lever stop, presses the salvo-latch out toward the lever cam, in a slot of which it bears with a hook, preventing the breech-mechanism from being unlocked until the salvo-latch is disengaged. During recoil, the inertia of the salvo-latch gives to it a pendulum motion around its pin, compressing the plunger spring and disengaging the latch. The latch is held in this disengaged position by the *locking-plunger*, which is pressed out by its spring and caught at the edge of the lug along which it was sliding. As the salvo-latch is not disengaged automatically except upon the discharge and recoil of the gun, it gives warning of misfires or hangfires which might pass unnoticed, when a number of guns are being fired in salvo. In such a case the breech can only be opened after releasing the latch by hand.

When the breech is opened, a shoulder on the lever cam forces the salvo-latch plunger back of the lug on the lever stop. When the plug is again closed and locked, the hook on the salvo-latch, under the action of the latch-spring and plunger, is caught over the hook on the lever cam in the "set" position, preventing the breech-plug from being unlocked until released either automatically by the recoil or by hand.

Gas ejector.—A 4-hole ejector system is used in connection with 12-inch Mark IX breech-mechanism and Mark V, Mod. III gun.

The air is conducted by a 1-inch pipe attached to the yoke and leading to the top of the gun and then downward along the breech face to the gas-ejector valve Mark V. The gas-ejector valve is operated by a trip lever attached to the breech-plug, and is automatically opened by the rotation of the plug in unlocking the breech-mechanism and is closed by hand after the breech is opened and the bore is cleared of gases.

Method of assembling and disassembling.—(1) Place the washers and hinge-lugs on the pins on the carrier, and secure the frictionless washer on what will be the lower pin. This will hold that lug in place when the carrier is lifted and while the lugs are being secured in place. After the hinge-lug bolts are in place, the frictionless washer should be taken off and secured in place on the upper pin.

(2) The carrier should be lifted by an overhead purchase which will permit of some little movement in all directions, in order that the hinge-lugs may be brought in position and the hinge-lug bolts screwed home.

(3) Place a heavy strap around the plug, and by means of the overhead purchase lift the plug and slip it on the end of the journal on the carrier and screw it in place. Use a short round wooden bar through the hole in the plug to line it up for the threads to catch.

(4) Place the pad and rings on the mushroom stem, point the stem through the hole in the plug and shove it home, taking care that the pad and rings are in place, and also that the keyway is in line with the key in the carrier; put the mushroom spring on over the stem; and put on and set up the mushroom nut.

(5) Assemble the crank-shaft in its bearing and put them in place in the carrier, securing the bearing with the two bolts through the carrier.

(6) Slip the cross-head on the crank-pin, and then slide the cross-head bearing on over it until the bearing engages the space made for it in the plug.

(7) Enter the large screw through the rear face of the bearing block and screw it home. Put in and set up the two keeper screws which pass through the plug from the side.



Closed. (Rear view.)



Closed. (Left-side view.)

14-INCH BREECH-M

(8) The salvo-latch pin, with salvo-latch completely assembled, should now be driven into the upper hole made for it in the carrier, and the keeper screw should be put in and set up.

(9) The lever stop is now slipped in place on the end of the carrier boss with one of the two holes on the stop engaging the pin on the carrier, the hole depending upon whether it is a right-hand or a left-hand mechanism.

(10) The lever is now screwed on the lever cam, and the two keys are driven in place, after which the lever and cam are slipped on the bearing on the end of the crank-shaft, and are secured by a bolt in the end of the shaft and a keeper screw in the bolt.

(11) Place the control-arc in position by sliding the flat part in the space cut for it in the gun, and enter and set up tight the four screw-bolts.

The firing-mechanism is assembled in position after the breech-mechanism has been set up.

To disassemble the mechanism, the order of assembling is reversed; the parts of the firing-mechanism should be removed in the following order: (1) Firing-spring, (2) receiver, (3) operator bar. The gas-ejector valve-trip must be removed from the plug before the latter can be unscrewed from the carrier hub.

Care of mechanism.—The parts of the mechanism should be given the care usually required for the mechanisms of powder-bag guns. Particular attention should be given to the gas-check pad and rings, to see that these are in proper alignment and free from cuts and bruises extending from front to rear. Before firing, the pad and rings should be slushed with a heavy mixture of white lead and tallow.

All metal parts should be kept clean and free from corrosion and grit, and working parts should be well lubricated. The hinge-lugs have oilers for oiling the hinge-pins; and the cross-head, cross-head bearing, and crank-shaft bearing may be lubricated through the opening in the side of the carrier.

If, by reason of wear in the carrier hinge, the plug drops so that the threads do not engage those of the screw-box fairly when the mechanism is being closed, the trouble may be remedied by using a carrier washer of greater thickness.

14-Inch Breech-Mechanism. Mark III (for Mark I, Mods. II, III, and VI, and Mark III Guns).

General design.—The 14-inch Mark III breech-mechanism is also of the Smith-Asbury type (Naval Gun Factory design). The principal features in which this mechanism differs from the breech-mechanisms of the same type on other guns are enumerated below.

This breech-mechanism is adapted to guns mounted in three-gun turrets, by turning it through 90° , so that the carrier opens downward. The operations of opening and closing the breech-mechanism are facilitated by the introduction of a *counterbalance spring* and a *closing-cylinder* operated with compressed air.

The carrier is provided with trunnions which are journaled in hinge-lugs, fitted in recesses cut in the front side of the flange on the screw-box liner. The hinge-lugs are screwed in place by body-fit bolts. The carrier extends upward across the breech face to the center of the gun, where it has a projecting journal which carries the breech-plug. The operating-lever is attached to the lower end of a vertical shaft, which is journaled in the carrier near the center line. The upper end of this shaft carries an overhung crank, the pin of which engages a cross-head which works in a cross-head bearing, set in the rear face of the breech-plug.

To open the mechanism, the operating-lever is swung to the rear and left either by hand or by means of a lanyard. This rotates the crank-shaft, which, by means of the cross-head, rotates and unlocks the plug. The mechanism is then swung open to the rear and downward by means of the plug handle and its own weight. When open, the mechanism is supported by the counterbalance spring, which also serves as a buffer.

When the valve which admits compressed air to the closing-cylinder is opened, the air-pressure on the piston closes the mechanism. The operating-lever is locked in the closed position by the salvo-latch, and is unlocked by the recoil of the gun or by releasing the salvo-latch by hand.

Screw-box liner and breech-plug.—The rear end of the gun is bored out and threaded to receive the *screw-box liner*, which is a cylindrical bushing with a flange bearing on the end of the gun. The screw-box liner and the breech-plug are slotted to form 16 sections—4 blanks and 12 threaded steps in 4 groups, the blanks

being wider than the threaded steps to permit the action of the rotating-cam roller.

Counterbalance and closing-cylinder.—This device consists substantially of closing-cylinder with bracket and pin, spring-rod piston with packing-rings, spring-rod, closing-cylinder bushing, spring with adjusting-nut, carrier-cam bracket with spring-rod pin, closing-cylinder valve body with valve plug, valve shaft and sleeve, valve handle, and valve-closing rod with pins and joint.

The *closing-cylinder* is supported by the *closing-cylinder bracket*, which is pivoted in a journal under the recoil-cylinder lug of the yoke. The *spring-rod piston*, which works in the closing-cylinder, is extended upward and to the rear by the *spring-rod*. The spring-rod terminates in a head with an offset hook which bears on a pin in the *carrier-cam bracket*. The cam bracket is bolted to the left-hand hinge-pin boss of the carrier. The *counterbalance spring* surrounds the spring-rod, and extends from under the head of the latter to the *spring-adjusting nut* which is screwed on the outside of the closing-cylinder. By means of this nut, the tension of the spring is adjusted. The body of the valve for admitting compressed air to the closing-cylinder serves as a cylinder-head. The *valve plug* is operated by the *valve handle* located on top of the spring-rod head and connected to the plug by the telescoping *valve shaft* and *sleeve* passing through the center of the spring-rod. Compressed air is led to the valve through a $\frac{3}{4}$ -inch pipe and flexible hose from the air-supply system.

The power of the spring and its lever arm are so designed that during the opening of the breech-mechanism this is nearly balanced until fully opened, when an extension on the carrier bracket is brought in contact with the head of the spring-rod, suddenly increasing the lever arm of the spring, which is thus enabled to take the shock and stop further motion of the mechanism.

To close the breech-mechanism, compressed air is admitted to the closing-cylinder by opening the valve by hand. The air-pressure on the piston is transmitted through the spring-rod to the carrier-cam bracket. When the mechanism is nearly closed, the ball on the closing-rod fetches up against the valve-closing rod pin, automatically revolving the valve shaft and closing the valve, and at the same time opening a by-pass from the closing-cylinder to the atmosphere.

Method of assembling and disassembling.—(1) Put the lever-buffer bracket in position on the right-hand hinge-lug.

(2) Place the washers and hinge-lugs on the trunnions of the carrier, and lift the whole by an overhead purchase, which will permit of movement in all directions in order that the hinge-lugs may be brought into position and the hinge-lug bolts be screwed home.

(3) Block up the carrier in a horizontal position, leaving unobstructed a space for inserting the mushroom nut.

(4) Place a heavy strap around the plug and, by means of the overhead purchase, lift the plug and slip it over the end of the journal on the carrier and screw it in place. Use a short, round wooden bar through the hole in the plug to line it up for the threads to catch.

(5) Place the pad and rings on the mushroom stem, point the stem through the hole in the plug and lower it home, taking care that the pad and rings are in place and also that the keyway is in line with the key in the carrier; put the mushroom spring on over the stem, and put on and set up the mushroom nut.

(6) Secure the plug handle to the plug.

(7) Close the plug, using the overhead purchase, guiding and locking it by means of the plug handle.

(8) Bolt the carrier-cam bracket in place on the carrier.

(9) Assemble the counterbalance and closing-cylinder device, with the spring-adjusting nut screwed down to its lowest position, and secure it in position with the pin in the closing-cylinder bracket and the spring-rod pin.

(10) Adjust the counterbalance spring, unlock plug by means of the plug handle (pushing inward on the crank, if necessary), and open the breech-mechanism.

(11) Assemble the crank-shaft in its bearing, and put them in place in the carrier, securing the bearing with the two bolts through the carrier.

(12) Slip the cross-head on the crank-pin and then slide the cross-head bearing on over it until the bearing engages the space made for it in the plug. Enter the large screw through the rear face of the bearing block and screw it home. Put in and set up the two keeper screws.

(13) Attach the valve-closing rod between the valve handle and the carrier-cam bracket, and connect the flexible air-hose to the valve body.

(14) The salvo-latch pin, with the salvo-latch completely assembled, should now be put into its hole in the carrier and the keeper screw should be put in and set up.

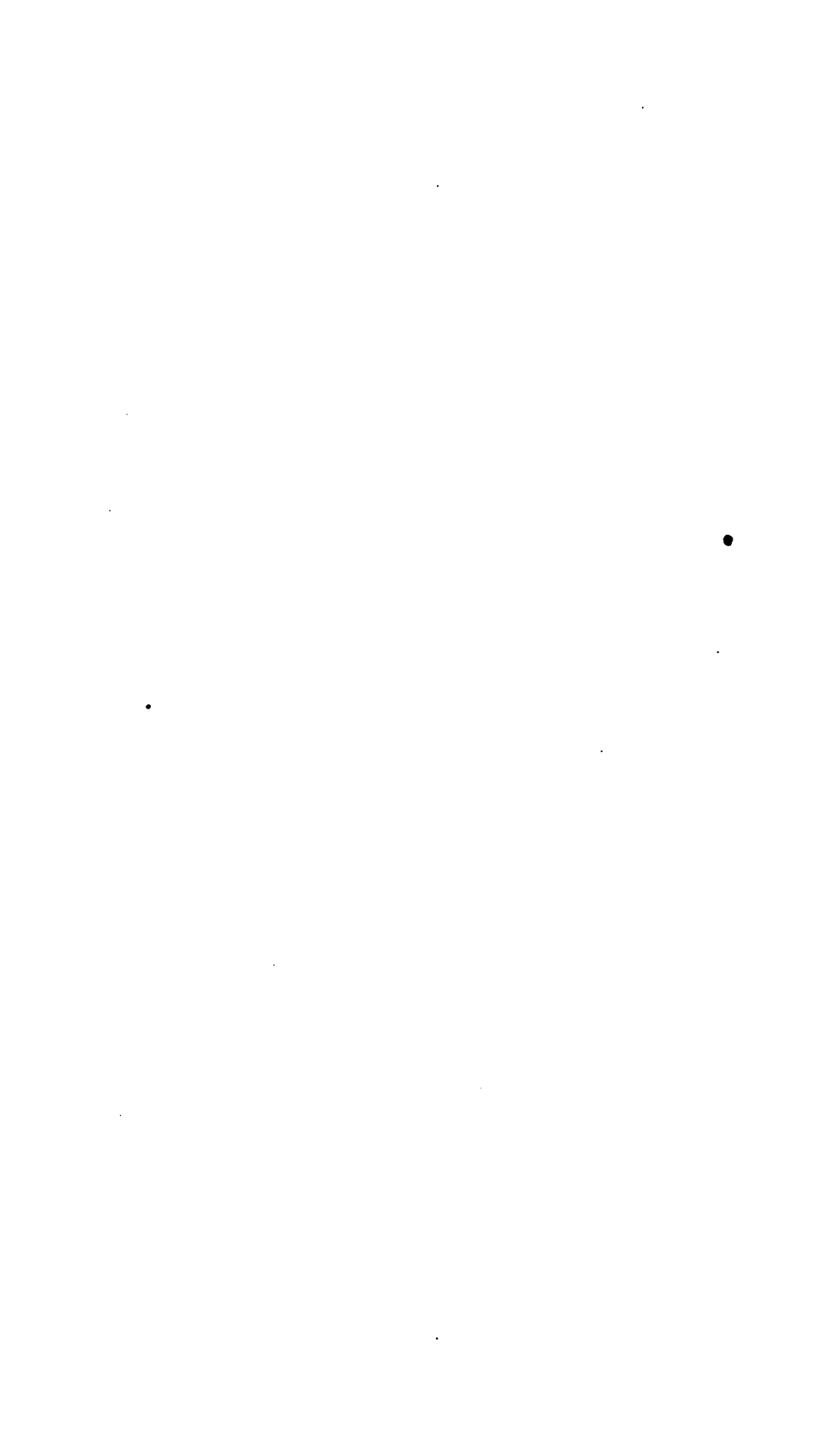
(15) The lever stop is now slipped in place on the end of the carrier boss, with the proper hole engaging the pin on the carrier.

(16) The lever is now screwed on the lever-cam hub, and the two keys are driven in place, after which the lever and cam are slipped into the bearing over the end of the crank-shaft and secured by a bolt in the end of the shaft and a keeper screw in the bolt.

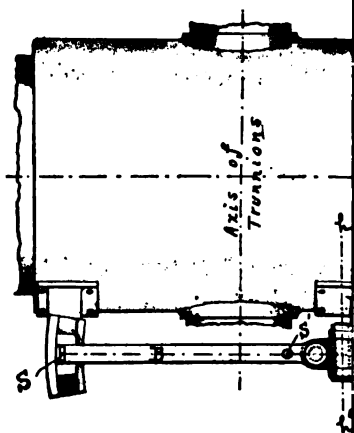
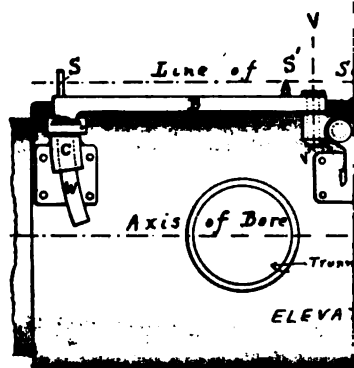
(17) Place the control-arc in position by sliding the flat part into the space cut for it in the gun, and enter and set up tight the four screw-bolts.

The firing-mechanism is assembled in position after the breech-mechanism has been set up, except the lock-operator bar and bearing, which have to be assembled in the carrier before the lever cam is put in place.

To disassemble the mechanism, the order of assembling is reversed. The parts of the firing-mechanism should be removed in the following order: (1) Firing-spring, (2) receiver, (3) operator bar.



CHAPTER VIII. PLATE I.



CHAPTER VIII.

NAVAL GUN-SIGHTS.¹

Preliminary definitions.

(1) **The axis of the bore** of a gun is its longitudinal geometrical axis.

(2) **The axis of training** of a gun is the axis of motion of the top carriage in azimuth; this axis must be installed so that, when the ship is on an even keel and normally trimmed, it will be perpendicular to the plane of the horizon.

(3) **The axis of the trunnions** is their common geometrical axis; the side must be so machined that this axis will be accurately at right angles with the axis of bore. The adjustment of the frictionless trunnions (or, in the case of small guns, the machining of the trunnion-seats) must be such that the axis of trunnions is accurately at right angles with the axis of training. Then, when the ship is on an even keel and normally trimmed, the axis of the bore will move in a plane vertical to the plane of the horizon when the gun is moved in elevation.

(4) **A modern naval sight-mount** is a mechanism, attached to or connected to the gun-slide, that carries two points, called the front and rear *sight-points*, whose positions relative to each other are rigidly fixed. In Fig. 1, Plate I, the front sight-point *S'* is the apex of a cone; the rear sight-point *S* is the bottom point of a V-shaped notch; the straight line prolonged through these two

¹ Rear Admiral Bradley A. Fiske, U. S. N., invented the application of the telescope-sight as a permanent part of the gun-mount, in 1892; prior to this telescopes had been used, but they were always removed from the gun before firing.

The development of the telescope as a night-sight was the result of original experiments that were made by Lieutenant Commander H. C. Mustin, U. S. N., while on duty at the Gun Factory in August, 1905. He also designed telescopes Marks XI, XII and XIII (prismatic) in 1905-1906. The other inventions of his referred to in the text are as follows: Periscope sight-mount for turret-guns, in 1904; periscope sight-mount for broadside guns, in 1906; focusing-cap, in 1906.

points is called the *line of sight*. The purposes of the mechanism are as follows:

(a) To set the line of sight at any specified angle with the plane through axis of bore and axis of trunnions; for this purpose there is required the *horizontal sight-axis* hh' , which necessarily must be installed exactly parallel to the axis of trunnions.

(b) To set the line of sight at any specified angle with the plane through the axis of bore that is perpendicular to the axis of trunnions; for this purpose there is required the *vertical sight-*

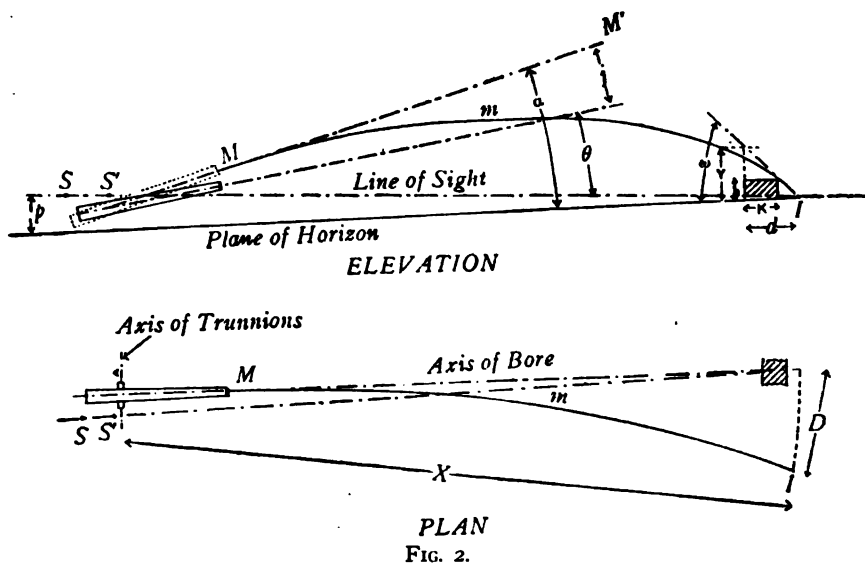


FIG. 2.

axis vv' , which must be installed exactly at right angles with the axis of trunnions.

(5) **The trajectory** is the curve described by a projectile in passing from the muzzle of a gun to the point of impact; its downward curvature MmI (Fig. 2, elevation) is due to the force of gravity; its lateral curvature MmI (Fig. 2, plan) is due to the rotation of the projectile that is imparted by the rifling of the gun. This deviation from the vertical plane of fire is called the *drift*, and is to the right in all our guns.

(6) **The line of departure** is the tangent to the trajectory at the muzzle of the gun; it is coincident with the axis of bore at the instant the projectile leaves the gun (MM' , Fig. 2).

(7) **The jump** is the small vertical angle, usually upward, which the axis of the bore describes in the act of firing (j , Fig. 2); it is due to a yielding in the supports of the gun, caused by the shock of discharge.

(8) **The angle of position** for a given target is the vertical angle between the plane of the horizon and the line of sight, when the line of sight passes through that target (p , Fig. 2).

(9) **The angle of elevation** is the vertical angle that the line of sight makes with the plane through axis of the bore and axis of the trunnions (θ , Fig. 2).

(10) **The angle of departure** is the vertical angle between the line of departure and the plane of the horizon (α , Fig. 2). When the jump and angle of position are negligible, as they are assumed to be in naval gunnery, the angle of departure is the same as the angle of elevation.

(11) **The range** is the linear distance between the gun and the intersection of the trajectory with the line of sight (X , Fig. 2).

(12) **The angle of fall** is the vertical angle that the tangent to the trajectory at the point of fall makes with the plane of the horizon (ω , Fig. 2).

(13) **The danger space** of a target whose height is h and whose beam is k is equal to $k + h \cot \omega$ approx. (d , Fig. 2).

(14) **The virtual height** of a target is equal to $d \tan \omega$ approx. (Y , Fig. 2).

Fundamental Principles.

The fundamental principles of a sight-mount are illustrated in Fig. 1; every modern naval sight, whatever its type may be, is based on principles shown in this figure. The bar which carries the front and rear sight-points, S' and S , is called the *pivot-bar*. To meet the first requirement of the mechanism (see paragraph (a), page 132), the *pivot-block* p , to which the front end of the pivot-bar is attached, engages the shaft whose axis hh' is the horizontal sight-axis installed exactly parallel to the axis of the trunnions. Vertical motion is imparted to the pivot-bar and to the line of sight by raising the curved bar W , called the *sight-bar*; this moves in the casing C , called the *sight-bar bracket*, which has a fixed position relative to the bearings of the horizontal sight-axis. The front

and rear faces of the sight-bar, and the interior front and rear faces of the sight-bar bracket, are machined to arcs of circles centered in the horizontal sight-axis. It is evident that the side faces of the sight-bar and the interior side faces of the sight-bar bracket must be in planes perpendicular to the horizontal sight-axis; otherwise, vertical motion of the sight-bar would cause an appreciable lateral motion of the rear sight-point, and a consequent deviation in the lateral setting of the line of sight.

To meet the second requirement of the mechanism (see paragraph (b), page 132), the pivot-bar engages a pin in the pivot-block whose axis is vv' , installed exactly at right angles to the horizontal sight-axis hh' . Lateral motion is imparted to the pivot-bar and to the line of sight by moving the rear end of the pivot-bar in a groove in the *azimuth-head*; the front and rear faces of this groove and its fitting on the rear end of the pivot-bar are machined to arcs of circles centered in the vertical sight-axis. It is evident that the flat contiguous faces of these parts must be in planes parallel to the horizontal sight-axis and at right angles with the vertical sight-axis; otherwise lateral motion of the sight-bar would cause an appreciable vertical motion of the rear sight-point and a consequent deviation in the vertical setting of the line of sight.

The means of imparting motion to the pivot-bar are, for the sake of simplicity in the drawings, omitted from Fig. 1 and the following illustrations of sight-mounts. They are as follows: Vertical motion is given by a *worm-wheel*, journaled in the sight-bar bracket, that engages a *worm* on the rear face of the sight-bar; the worm-wheel is connected by miter-gears to a hand-wheel which has a small crank-handle. Lateral motion to the pivot-bar is given by a worm-wheel on the *azimuth-head* that engages a worm on the rear end of the pivot-bar; the hand-wheel for lateral motion is similar to the hand-wheel for vertical motion.

Sight-scales.

There are two kinds of scales on every sight. One kind indicates the movement of the line of sight about the horizontal sight-axis; this is called the *range-scale*. The other kind is for indicating the movement of the line of sight about the vertical axis, and is called a *deflection-scale*. Sight-scales are either *direct-reading* or *multiplying*; the direct-reading type will be described first.

A direct-reading range-scale suitable for the sight-mount in Fig. 1 is shown in Fig. 3. The *range-strip*, made of white metal, is engraved with the divisions and numbers of the scale; it is dovetailed to fit in the *sight-bar* flush with the outer side face, and is

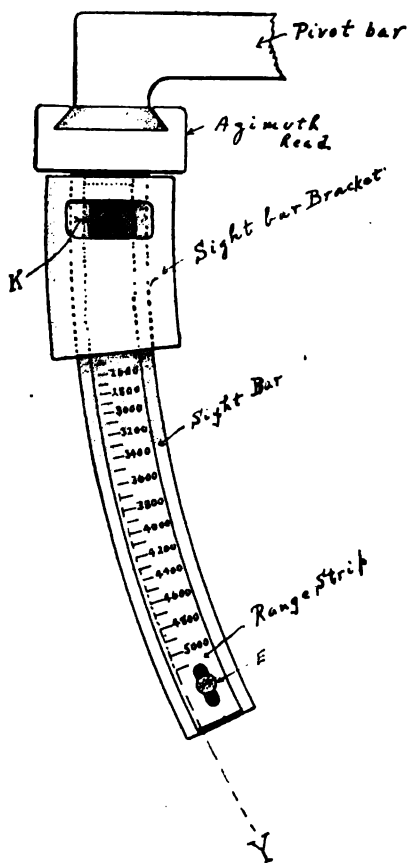


FIG. 3.

adjustable within the limits of the elongated hole for the clamp-screw *E*. The arc of a circle *Y* (shown in broken lines), which touches the rear ends of the scale divisions and front end of *K*, the reference mark on the *sight-bar bracket*, is centered in the horizontal *sight-axis hh'*, Fig. 1. This circle gives a basis for laying off the spacing of the scale divisions, which are calculated

from data obtained at the proof-firing of the gun. The divisions read in yards of range for certain standard conditions as follows:

- (a) Atmosphere of unit density.
- (b) Powder charge of a certain weight and index that, at a temperature of 90° F., will give a muzzle velocity of a certain number of foot-seconds.
- (c) Projectile of a specified weight and coefficient of form.
- (d) Force of wind on the range zero.

For the above conditions, the angle of elevation for every range from 100 yards up to that which will be given by an elevation of 15° is computed and laid off on the arc Y , measuring from the zero mark. For instance, under standard conditions, it is determined that a range of 5000 yards requires an angle of elevation

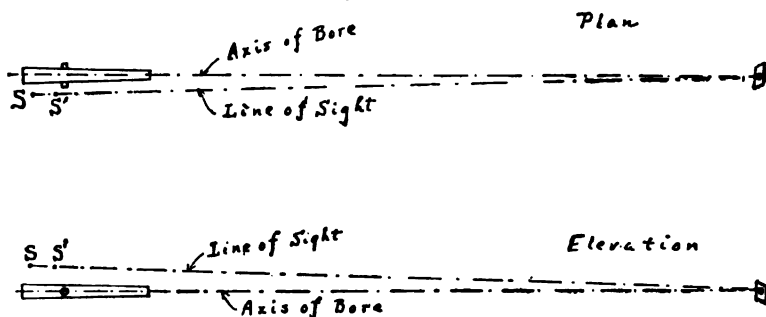


FIG. 4.

of $5^{\circ} 40'$; then an arc of $5^{\circ} 40'$, measuring from the zero division, is laid off, and the division numbered 5000 is plotted.

Adjustments of the zero divisions are two of the details of *bore-sighting*—a subject which will be described more fully later on. A *bore-sight* consists essentially of two *sight-points* placed accurately coincident with the axis of the bore; by means of these and the elevating- and training-gears of the gun, we can lay the axis of bore on a certain mark which is at a mean target-practice or battle range; then, by motion of the pivot-bar we can direct the line of sight to the same mark (Fig. 4).

At present we are interested only in the range-scale; this must now be shifted to read zero by shifting the position of the range-strip or, as is arranged for in some sight-mounts, by shifting the reference mark. After this is done, the gun is said to be *bore-sighted in range* for the mean range selected. Say this is 5000

yards. Now if we raise the sight-bar to the reading 5000, and move the elevating-gear of the gun until the line of sight is directed to the target, the gun will be at the proper elevation to give a range of 5000 yards under the standard conditions (a), (b), (c), and (d), page 136. Now if the gun is fired under these conditions, from a motionless ship at a motionless target, the projectile will attain a range of 5000 yards; but it will fall to the right of the target an amount D (Fig. 2), which is the drift corresponding to 5000 yards range.

In the above example we bore-sighted for a mean range of 5000 yards; it is therefore evident that there will be a small vertical pointing-error, when we fire at other ranges, unless we have a sight-mount that has its horizontal sight-axis coincident with the axis of the trunnions. For instance, if the horizontal sight-axis is 5 feet higher than the axis of the trunnions—as it is in some turret sight-mounts—and we have bore-sighted for a mean range of 5000 yards, we shall have a pointing-error $2\frac{1}{2}$ feet low when firing at a range of 2500 yards, or we shall have a pointing-error of $2\frac{1}{2}$ feet high at a range of 7500 yards. But we are better off than if we had bore-sighted by the old method of pointing at a star, and thereby adjusting the line of sight parallel to the axis of bore; this, in the above example, would give us a pointing-error of 5 feet low at all ranges.

Drift-compensation.—The lateral error D , in Fig. 2, due to the drift at a range R , represents an angular error, which is practically $\tan^{-1} \frac{D}{R}$. To compensate this, we move the rear end of the sight-

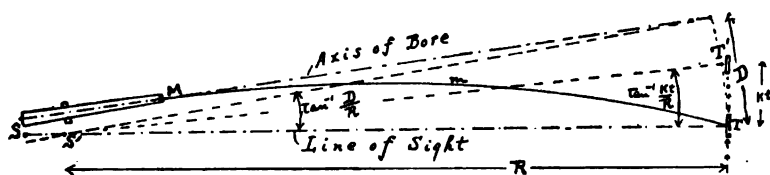


FIG. 5.

bar to the left through an angle $\tan^{-1} \frac{D}{R}$; then train the gun to the left until the line of sight is again directed to the target T , as shown in Fig. 5. The next shot will be a hit, provided we have the standard conditions (a), (b), (c), and (d), page 136.

A **deflection-scale** is used primarily for making the drift-compensation; a direct-reading deflection-scale with its mounting, suitable for the sight-mount shown in Fig. 1, is shown in Fig. 6.

The *pointer P* is attached to the rear end of the pivot-bar by the screws *a* and *b*, and is adjustable vertically, with reference to the pivot-bar, within the limits of the elongated holes for these screws. The rear surface of the *azimuth-plate* is machined to the

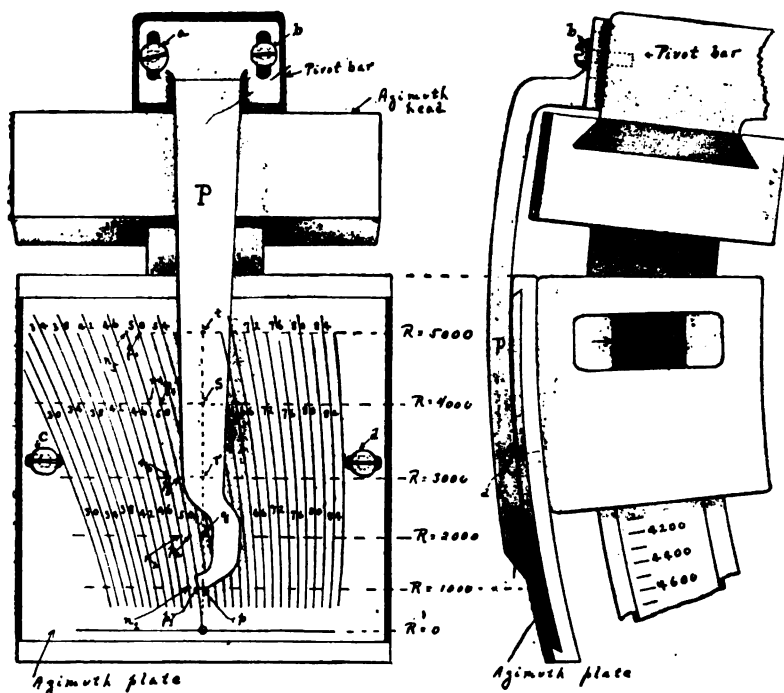


FIG. 6.

surface of the toroid that is generated by the lower end of the pointer *P* when the pivot-bar is moved about its two axes; this plate is dovetailed into the sight-bar bracket, and is adjustable horizontally within the limits of the elongated holes for the clamp-screws *c* and *d*.

In bore-sighting the gun, after the range-strip has been shifted to read zero, the next step is to make the deflection-scale read zero. First, raise or lower the pointer *P*, with reference to the pivot-bar,

until the lower end of the reference mark is on the level of the zero mark on the azimuth-plate; then shift the azimuth-plate to the right or left until the center of the zero mark is at the lower end of the reference mark. Fig. 6 shows the sight-bar raised to the reading 1000 yards after range- and deflection-scale adjustments have been made; the lower end of the reference mark is now at the position p ; its position for ranges 2000, 3000, 4000, 5000 would be q, r, s, t , respectively, if no lateral motion is given to the pivot-bar. Now, if we move the rear end of the pivot-bar to the left from the position p through an arc $pp_1 = \tan^{-1} \left(\frac{\text{drift at 1000}}{1000} \right)$

to the position p_1 , we shall have compensated the drift at 1000 yards range as in Fig. 5. Similarly, we can locate the points p_2, p_3, p_4, p_5 , etc., by laying off the arcs, qp_2, rp_3, sp_4, tp_5 , etc., which correspond respectively to the drift at ranges 2000, 3000, 4000, 5000, etc., and can lay down a fair curve through the zero mark and the points p_1, p_2, p_3, p_4, p_5 , etc. When the sight-bar is raised to any range-reading and the pivot-bar is moved to the left until the reference mark on the pointer touches **this curve**, a shot fired under the standard conditions (a), (b), (c), and (d), page 136, will have no drift error. This curve was formerly called the *zero-line*, but now, for convenience in sight-setting (as will appear later), it is called the *fifty-line* and is numbered as in Fig. 6.

Speed-compensation.—Thus far we have considered the ship and target motionless, but, in naval gunnery, either the target or ship or both are steaming ahead. We will examine the case of firing from a stationary ship at a target steaming at a speed of k knots per hour on a course at right angles to its bearing; we assume that there is no breeze, and that we have standard conditions in the atmosphere and ammunition.

In Fig. 5, $SS'T$ is the line of sight, MmT is the trajectory, R is the range; the sight has been set in azimuth with deflection-pointer touching the fifty-line, so the drift is compensated. T is the position of the target at the instant of firing, and t is the time of flight of the projectile for the range R . The shot will fall to the right of the target: for, during the time of flight, the target has moved to the position T' . The lateral error is $TT' = kt$, and the angular error is $\tan^{-1} \frac{kt}{R}$. To correct this error we move the

pivot-bar to the left through an angle $\tan^{-1} \frac{kt}{R}$, which gives the condition shown in Fig. 7.

In the above example, we will assume the range is 1000 yards, the time of flight is t_1 and the speed of the target is two knots per hour. Then, laying off on the azimuth-plate in Fig. 6 the arc $p_1n_1 = \tan^{-1} \frac{2t_1}{1000}$, we locate the point n_1 ; when the pivot-bar is moved to the left so that the reference mark on the deflection-pointer is at the position n_1 , the sight will be set for compensating the speed of two knots in the example given. Similarly, for ranges 2000, 3000, 4000, etc., and corresponding times of flight t_2, t_3, t_4, t_5 , etc., we locate the points n_2, n_3, n_4, n_5 , etc., and can lay down a fair curve through these points and n_1 ; then, when the sight-bar is raised to any range and the pivot-bar is moved to

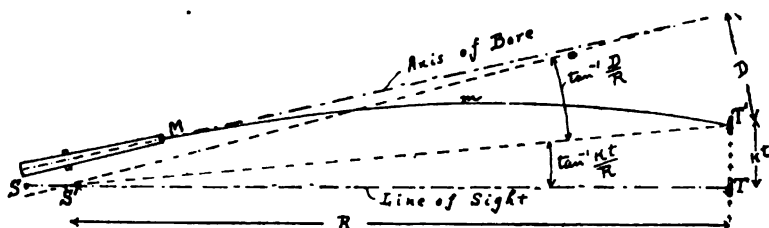


FIG. 7.

the left until the reference mark touches this curve, the error due to two knots speed will be compensated when the target is moving in the direction shown in Fig. 7. The curve for compensating two knots speed when the course of the target is in the opposite direction, is plotted by laying off arcs equal to $p_1n_1, p_2n_2, p_3n_3, p_4n_4, p_5n_5$, etc., to the right, instead of to the left, of the fifty-line. The other speed-lines shown in Fig. 6 are computed in the same manner, using the proper values of speed, range, and corresponding times of flight. The method of numbering the lines shown in this figure obviates the use of the words "right" and "left" in designating the setting of the sight in azimuth. This avoids the errors that formerly were frequent on account of confusing right with left; it also simplifies the visual fire-control instrument, because the indication for the azimuth setting requires only two numerals, instead of two numerals and the designation "right" or "left."

Sight radius.—The length of the bar B (Fig. 1) is the distance between the front and the rear sights, and is called the *sight radius*. Knowing the sight radius, we are able to obtain definite values for these arcs by spacing off the distances between the drift curves on the azimuth-plate (Fig. 6).

Assume that we are firing a 12-inch gun having an initial velocity of 2900 foot-seconds at a target 1000 yards distant and moving at two knots speed (3.38 f. s.). By referring to the 12-inch 2900 f. s. range table (column 4), we find that for a range of 1000 yards the time of flight is 1.05 seconds. Let the sight radius of the gun equal B inches, and let x equal the length in inches to lay off on the azimuth-plate to compensate for the speed of the target.

$3.38 \text{ feet} \times 1.05 \text{ (time of flight)} = 3.549$ feet, the distance the target will steam at 2 knots in the time of flight of the projectile.

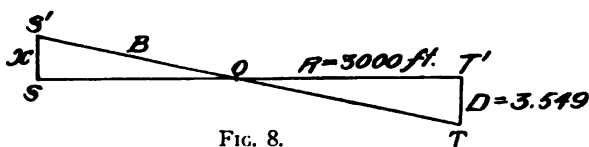


FIG. 8.

Then from similar triangles, considering $OT = OT'$ and $OS = OS'$,

$$B : R = x : D,$$

$$B \text{ in inches} : 3000 = x : 3.549.$$

$$x = \frac{3.549B}{3000}.$$

Let us give B a value of, say, 100 inches. Then $x = .118 +$ inch.

By the same method for 3000 yards range, we find $x = .123$ inch; for 5000 yards range, $x = .127 +$ inch. Working it out for longer ranges, we get gradually increasing lengths of x , which illustrates why the drift curves are close together at the bottom of the azimuth-plate and wider apart at the top.

Azimuth-plates are marked in knots for speed of target. This is obviously the right method, as will be seen. Let us try to mark the azimuth-plate for speed of ship, the target being stationary. Assume the ship steaming ahead at 2 knots speed, firing at the target T . The speed of the ship will give to the projectile a component in the direction of motion of the ship equal to 2 knots per hour, which, if the firing were in vacuum, would cause the pro-

jectile to fall at A , and $AT = Oa'$, the distance the ship would steam in the time of flight. However, we are not firing in vacuum, but in still air, and the projectile would be driven to the right by an apparent wind of 2 knots per hour, which would begin to act as soon as the projectile left the gun, and its effect would increase with the range. Therefore the projectile would fall at B .

Referring to the 12-inch range table, we find that for a range of 1000 yards the effect of the apparent wind on a 12-inch shell would be practically negligible; the firing ship would advance $1\frac{1}{8}$ yards, and the shell would be deflected to the left $1\frac{1}{8}$ yards. (As a matter of fact, the shell would feel the effect of the apparent wind; but at this short range we can neglect it.) At 5000 yards range the firing vessel would advance $6\frac{1}{2}$ yards; the shell would miss the target by $5\frac{1}{2}$ yards. The difference, $\frac{3}{8}$ yard, is the effect of the apparent wind on the shell during the time of flight. At 10,000

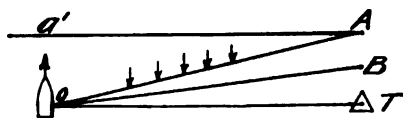


FIG. 9.

yards range the firing ship would advance 14 yards; the shell would miss the target by $11\frac{3}{8}$ yards. The difference, $2\frac{3}{8}$ yards, is the effect of the apparent wind during the time of flight. In every case, in order to know the number of yards to be allowed for speed of ship, we should necessarily take into account the effect of the apparent wind, which varies with the strength of the wind and the time of flight. The target, however, during this time of flight, steams a certain definite distance which is dependent on no other elements. It is thus much simpler to mark the azimuth-plate for speed of target than to mark it for speed of ship.

If the target is speeding at 10 knots at right angles to the line of fire, we set the deflection-scale at 50 ± 10 , to compensate for the speed of the target. If the target is anchored and the firing ship is steaming at 10 knots speed at right angles to the line of fire, the setting of the deflection-scale would be $50 \pm (10 - \text{effect of the apparent wind})$. This can be readily obtained from the range tables.

Azimuth errors.—The speed-curves on the deflection-scale shown in Fig. 6 are accurate only under the following circumstances: (a) When there is no breeze on the range, (b) when we have standard conditions in ammunition and atmosphere, and (c) when we fire from a stationary ship at a target steaming on a course at k knots per hour at right angles to its bearing.

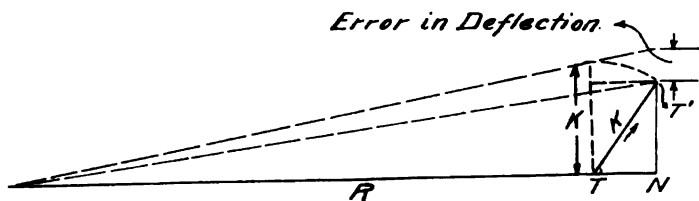


FIG. 10.

The error that arises if the deflection scale be set for the full speed of the target when the course of the latter is at an angle C with its line of bearing is shown in Figs. 10 and 11. In these figures R is the range at the instant of firing; t is the time of flight for that range; T is the position of the target at the instant of firing; T' is its position at the instant of impact. It should be

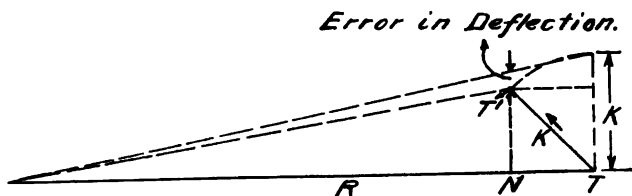


FIG. 11.

noted in both figures that an error in range as well as an azimuth error is introduced. In both cases the sight is over-compensated in azimuth.

In the first case the target is steaming partly with the direction of motion of the projectile, and in the second case partly in the opposite direction. Since the distance the target steams in the time of flight is small in comparison with R , we can say without much error that there has been no change in range. But since we are now dealing only with azimuth errors, we are interested in

obtaining the component of the target's speed at right angles to the line of bearing, in order to know the azimuth setting. In both cases it is $T'N$, which is equal to $k \cos C$; and the setting of the deflection-scale should be $50 \pm k \cos C$.

When both ship and target are moving.—Let us assume the firing ship S (Fig. 12) is steaming at 10 knots on course North, and the target ship T 10 knots on course South, and that at commencement of firing with 12-inch guns the target ship bears 60° on the starboard bow of the firing ship. The combination setting is the algebraic sum of the compensation for speed and course of the target and for speed and course of the firing ship. If there is no breeze, that part of the setting involving speed and course of the firing ship will be in error by reason of the effect of the apparent-wind component. If there is a breeze, both parts of the com-

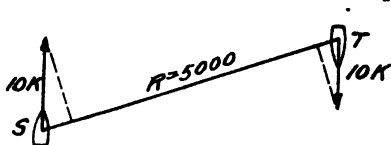


FIG. 12.

pensation may be in error. The setting of the deflection-scale will be:

Due to target ship: $50 + 10 \sin 60^\circ = 58.7$

Due to firing ship: $50 + 10 \sin 60^\circ = 58.7$

Therefore, if the deflection-scale is set at $50 + 17.4 = 67.4$, the compensation is made; but it is in error because we have neglected this effect of the wind component on the shell.

To get the true azimuth setting we would proceed as follows: Referring to the 12-inch 2900 f. s. range tables, 5000 yards range,

Due to target ship:

Lateral deviation to left of target, $\frac{8.7}{12} \times 38$ (col. 18) = 27.6 yards.

Due to firing ship:

Lateral deviation to left of target, $\frac{8.7}{12} \times 35$ (col. 17) = 25.4 yards.

Total, 53.0 yards.

This is the number of yards the shell would miss the target laterally if the gun were fired with the deflection-scale set at 50.

From the range tables (column 18) we find that 3.17 yards at the target at 5000 yards range is corrected by one division on the deflection-scale. Dividing by 3.17 the total number of yards to be compensated, we get the total number of divisions to the right of the fifty-line that the deflection-scale must be set in order to make a hit. This is 16.4, which, added to 50, gives the setting, 66.4.

The initial azimuth setting should be as close an approximation as it is possible to make, considering all the elements affecting it, in order that the lateral deviation of the fall of the shell may be as small as possible. The smaller this error, the easier it is for the spotter to bring the next shot on the target.

Range errors under standard conditions.—Even when we have standard conditions in ammunition and the atmosphere, it will be evident, from the preceding article, that when either the ship or the target is steaming there will be a range error in the fall of the shot. Under the usual conditions of battle, where the differences in course and speed of ship and target are not large, this error will probably be less than the danger space. A wind component in the plane of fire will decrease or increase the range according as it is towards or away from the ship. This error is comparatively small; for instance, with the 12-inch gun, when the target is distant 9000 yards, a wind component of 12 knots in the plane of fire will cause a change of 21 yards in the range. (See column 13, Range Table, 1912.)

Range errors due to variations from standard conditions are as follows:

(a) *Change of range caused by variation of the density of the atmosphere.*—A density above unity, the density for which the range-strip is calculated (barometer 29.53 inches, thermometer 59° F.), will make the shot go short; density below unity will make the shot go over; other conditions being normal. For instance, a variation of 5 per cent will make a change in range of 87 yards at 9000 yards range with the 12-inch gun. (See column 12, Range Table, 1912.) This is an error that can be foretold by observation of the barometer and thermometer (outside) immediately before firing; if the change of distance of the target is not to be considerable, it can be satisfactorily compensated by applying a correction to the initial sight-bar range equal to the error picked

out for the mean distance of the target. But as the error for a given density of the atmosphere varies with the range, it is evident that this method of compensation fails when there is a wide change in the distance of the target during the firing.

(b) *Variation in the range caused by variation in the temperature of the powder.*—Temperature of the charge above 90° F., the standard for which the range-strip is calculated, will make the shot go over; and temperature below 90° will make it short. This is an error that can be avoided by keeping the magazines at the standard temperature by means of refrigeration or heating. On ships where these appliances are not installed, the worst feature of the temperature error is that magazines in different parts of the ship, for guns of the same caliber, will have different temperatures, and so the guns they supply will have different range errors. For instance, if the forward 12-inch magazine has a temperature of 93° and the after 12-inch magazine has a temperature of 87° , when the target is distant 9000 yards, the forward 12-inch guns will shoot 53 yards over, while the after 12-inch guns shoot 53 yards short. (See column 10 and explanatory note in Range Table, 1912.) Here is a difference amounting to more than half the danger space of 20-foot target-screen (84 yards at that range); consequently one turret may be hitting at the base of the target while the other is firing over the top edge. We must therefore apply corrections to the initial range to each gun in accordance with the temperature of the magazine that supplies it; and, since the temperature error varies with the distance of the target, we must select the correction for the mean range expected. If there is not much variation in the distance from this mean, this method of compensation will be satisfactory.

(c) *Change of range caused by variation in weight and coefficient of form of the projectile.*—A projectile of different weight from that for which the range-strip is calculated will fall short if over weight, or will fall over if under weight. For instance, a 12-inch projectile 5 pounds under weight will fall 20 yards over when the target is distant 9000 yards. (See column 11, Range Table, 1912.) Where the projectile is of standard weight, but is of a coefficient of form different from that for which the range-strip is calculated, the trajectory will differ in range and drift. The new long-pointed projectile has a flatter trajectory than a blunt-pointed projectile of equal weight. Of late the inspection

of projectiles before issue to the ship has become so reliable that errors in the weight need not be expected. When projectiles of different coefficients of form are supplied, range- and deflection-strips for each kind are furnished.

Multiplying-scales.—With high-power guns it is often impracticable to design the pivot-bar long enough for distinct spacing and numbering of the range divisions at 100-yard intervals and the deflection divisions at 2-knot intervals. In such cases the range-scale is placed on a dial geared up from a rack on the sight-bar, and the deflection-scale is placed on a drum geared up from a rack on the rear end of the pivot-bar; this amounts to a mechanical magnification of the scales. As the details of the various methods of accomplishing it are readily understood upon examining the sight-mount, no illustrations are given.

In sights of this type great care must be taken to keep lost motion out of the multiplying-gears; this would result in sight-setting errors in range or in deflection, or in both. Such errors are detected as follows: Lay the gun by the bore-sight on some fixed mark; then move the rear end of the sight-bar up and to the right until the line of sight is directed to some other point whose position with reference to the first mark is fixed; note the exact reading of range- and deflection-scales. Now run the sight-bar well up above, and move the pivot-bar well to the right of these readings; then by motion down and to the left come back to the noted readings. See that the axis of bore is directed to its mark; then, if the line of sight is not directed to its mark there is lost motion between the pivot-bar and the scales. The errors may be due to any of the following causes:

- (a) Lost motion in the multiplying-gear.
- (b) Bending of the sight-bar, due to very tight fitting of sight-axes.
- (c) Play in the front end of the sight-bar, due to loose fitting of the sight-axes.

The above test, in the case of parallel-motion sight-mounts, should be made in dry dock or in still water with the ship moored to the dock unless both marks can be set up on the ship; the reason for this will appear later when that type of turret sight-mount is described.

The calibration of a gun is determined by firing a string of accurately aimed shots at a target bearing nearly abeam, whose

distance, at a mean battle range, is accurately measured. The point of fall of each shot is plotted as accurately as possible. The setting of the sight is the same for each shot, making the sight-bar range the same as the actual range; and care is taken that there are no errors in the adjustment or in the mechanism of the sight-mount, or in the adjustment of the telescope. Prior to this the graduations of sight-strips should be checked up. The ship is moored in still water and normally trimmed; the powder is all of one index and is kept at the same temperature for each shot of the string—preferably as near as possible to 90° ; the projectiles are brought to standard weight if any variation is found; and the density of the atmosphere is carefully recorded throughout the string. The mean force and direction of the wind on the range are determined as well as possible, but on account of the difficulty in getting reliable data of this kind, the firing should be done in nearly calm weather.

After applying to the mean point of impact the corrections for height of bull's-eye from the water, variation from standard density of atmosphere, variation from standard temperature of powder, and the effect of a wind component in the plane of fire, and across the plane of fire, there will still be found a discrepancy between the setting of the sight in range and azimuth and the mean point of impact. A small part of the discrepancy may be due to unlevel installation of the gun-mount or improper adjustment of the frictionless trunnions, either of which will produce "tilting" of the line of sight and consequent vertical and lateral errors. These two errors can now be compensated by shifting the range- and azimuth-strips; for example, we find that the mean point of impact for a string of four shots at a target distant 7500 yards is 250 yards over and 25 yards right, the sight being set to range 7500, deflection 50. Correcting the observed mean error for the height of bull's-eye and the variations from standard conditions, we find the standard error is 100 yards over and 12 yards right. To calibrate this gun in range we would lower the sight-bar to reading 7400, then shift the range-strip to make it read 7500. To calibrate the gun in azimuth we would set to the fifty-line (when range reads 7500), then shift the azimuth-scale to the left the number of knots corresponding to 12 yards lateral error at 7500 yards range. (For instance, with 12-inch guns, column 18 of Range Table, 1912, gives 60 yards deviation for 12 knots; then

1 knot corresponds to 5 yards and 2.4 knots correspond approximately to 12 yards.)

Calibration errors of different guns of one caliber will usually be found different; when each has had its correction applied, all guns of this caliber will bunch their shots well, when the target is at a distance that does not differ greatly from the distance of the calibration target and when its bearing is about the same, relative to the ship, as the bearing of the calibration target. A change of index of powder from that with which the calibration tests were made will make but little difference in the results, provided the powder is in good condition.

When calibrating a ship's battery, one gun is selected as the standard gun. This selection is made because its standard error is small and because the four shots from the gun have given the most consistent results. The errors of the other guns are compared with the standard gun, and the sights are changed to bring all the guns to the standard gun, after which all the guns will bunch their shots—which is what we strive for in naval gunnery.

TYPES OF SIGHTS AND SIGHT-MOUNTS.

The **line of sight** was defined in paragraph (4), page 131, as the straight line prolonged through the front and rear sight-points. There are three principal arrangements for establishing these sight-points, any one of which may be applied to the sight-mounts described in this chapter. These arrangements are named: (1) The *open sight*, (2) the *peep-sight*, and (3) the *telescope-sight*.

The **open sight** is the earliest and least efficient arrangement of the sight-points. As shown in Fig. 1, the *front sight-point* is the apex of a cone and the *rear sight-point* is the bottom point of a V-shaped notch.

The chief defect in the open sight lies in the fact that the eye cannot simultaneously see the target and the two sight-points distinctly; it must accommodate (focus) successively for three different distances. This sight is not only fatiguing to the eye but is inaccurate even under the most favorable conditions (namely, when both gun and target are still, and there is no difficulty in keeping the optical axis coincident with the line joining the sight-points); this is because changes in the direction and intensity of the illumination of the front sight-point will make an apparent

change in its position and a consequent apparent change in the direction of the line of sight. In addition to the above, there is no magnification of the target, and a considerable portion of its

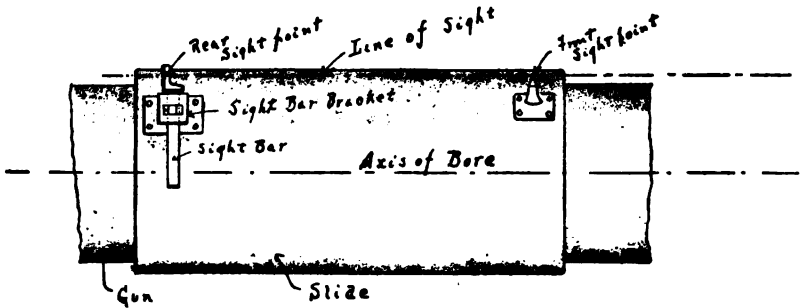


FIG. 13.

area is obscured by the sight-points. This type of sight is rapidly disappearing from the service, and its use probably will soon be restricted to revolvers and automatic pistols.

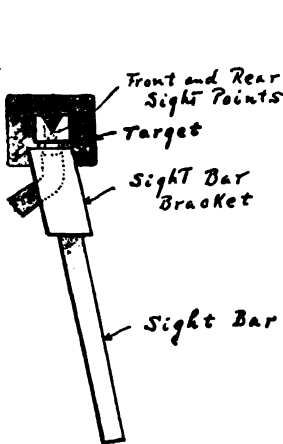


FIG. 14.

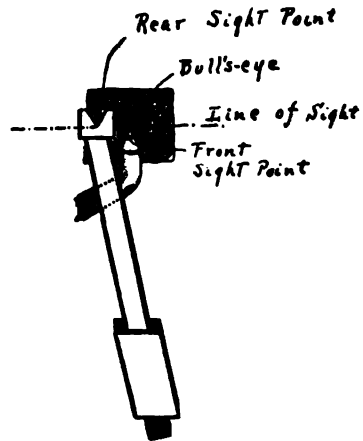


FIG. 15.

In Fig. 13 it will be seen that there is no pivot-bar. The sight-bar is straight, instead of being machined to an arc of a circle. The compensation for drift is accomplished (approximately) by fitting the sight-bar bracket so that the sight-bar is inclined slightly to the left at a permanent angle. This is illustrated in Figs. 14 and

15. In Fig. 14, with the sight-bar at zero, the front sight, rear sight and bull's-eye are in line; in Fig. 15, with the sight-bar raised and the gun elevated until the two sight-points and bull's-eye are in one plane, it will be seen that the line of sight is pointing to the right of the bull's-eye. Now, to bring it on, we must train the

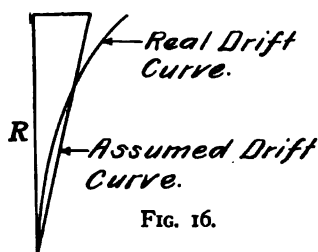


FIG. 16.

gun a little to the left, which in a measure will compensate the right-hand curvature of the trajectory.

In sights that are inclined to the left at a permanent angle to compensate for drift, the drift is over-compensated at short ranges and under-compensated at long ranges. In the installation of sights of this character it is assumed that the drift is proportional to the range, which, however, is not the case, as the rate of increase of the drift increases with the range.

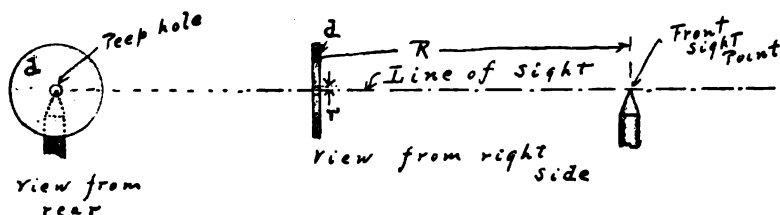


FIG. 17.

The peep-sight is an improvement on the open sight, for the reason that it requires the eye to focus successively for two distances instead of for three. Fig. 17 shows the essential parts of this type of sight.

The front sight-point in a peep-sight is about the same as in an open sight; but instead of a notch for the rear sight-point there is a circular hole in a *diaphragm* (*d*, Fig. 17). The line of sight is defined by the tip of the front sight-point and the center of the

peep-hole. It is evident that the accuracy of this type of sight depends primarily on the accuracy with which the eye is centered at the peep-hole; if r be the radius of the hole and R be the distance between it and the front sight-point, by moving the axis of the eye from the center of the hole over to the edge we shall make an angular error, called *parallax*, in the line of sight that is equal to $\tan^{-1} \frac{r}{R}$. Now the value of r determines the sectional area of

the pencils of light from the target that reach the eye. Since the apparent brightness of an object of a given intensity of illumination per unit of area is dependent on the sectional area of the pencils of light from it that enter the eye, it is evident that if r_1 , the radius of the eye pupil, be larger than the radius of the peep-hole, the apparent brightness of the target as seen through the peep-hole is to its apparent brightness when viewed by the unobstructed eye as the ratio $\frac{r^2}{r_1^2}$. Since the radius of the normal eye

pupil when dilated at night is one-tenth inch, if our peep-sight is to be effective at night the radius of the peep-hole should be at least one-tenth inch; but with this value of r , it is impracticable to make R , the distance to the front sight, great enough to ensure sufficient accuracy. For this reason, even if there were no others, the peep-sight could not be made an efficient night-sight. However, in the daytime the apparent brightness of the target is of no consequence, and we can make the peep-hole small enough to reduce the parallax error to a negligible quantity.

The peep-sight is installed on many of our sight-mounts, and was designed to be the night-sight, being arranged so that the front sight-point can be illuminated; but in August, 1905, after some experiments in the subject of night-sights at the Naval Gun Factory, the telescope was developed to such an extent that its gain in efficiency over the peep-sight for night work is something over 3000 per cent. The peep-sight is therefore retained merely as a stand-by in event of injury to the telescope.

The telescope-sight is the most convenient and most efficient means of establishing the sight-points. It may be defined as the combination of two systems of lenses on a common axis spaced so that the second focal plane of the first system (the objective equiva-

lent) is coincident with the first focal plane of the second system (the eye-piece equivalent), which plane contains a pair of intersecting cross-wires or etched cross-lines.

There are three points in the telescope that determine the line of sight; namely, the intersection of the cross-lines, and the first and second unit points of the objective equivalent. The stability of the line of sight with reference to the sight-mount therefore depends on the rigidity of the point of intersection of the cross-lines and all optical parts in front of it.

The telescope is so attached to the gun that the line of sight can be set at any desired angle with the axis of the gun. Some confusion exists as to the nomenclature of "telescopic sights." In the case of telescopic sights the word "sight" refers to the heavy steel yoke attached to the gun-slide or to the trunnion, while the word "telescope" refers to the optical instrument through which the gun-pointer sees the target. In making surveys, requisitions, target-practice reports, etc., "sights" should not be confused with "telescopes."

Care of sights.—The sights of a gun, being instruments of accuracy, require most careful attention. They should be kept in proper condition by the division officer, and he should allow no one except himself to disassemble or dismount the sighting-mechanism or telescope. The sights should be handled as little as possible, since each time they are worked, lost motion in the various worn gearings, etc., is increased.

Telescope-Sights.

There are four varieties of telescopes used as gun-sights in the navy.

The first type has the *universal focus*; i. e., has no adjustment whatever, for focusing. The first of these was of $2\frac{1}{2}$ power, and had no means for focusing the eye-piece to suit individual eyes. This form is obsolete, as modern fixed-power telescopes have a means of focusing the eye-piece so as to accommodate the individual eye.

The second type is the standard *variable-power telescope*. The variable power is secured by moving the eye-piece tube in and out and then clamping it at the desired power, after which the telescope is focused.

In the modern type of variable-power telescope used for turret trainers, two magnifications are obtained by moving the position of the erecting-system. Distinct vision is obtained only at two powers in this type.

Another form of variable power is obtained in the continuously variable-power telescope. By means of a spiral on the inside of the telescope, the position of the erecting-system is changed, and at the same time the relative positions of the lens of the erecting-system themselves are changed. This gives a clear, distinct vision while changing from one power to another.

The third type is the *prismatic telescope*, which has two 90° elbows, so that an indirect line of sight is obtained. This telescope is fitted with prisms, to obtain the required change of direction.

This type was originally intended for turrets only, but is now supplied for broadside guns.

The fourth type is the *checking telescope*, which may be any of the above three types fitted with a second eye-piece, so that two observers may see through the telescope at the same time. This is attained by means of a prism inserted in the path of the rays from the objective to the primary eye-piece. One disadvantage of this scheme is that each observer gets only half the light that he would receive ordinarily.

As this checking eye-piece is intended for use in training pointers, the latest telescopes are fitted so that the checking eye-piece system can be thrown out at will.

Advantages of the telescope-sight.—The first point of superiority of the telescope as a sight is the fact that the eye is focused for only one distance, instead of successively accommodating for three, as with the open sight, or successively for two, as with the peep-sight. This is because the eye, when the adjustment of the telescope is correct and the target is at long range, sees, through the eye-piece equivalent, the intersection of the lines and the image of the target in one plane. Furthermore, under the above conditions the pencils of light that emerge from the eye-piece are parallel pencils, and the accommodation muscles of the normal eye are at rest when it is receiving such pencils. With the open sight and peep-sight, if the eye is moved off the line of sight, errors in pointing will occur; but with the telescope, motion of the eye either across

or along the line of sight will not affect the accuracy of pointing, provided the telescope is properly adjusted and the target is at long range. For as long as the eye is in some position where it will receive a part of some pencil that emerges from the eye-piece after diverging from the intersection of the lines, it will see the intersection of the lines and some part of the field of view. There are limits along the axis of the eye-piece and across it within which the eye should be placed if it is desired to utilize the full field of view and receive the maximum amount of light from the target; however, the rubber buffer fitted on the eye end of the telescope makes it easy for the eye to place itself within the proper limits.

The next point of superiority of the telescope is its magnifying power. At modern battle ranges it is necessary to have an apparent enlargement of the target in order to point the gun with sufficient accuracy. Where F is the focal length of the objective equivalent, and f is the focal length of the eye-piece equivalent, the magnifying power of the instrument will be $M = \frac{F}{f}$ diameters. For instance, if F be 20 inches and f be $2\frac{1}{2}$ inches, the magnifying power will be 8 diameters. When using this telescope on a target distant 8000 yards, we can lay the gun with as much facility as we could lay it on the same target distant 1000 yards with a sight that has no magnifying power. But the increase of magnifying power is attended with a corresponding decrease in the field of view. Roughly, the field of view of any telescope will be 35° divided by the magnifying power. We are therefore restricted in the application of this point of advantage by the size of field of view which is large enough to permit the gun-pointer to "pick up" the target.

Another point of advantage in the telescope-sight is the fact that the size of the emergent pencils does not affect the accuracy as does enlargement of the hole in the peep-sight. When M is the magnifying power and A is the aperture of the telescope, the diameter of emergent pencils will be $\frac{A}{M}$. By making the proper relation between A and M we can utilize the full area of the dilated eye pupil at night; and so, instead of making it more difficult to pick up a target when looking through the sight than it is when looking

with the naked eye, we can, with the new telescopes in service, pick up and lay on a target that is so dimly illuminated as to be invisible to the naked eye. But the proper relation between aperture and magnifying power is only one of several points in the design of our telescopes (some of which are confidential) that make them highly efficient night-sights.

Parallax will appear in a telescope-sight if the image of the target and intersection of cross-lines do not lie in the same plane. It is easily detected by laying the telescope on a fixed mark, keeping it in a fixed position, and then moving the eye up and down or sideways across the eye-piece. If there is no apparent motion of the intersection relative to the image, they are both in the same plane; if the intersection appears to move over the image in an opposite direction to the motion of the eye, the image lies forward of the lines; if it appears to move over the image in the same direction as the motion of the eye, the image lies in rear of the lines. The second-mentioned condition would be due to incorrect adjustment of the telescope; the third condition would be due to incorrect adjustment if the mark selected for the test is more than a mile distant. When a telescope has an objective equivalent of a moderate focal length like that in our telescope-sights, and the telescope is in correct adjustment, the image of an object distant anywhere from infinity to a mile is not perceptibly in rear of the second focal plane of the objective equivalent—the position of the cross-lines. Actually, however, the image is in rear of this position a distance $Y = \frac{F^2}{X}$, where F is the focal length of the objective equivalent, and X is the distance of the object measured forward of the first principal focus of the objective equivalent. From this it is evident that, if our telescope is adjusted for long range, the image of a miniature target as close as the end of a Morris Tube boom (or in the corresponding position in a dotter), will be so far in rear of the cross-lines that it will give a very large amount of parallax.

Formerly, to obviate this condition the telescope was re-focused (by increasing the distance between cross-lines and objective equivalent) to make the image of miniature target and cross-lines coincident; but this is bad practice, for the reason that it involves a

disturbance of the bore-sighting adjustment, which makes it necessary for the ship to go into still water, readjust the telescope for long range, and bore-sight again before the gun can be fired. We now have an optical instrument called a *focusing-cap* which makes it possible to use the telescope on a near miniature target without disturbing its adjustment or the adjustment of the sight-mount for long-range firing. Focusing caps consist of a *positive lens* (7) and a *negative lens* (8) so mounted that the distance between the two lenses may be varied at will. The two lenses are held at the desired distance apart by the *clamping-ring* (6). By means of

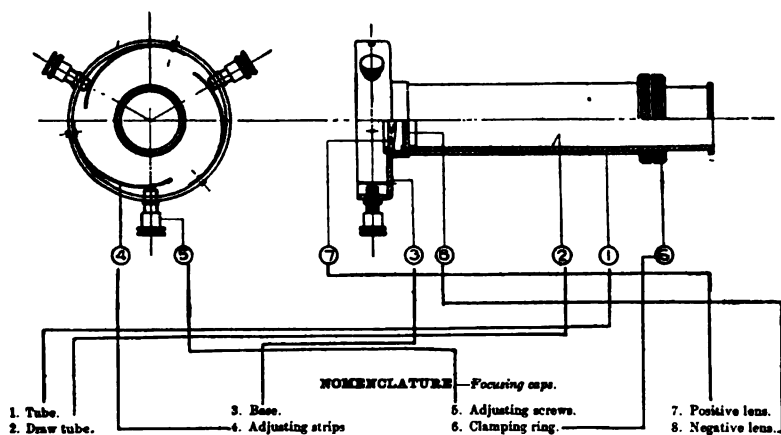


FIG. 18.

the three adjusting-strips (4) and the adjusting-screws (5) the focusing-cap can be adjusted to most telescopes. Special base-fittings are required with the latest marks of telescope, but in such cases the special bases are furnished with the caps.

In using, the telescope itself should be focused on a distant object until free from parallax. The focusing-cap is then shipped in place on the objective end of the telescope, the telescope is directed toward the dotter target, and the draw tube (2) is moved in and out until the image of the target is clear and distinct and the cross-lines are sharp and without parallax.

Parallel-motion sight-mounts.—When the opening for the line of sight is in a *hood* on the roof of a turret, it is impracticable to attach the sight-mount directly to the slide; the pivot-bar is so far

from the trunnions that elevation of the gun causes it to move to the rear and downward a considerable distance. This condition is illustrated by Figs. 19 and 20, which show, respectively, the relative position of gun and line of sight when the gun is level and when it is elevated. In Fig. 20 it will be seen that the line of sight

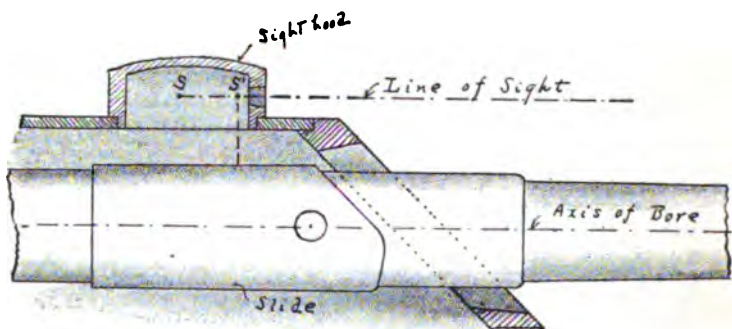


FIG. 19.

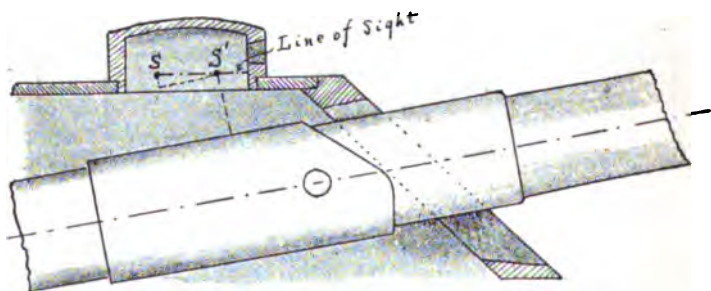


FIG. 20.

is below the opening in the hood, although the gun is not at extreme elevation.

Roof sight-mounts are therefore indirectly attached to the slide by a parallel-motion mechanism; the *pivot-bar* with the fittings for its horizontal and vertical axes, the *sight-bar*, and *sight-bar bracket* are mounted on an arm, called the *connecting-arm*, that has a horizontal axis at its upper end in a fixed position with reference to the deck-lug, and is connected to the slide so that it will move in elevation with an angular motion exactly equal to the angular

motion of the gun in elevation. One method of imparting this motion to the connecting-arm is shown in Fig. 21.

In Fig. 21 the connecting-arm pP has its fixed axis at P in the sight-bracket B , which is made up of two parts bolted to the deck-lug. At its rear end it engages the bar pt , called the *connecting-bar*, on the shaft-bolt p ; this in turn is connected to the slide on the shaft-bolt t . In the parallelogram $PpTt$, the side $PT = \text{side } pt$, and side $pP = \text{side } Tt$; P and T are the fixed points of the parallel motion, T being the axis of trunnions of the gun. A *guide-block* b , which

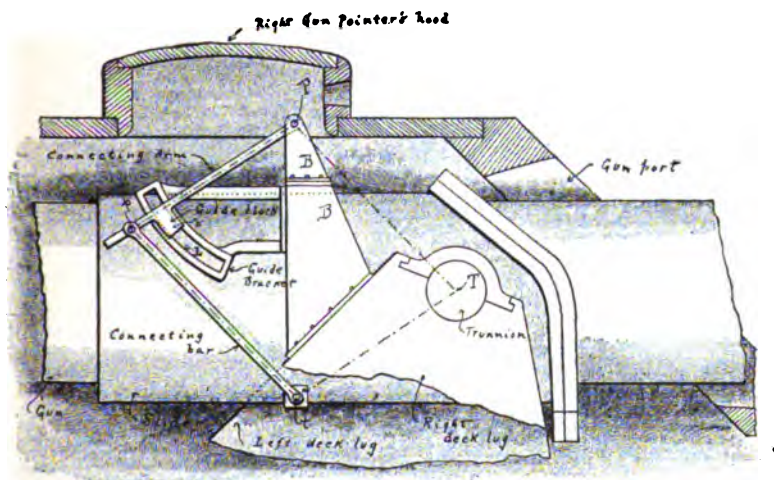


FIG. 21.

is a part of the connecting-arm, works in the circular slot L , in the *guide-bracket*, machined to arcs of circles centered in the axis P . The guide-bracket is bolted to the lower part of the *sight-bracket*; with the guide-block, it prevents lateral bending of the connecting-arm. The connecting-arm will work through angles exactly equal to angles described by the axis of the bore of the gun only when the following conditions are maintained:

(a) That the axes P , p , and t are installed exactly parallel to the axis of the trunnions.

(b) That the distance from the axis P to the axis p is exactly equal to the distance from the axis t to the axis of the trunnions T ; also that the distance from the axis p to the axis t is exactly equal to the distance from the axis P to the axis of the trunnions T .

Although the parallel motion may have been installed in conformity with the above conditions, it is evident that any bending or springing of the connecting-arm or the connecting-bar will distort the parallelogram and cause pointing-errors that may be either vertical or horizontal. A material looseness caused by wear in the working-surfaces will result in vertical errors in pointing. Any change of the position of the trunnions with reference to the deck-lug will also distort the parallelogram. When the gun is being

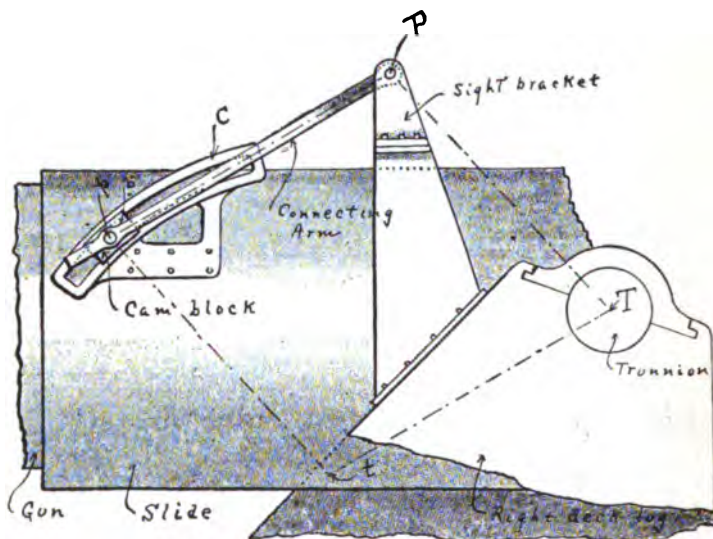


FIG. 22.

elevated, the slide tends to shift forward in the deck-lugs; so, if there is too much clearance in the trunnion seats, the axis of trunnions will shift forward far enough to make a material error in the parallelogram. Upon depressing the gun, the shift is in the opposite direction. Naturally, any adjustment of the frictionless trunnions that is different from the adjustment at the time the parallel motion was installed will affect the parallelogram.

Another form of parallel motion is shown in Fig. 22. The connecting-bar pt and shaft-bolt t of Fig. 21 are replaced by the circular cam C that is bolted to the slide; the center of curvature of this cam is at a point t which is in a fixed position with reference to the slide and axis of trunnions, such that $tT = pP$ and $tp = TP$. The rear end of the connecting-arm contains a shaft-bolt p set up

in the *cam-block b*. The flat face of the cam must be installed exactly in a plane perpendicular to the axis of trunnions. The parallelogram then is $PpTt$, as in the preceding figure.

The advantages of this form of parallel motion are: No matter how long the connecting-arm may be, the cam prevents its rear end from being sprung laterally; and, as there are fewer working parts, there are fewer errors due to wear in bearing-surfaces.

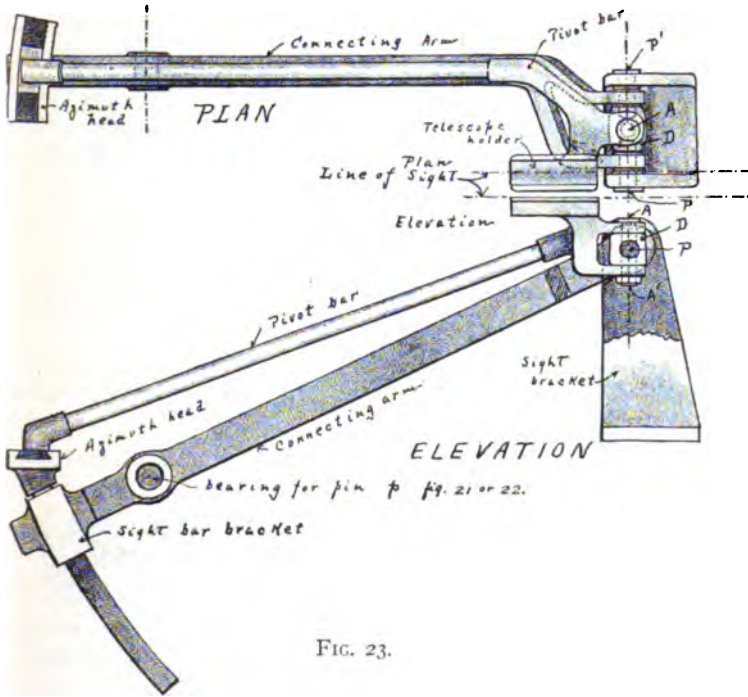


FIG. 23.

A method of mounting the pivot-bar, sight-bar and sight-bar bracket on the connecting-arm is shown in Fig. 23. It will be seen that the *horizontal sight-axis* PP' is coincident with the upper axis of the connecting-arm. It is formed by the two trunnion-bolts P and P' tapped into the jaws of the bracket; these are the bearings for the jaws of the connecting-arm and for D , the *pivot-bar block*, into which is tapped the bolt A that forms the *vertical sight-axis* AA' . The sight-bar bracket is bolted to the connecting-arm at its rear end.

Tests of parallel-motion mechanism.—For tests of parallel-motion mechanism, two observers are required—one to look along the axis of bore, the other to look along the line of sight.

First inspect for lost motion as follows: Direct the axis of bore to a distant mark by motion of the gun, and direct the line of sight to the same mark by motion of the pivot-bar. Move the gun to extreme elevation, and then depress it until the observer at the breech notes the axis of bore on the distant mark. Then move the gun to extreme depression and elevate until the observer at the breech notes the axis of bore again on the mark. Each time the observer at the breech is exactly on, the observer at the sight should also be exactly on. Lost motion may appear as follows: Both may be on when the axis of bore has been elevated to the mark, but the line of sight will point high after the gun has been depressed to the mark; or else both may be on when the axis of bore has been depressed to the mark, but the line of sight will point low after the gun has been elevated to the mark. The error may be due to any of the following conditions:

- (a) Looseness in the bearings of the parallel motion.
- (b) Bending of either the connecting-arm or connecting-bar, caused by very tight bearings.
- (c) Shifting backward and forward of the axis of trunnions, caused by too great clearance in the trunnion-seats.

After the parallel motion has passed a thorough test for lost motion, it should be tested for accuracy of the parallelogram as follows: Elevate the gun until the axis of bore is directed to the center of a heavenly body in the west, selecting a time that will give extreme elevation to the gun. Simultaneously, by motion of the pivot-bar, bring the line of sight to the center of the same body. When the body is near the horizon, lay the axis of bore on its center; now, if the line of sight is also on, we can be satisfied that the parallelogram is properly proportioned and that the upper axis of the connecting-arm is parallel to the axis of the trunnions. If the parallelogram is not properly proportioned, the line of sight will be high or low when the axis of bore is on; if the upper axis of the connecting-arm is not parallel to the axis of the trunnions, the line of sight will point to the right or left when the axis of bore is on. It is obvious that, before making this test, we should

see that the frictionless trunnions are correctly adjusted to the positions they are to be in during firing.

Turret trainer's sight-mount.—The trainer's sight-mount in turrets is usually placed between the two guns. It is not connected to either gun-slide but has two parts that are in a fixed position relative to the two pairs of deck-lugs. In Fig. 24 these fixed parts are the *sight-bracket* and the *azimuth-head*.

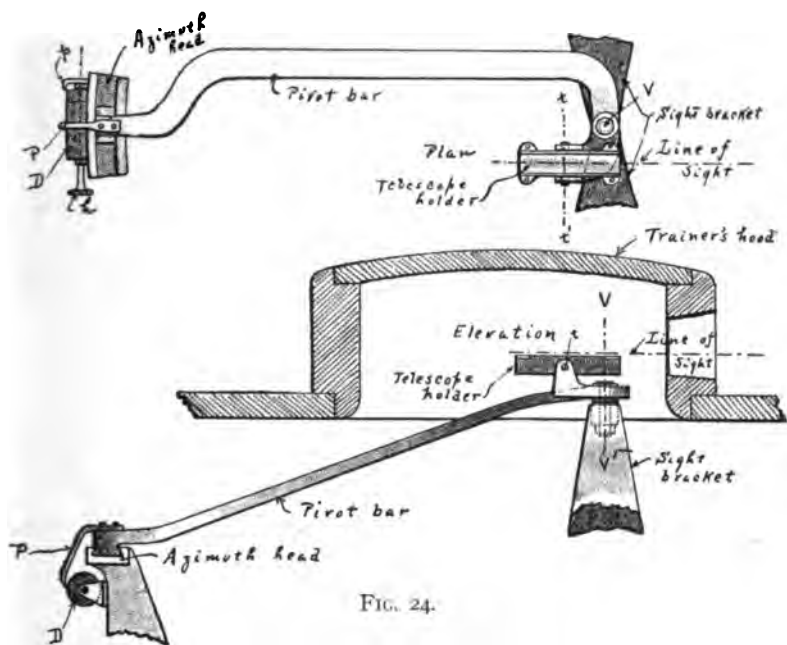


FIG. 24.

The pivot-bar is capable of motion in azimuth about the vertical sight-axis vv' . This axis must be installed exactly perpendicular to the plane of the roller path of the turret. The rear end of the pivot-bar travels in the circular slot in the azimuth-head and carries the pointer P for indicating the setting in azimuth. It will be seen that the pivot-bar has no vertical motion; therefore, in order that the trainer may keep the target within the field of view of his telescope while the ship is rolling, the *telescope-holder* has a *trunnion-mounting* on the pivot-bar. The axis of this trunnion-mounting, tt' , must be installed exactly at right angles with the vertical axis vv' . The azimuth-scale is engraved on the *deflection-*

drum *D*, of which a development is shown in Fig. 25; the graduations on this drum are determined from the graduations on the azimuth-plate on the pointer's sight. In order that the azimuth changes of the trainer's line of sight shall equal the azimuth changes of either pointer's line of sight, the drum must be rotated by the handle *h* until the reading by the scale and small reference pointer *p* on the end is opposite the range-reading set on the pointer's sight; then, when the pivot-bar is moved to the left or right until the reference mark on the pointer *P* touches the speed-

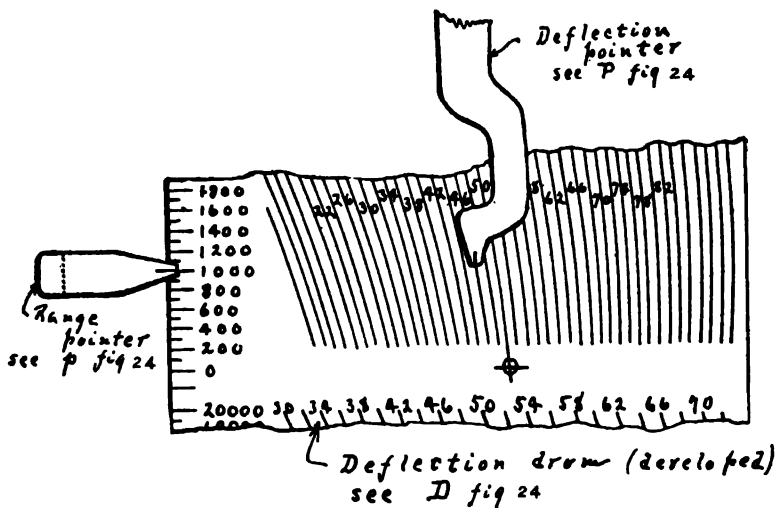


FIG. 25.

line that has the same number as the speed-line to which the pointer's sight is set, the azimuth change from the bore-sighting position will be the same in each sight.

Adjustment of trainer's sight.—Turret-guns are required to be installed so that the axes of the bores are parallel or converge slightly. In bore-sighting all three sights, if the firing is to be at long range, the position of the trainer's line of sight should be midway between the pointers' lines of sight when all scales read zero; this, of course, puts both pointers a little bit off laterally when the trainer is on. At short-range firing, where this discrepancy will amount to a considerable portion of the area of the target, the trainer should lay his line of sight a certain amount to

the right of the bull's-eye when the left gun is to fire, or a certain amount to the left when the right gun is to fire, the amount he is to aim off the bull's-eye being half the divergence between the two pointers' lines of sight.

Yoke sight-mounts.—The two lines of sight, one for the pointer and one for the trainer, with guns not mounted in turrets, are now carried on one sight-mount which is a modification of the type shown in Fig. 1. This modification, which is called the *yoke-mount*, is illustrated by Fig. 26.

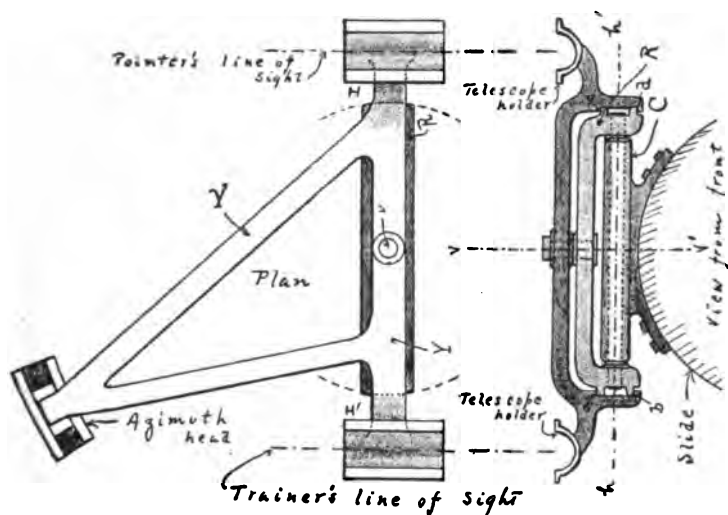


FIG. 26.

Instead of a pivot-bar we have a *yoke Y* which amounts to a pivot-bar spread out wide enough to carry a telescope on each side of the gun. The rear end of the yoke works in the azimuth-head on the sight-bar in the same manner as the rear end of the pivot-bar in Fig. 1. The horizontal sight-axis is formed by a shaft *hh'*, called the *saddle-pin*, in a casting *C* called the *saddle*, and engaging a casting *R* called the *rocker*. The vertical sight-axis is formed by the pin *vv'* which centers the yoke in the rocker. The upper and lower side edges of the rocker, *a*, *b*, *c*, *d*, are machined to arcs of circles centered in *vv'* to a working fit in the yoke; this gives stiffness at the positions *H* and *H'* where the castings called *telescope-holders* are connected to the yoke. The

left-hand telescope-holder carries the pointer's telescope; in bore-sighting, this line of sight is adjusted to the axis of bore by motion of the yoke in the azimuth-head and by motion of the sight-bar. The right-hand telescope-holder carries the trainer's telescope, and is adjustable with reference to the yoke, so that this line of

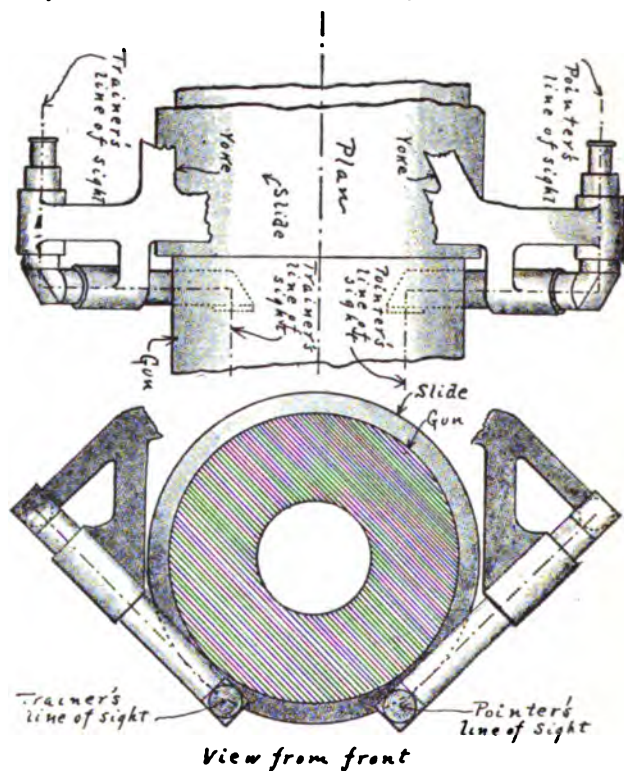


FIG. 27.

sight can be directed to the point of intersection of the axis of bore and the pointer's line of sight; the mechanism of this adjustment is not shown in the figure. The sight-bar, and sight-bar bracket, are the same in principle as those in Fig. 1.

Periscopic sights for broadside guns.—With the sight-mount shown in Fig. 26, the wide distance between the two lines of sight makes the opening in the gun-shield very large. Besides this, the effective arc of train of the gun is considerably less than

the actual arc that the gun covers in moving from one edge of the port to the other; the pointer's line of sight will be masked when the gun is at extreme train left, and the trainer's line of sight will be masked when the gun is at extreme train right. These two faults are corrected by using *prism telescopes* in which

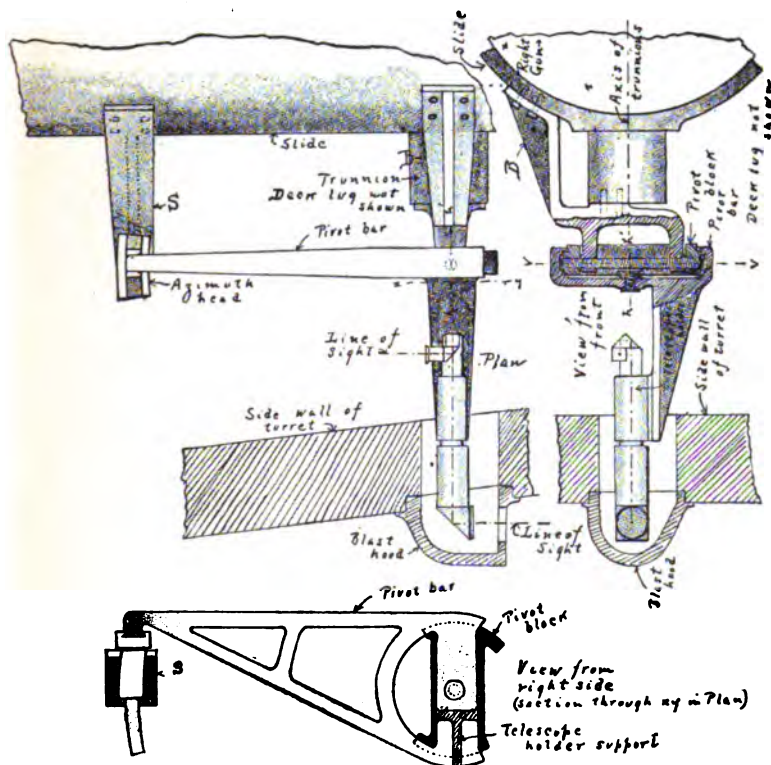


FIG. 28.

the line of sight, in effect, is turned through two right angles, as shown in Fig. 27. The sight-mount for these telescopes is practically the same as the mount shown in Fig. 26; so it will be sufficient in Fig. 27 to show a portion of the yoke, with the telescope-holders, and the positions of telescopes relatively to the gun when the sight-bar is set at zero.

Periscopic sights for turret-guns.—Troubles with the adjustment and difficulties with the installation of parallel-motion sight-

mounts have led to the design of a prism-telescope in which the line of sight is, in effect, turned through two right angles. This telescope is placed so that it projects through a hole in the side of

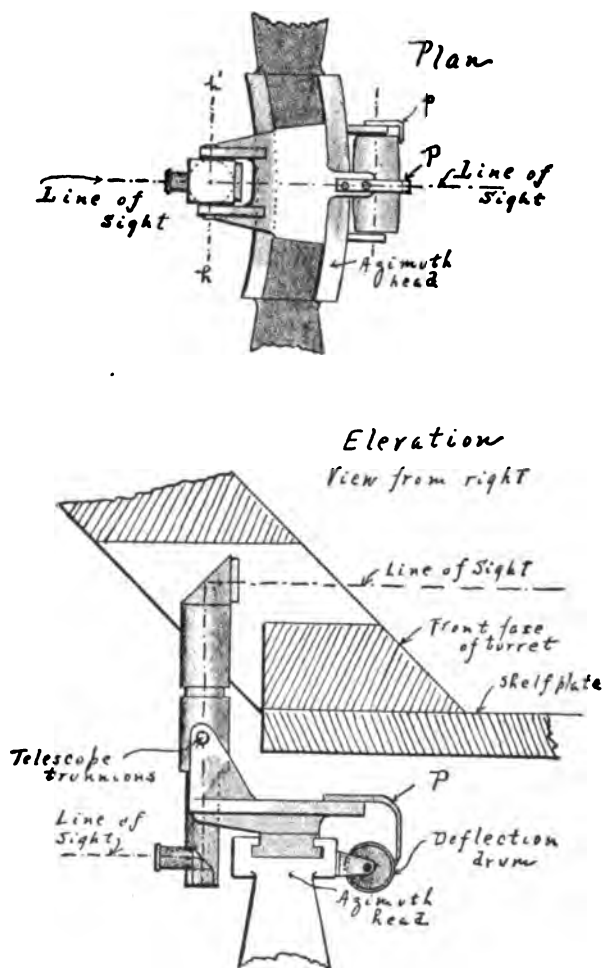


FIG. 29.

the turret in line with the axis of the trunnions of the gun, as shown in Fig. 28. It is carried in a sight-mount similar in principle to the mount shown in Fig. 1; being attached directly to the slide and trunnion, it has no parallel-motion mechanism.

The fixed parts of the sight-mount are the sight-bar bracket *B*, bolted to the slide and trunnion, and the sight-bracket *S*, bolted to the slide. The pivot-block engages the shaft-pin *vv'*, which journals in the sight-bar bracket, and forms the vertical sight-axis. The pivot-bar is machined to bearings on the top and bottom of the pivot-block in order to give lateral stiffness to the support for the telescope-holder; it also engages the pin *hh'* which is tapped into the rocker and forms the horizontal sight-axis. The two sight-axes intersect at right angles. The rear end of the pivot-bar works laterally in a slot in the azimuth-head, which, with the sight-bar and sight-bar bracket, is practically the same as in Fig. 1. On account of the flatness of the trajectory of the gun with which this sight is used, the range- and deflection-scales are of the multiplying type. The directions of the line of sight at the objective end and eye-piece end of the telescope are shown in dot-and-dash lines on the plan. The outer end of the hole in the side wall of the turret is partly covered by a small hood called the *blast-hood*.

The trainer's telescope in turrets fitted with periscopic sights is of the same design as the pointers' telescopes, but is mounted vertically instead of horizontally. The opening for it, in the turret armor, is in the front face of the turret between the guns and close to the shelf-plate. On account of the restricted space available, the mount for this sight, as shown in Fig. 29, is somewhat different from the trainer's sight-mount shown in Fig. 24. Here, instead of a pivot-bar, the part that carries the telescope-trunnions moves in a slot in the azimuth-head which is machined to the arc of a circle that has a virtual center corresponding to the vertical axis of the pivot-bar in Fig. 24. The deflection-drum and pointers are practically the same as in Fig. 24, but the sight-setter's position is in front instead of in rear of the trainer.

Latest turret-sights.—On the latest turret-guns a yoke-sight is installed, but instead of being pivoted to the top of the slide it is pivoted underneath. It is fitted with a prism telescope. The line of sight from the objective end of the telescope is underneath the guns. The guns are fitted with shields which give the protection made necessary by the larger port openings in the front face-plate of the turret.

A **bore-sight** is a telescope-sight mounted as shown in Fig. 30. The telescope-holder *H* screws into a threaded hole in the center of the casting *D*, called the *breech-disk*, which is machined to fit into the screw-box of the gun with which the bore-sight telescope is to be used. The telescope is mounted in its holder by a ball-and-socket joint *J*—the center of the ball, *c*, being in the axis of the holder and the geometrical axis of the telescope. The specifications for the telescope require its line of sight to be coincident with its geometrical axis; thus *c*, the center of the ball-and-socket, lies

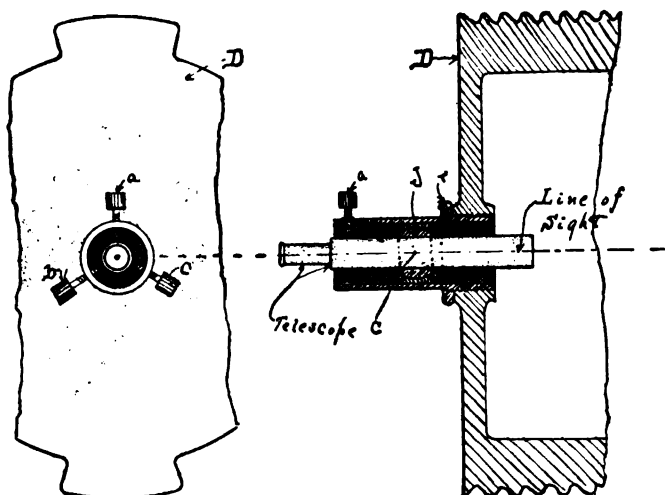


FIG. 30.

in the line of sight. The telescope is adjustable about *c* as a center of motion by means of the three thumb-screws *a*, *b*, and *c*.

There is an accessory of the bore-sight called the *muzzle-disk*. This consists of a circular casting machined to fit snugly in the muzzle of the gun with which the bore-sight telescope is to be used. It contains a central hole that is $\frac{1}{8}$ inch in diameter, if the disk is for heavy guns, but is smaller in the disks for short guns.

To adjust the bore-sight we proceed as follows:

- (1) Open the breech-plug of the gun and lash it open, so there will be no chance of its swinging part way shut and injuring the bore-sight.
- (2) Ship the breech-disk in the screw-box and clamp it rigidly in position.

(3) Enter the telescope-holder in the threaded hole in the breech-disk, screw it home, and then set up tight on the locking-ring *r*.

(4) Focus the telescope for distinct vision on an object distant not much less than one mile, by moving the eye-piece tube in or out. The cross-lines of this telescope are permanently fixed in the second focal plane of the objective; so there should never be any appearance of parallax when sighting on a distant object.

(5) Ship the muzzle-disk; see that the lip on its periphery touches the face of the muzzle all around.

(6) By motion of the thumb-screws *a*, *b*, and *c*, direct the line of sight of the telescope to the hole in the muzzle-disk. Since this hole is comparatively close, its image will lie in rear of the cross-lines and will appear as an indistinct, rather large, round bright spot. We would have considerable parallax between the cross-lines and this image if it were not for the fact that the brass cover on the eye end of the telescope has only a small opening, and therefore the eye cannot move much off the axis of the telescope without losing sight of the image. When the intersection of the cross-lines appears to lie in the center of the image, see that the three thumb-screws are set up tight. On a cloudy day, there may not be enough light through the hole in the muzzle-disk to make the cross-lines visible. In this event the lines can be seen by means of a portable electric light hung inside the breech-disk, a little to one side of the telescope.

(7) Test the adjustment of the bore-sight by rotating the muzzle-disk through 180° ; if this makes no difference in the apparent position of the intersection of the cross-lines on the image, it is evident we have placed the line of sight coincident with the axis of the bore.

(8) Remove muzzle-disk.

After the bore-sighting of the gun has been completed, put the muzzle-disk in again and see if the bore-sight line of sight is still coincident with the axis of bore. Then unship bore-sight telescope and both disks, and stow them away.

Notes on Care and Handling of Telescopes.

General directions.—Telescopes should never be dismounted unless it is absolutely necessary, and then only by an officer or other person skilled in such work.

As optical parts of a telescope are not interchangeable, one telescope should be completely reassembled before starting to disassemble another. A line scratched across a joint between two parts of a telescope before disassembling, will facilitate reassembling.

The objective lens is provided with a cover, and it should be kept in place at all times when the telescope is not in use; otherwise the sun will cause the balsam cement to crystallize.

When possible, telescopes should be stowed in a warm, dry place, in boxes provided for them.

Telescopes should be cleaned with a dry cloth (nothing else), and the cloth should never touch the lenses.

Special care should be taken to prevent injury to pentagonal bearings, especially the two lower faces.

All telescopes are marked "up" on the side which should be uppermost when shipped.

Care should be taken that the telescope-holders are kept clean and smooth. Emery, etc., should never be used for cleaning them.

Whenever possible, a gun should be bore-sighted after shipping a telescope. While such telescopes as have non-adjustable cross-lines have been carefully inspected to see that the cross-line, intersection of all telescopes coincides for a distant object, bore-sighting should always be resorted to if possible after changing a telescope in the telescope-holder.

Care must be taken that the screw-heads of the telescopes are not allowed to become rusted. In all future telescopes, these exposed parts will be made of Monel metal. Frequent examination of these should be made to see that they are not slacked back.

Do not tamper with the bolts which are used to fasten together the flanges of the various parts of a prismatic telescope. This adjusting can only be done by an experienced man, and requires tools not to be had aboard ship.

Cleaning lenses.—Lenses should be wiped off only when necessary, for cleaning destroys the polish, thereby diminishing the amount of light passing through. If they are very greasy, a few drops of alcohol applied with a brush and then wiped with clean chamois skin will usually be sufficient. Handle lenses by the edges. Dust can be removed by means of a dry camel's-hair brush.

Each pointer and trainer should have at hand a piece of chamois selvyt, or lens paper, so that he may be able to wipe off the eye-piece lens in case it becomes covered with moisture, as it does sometimes. In no case use waste. A few small holes punched in the rubber eye-guard will tend to correct this trouble.

In cleaning the objective lens of a telescope when in place, special attention must be given that the objective lens does not rotate, as this will cause large errors in the line of collimation.

Compound lenses are usually cemented together with Canadian balsam, which is soluble in alcohol; hence care must be taken that too much alcohol is not used in cleaning.

The above remarks apply to the polished surfaces of prisms as well as of lenses.

In looking through a telescope, it is well to remember that all dirt that may be seen very clearly defined must lie in or very near to a focal plane. For this reason dirt on the cross-line lens is clear and distinct, while that on the objective and eye-piece lens will appear as a blur. However, dirt on any lens lessens the amount of light that is transmitted to the eye.

In cleaning cross-line lenses, do not use alcohol, as it removes the filling-in material of the etched line.

Replacing broken cross-wires.—While all modern gun-sight telescopes have the cross-lines etched on the lens, the method of replacing a broken cross-wire in the old type is given.

Remove the diaphragm from the eye-piece tube, and scrape off the old solder from the face of the diaphragm, thus disclosing the grooves for the wires. Then remove the solder from the grooves with the point of a knife, being careful not to widen the grooves.

Place the diaphragm in a vise, being careful not to squeeze it hard enough to distort it; otherwise, after a wire is soldered in and the vise comes up, the wire will be found slack. Lay a piece of the regulation wire (platinum, .001 diameter) across the diaphragm in the grooves, the proper tension being given by the weight of a small piece of lead on each end. These are most conveniently attached to the ends of the wire by partly splitting the lead and then snipping the wire by means of a pair of pincers. After a wire has been successfully laid on the diaphragm, touch each groove with a small stick that has been dipped in muriatic acid. Then over each part of wire in a groove lay a small bit of

solder. After heating and tinning a small soldering-iron, touch each piece of solder. After soldering the first wire, shift the diaphragm in the vise and put in the second. After both wires have been soldered, carefully shave off the excess of solder from the diaphragm with a sharp knife.

Adjusting the illuminator.—The illuminator, when in correct adjustment, should render visible only the intersection of the cross-lines, and not the entire cross-line. If the beam of light should get off the intersection, it can be adjusted by means of the four set-screws at the top of the illuminator, on the outside of the telescope. Keep caps on illuminators when not in use.

Focusing.—The older type of variable-power telescope (Mark X) is focused by sliding the inner tube in or out (after adjusting the outer tube for desired power) until there is no parallax. This position of no parallax marks the position of accurate focus. Once focused at, say, 2000 yards, the telescope requires no further adjustment for any distance for which it is to be used by the same observer. A knurled ring or a lever attachment is provided on later types of variable-power telescopes for shifting from one power to the other, while the focusing is done by means of the eye-piece. In *all* fixed-power telescopes the focusing is accomplished by means of the eye-piece.

Ray-filters.—The ray-filters accompanying telescopes are to be inserted inside the rubber buffer, close up to the eye-lens. In some new telescopes, ray-filters are included in the telescope itself. The dark smoked one is for night use against searchlights, while the amber-colored one is for day use.

CHAPTER IX.

GUN-MOUNTS FOR SECONDARY-BATTERY AND MINOR-CALIBER GUNS.

Nomenclature of Gun-Mounts.

The mount.—The entire system interposed between the gun and the structure of the ship which serves to support the gun, secures it to the ship's structure, and provides for its elevation, train, recoil, and counter-recoil, shall be known as the *mount*.

The mount consists of the following parts: (1) *Stand*, (2) *carriage*, (3) *slide*, (4) *sleeve*. One or more of these parts are missing from mounts of certain types, and in those of other types two or more are combined.

The parts are defined as follows:

(1) The *stand* is that part of the mount which is secured to the structure of the ship, and in or upon which the carriage rests and is moved in train.

(2) The *carriage* is that part of the mount, borne in or upon the stand, in which are the trunnion-seats; the carriage moves with the gun in train, but is fixed in elevation, the gun moving in elevation in or upon it.

(3) The *slide* is that non-recoiling part of the mount of which the trunnions form a part and in, through, or upon which the gun moves in recoil and counter-recoil; it moves with the gun in train and elevation.

(4) The *sleeve* is found in mounts of a few types only; it is rigidly secured to the gun and moves with it in recoil and counter-recoil in or upon the slide.

Application of the Nomenclature.

Turret-mounts.—*Stand*: None; its place is supplied by the structure supporting the turret.

Carriage: The deck-lugs in combination with the turret itself.

Slide: In all, except the earlier hydraulic-return mounts, the sleeve encircling the gun to which the recoil cylinders are secured. In the earlier mounts, the slide-rails on which the gun moves in recoil.

Sleeve: None in the later mounts; in the earlier mounts, the part known heretofore as the "saddle" or "cradle."

Pedestal mounts (so called).—This class embraces all the 3-inch, 4-inch, 5-inch, 6-inch, and 7-inch mounts designed in the last seven years, and the application of the nomenclature needs no explanation. These mounts have no sleeves.

In the earlier 4-inch mounts, the arrangement is the same as in the recoil mounts for minor-caliber rapid-fire guns hereinafter described.

Non-recoil rapid-fire mounts.—These consist of *stand* and *carriage* only.

Recoil mounts for minor-caliber rapid-fire guns.—(1) In mounts designed for trunnion guns, the part sometimes called the "combined cylinder and trunnion bearing" is the *sleeve* of the present nomenclature. The so-called "oscillating slide" is the *slide*. The "saddle" and "saddle pivot" are the *carriage*.

(2) In mounts for trunnionless guns, the combined sleeve and recoil cylinder is the *sleeve*; the other parts are as in other mounts.

Field-mounts.—The *stand* is the vehicle on which the gun is transported, commonly called the "field-carriage." It also performs one of the functions of a *carriage*, as it is that part which trains with the gun.

The cylinder through which the gun recoils is the *slide*.

Stands may be "pivot-stands," "cage stands," "rail sockets," "port-sill sockets," "military-top stands," "boat stands," "pillar stands," "field-carriages," or any of numerous other special types.

In general, type-names, such as "turret," "pedestal," "port-sill," "military-top," "rail," "boat," "field," etc., are sufficiently descriptive of a mount, and the names of the several parts may be used without modifying words.

While nearly all mounts are now hydraulic-recoil and spring-return, there are still in service some non-recoil mounts and hydraulic-return mounts, so that these terms must be used to give a complete description of a mount.

Discussion—Definitions.

The principal requirements of a modern gun-mount are:

(1) Safety under all conditions, which necessitates proper design and requisite strength of materials; (2) rapidity, ease, and smoothness of working; (3) durability; (4) simplicity; (5) gradual absorption of the shock of recoil and its dispersion over a sufficient area of the ship to prevent injury to the ship's structure; (6) good control of the motive power, which, whether it be hand-power or other, should be powerful and reliable; (7) provision for substituting hand-power, as far as practicable, if other motive power is ordinarily used; (8) interchangeability of parts of mounts of same mark.

All modern guns have an arc of elevation as follows: Turret-guns, 15° elevation, 5° depression; secondary-battery guns, 15° to 20° elevation, 10° to 15° depression. The train is usually limited only by the form of gun-emplacement.

Mounts are conveniently divided into classes according to the kind of recoil-mechanism used. These classes are (1) *non-recoil mounts*, (2) *hydraulic-recoil spring-return mounts*, (3) *hydraulic-recoil hydraulic-return mounts*, and (4) *hydraulic-recoil gravity-return mounts*; to which must be added (5) *field-mounts*. In all recoil mounts, means are afforded for returning the gun to battery, *i. e.*, its initial position; this mechanism usually *assists* in checking the recoil. In all but the smaller mounts, buffers of some form are provided for cushioning the counter-recoil. The gun recoils in line of fire except in mounts of class (4).

A hydraulic-recoil spring-return mount (all modern pedestal mounts are of this class) is one in which the recoil is checked by hydraulic cylinders, closed and kept constantly filled with a "recoil-liquid" (glycerine and water), the gun being returned to battery by the extension of spiral springs, also inside the cylinders, which are compressed during recoil. The cylinders are usually secured to a stationary part of the mount, and the piston-rods to the gun, though in some mounts the reverse obtains. During recoil the pistons move along the cylinders, and the recoil is checked by the friction of the liquid as it passes from one side of the piston to the other through apertures of variable area. The apertures consist of shallow grooves in the cylinder, not filled by the piston, and

the variable area is obtained by tapering the width of the grooves, which finally disappear when the limit of safe recoil is reached; when the gun is in battery, the position of the piston is at the widest part of the grooves, which are from three to five in number. During the counter-recoil the liquid again passes over the pistons, aiding in controlling the counter-recoil.

The *counter-recoil springs* surround the piston-rods, being held between the piston and cylinder-head under initial compression to keep the gun "in battery" as the ship rolls. Thus, when the recoil is checked, the springs are highly compressed and immediately shoot the gun out to battery. The counter-recoil is violent, and in large gun-mounts a *counter-recoil check* is fitted, which may consist of spring buffers or of hydraulic checks. In the latter case, an extension of the piston-rod beyond the piston enters a tapered hole in the front cylinder-head, or, *vice versa*, a *plunger* projecting inward from the cylinder-head enters a tapered counterbore in the piston-rod. The hole, of course, fills with liquid at the beginning of the counter-recoil and together with the plunger acts in the same manner as the main cylinder, when the gun nears its position in battery.

This counter-recoil plunger is tapered and acts as a cushion. It checks the velocity of the counter-recoil and minimizes the blow at battery caused by the rebound of the recoil springs that are in compression at the end of recoil.

A **field-mount** is one intended for shore use, and consists essentially of an axle mounted on two wheels, bearing a trail-piece with a small trail-wheel and a socket, to which is secured the gun-mount proper. Except for machine-guns, which have non-recoil mounts, hydraulic-recoil spring-return mounts are used. Train is effected mainly by swinging the whole mount on its wheels; the elevating-gear is fitted to the non-recoiling part of the mount. The general navy method is to carry ammunition on the gun-mount, as a combination of "limber" hooked to the trail of the mount is too heavy to be dragged by men.

A **turret-mount** is one in which heavy guns are mounted in an armored structure which is revolved on rollers by suitable machinery, the guns being elevated independently of the structure.

The **training-gear**, hand or power, is the machinery that revolves the movable parts of the gun-mounts, to which parts it is secured in all except turret-mounts.

The **elevating-gear**, hand or power, is that machinery secured to the carriage which, working on the breech end of the gun-slide, elevates or depresses the gun's muzzle. On firing, the gun (which, with its powder charge and projectile, was balanced at the trunnions) moves to the rear, thereby disturbing this balance because the extra weight of gun to the rear of the trunnions is very much more than the weight lost in the discharge of charge and projectile. This preponderance of weight to the rear of the trunnions tends to cause the breech to fall and the muzzle to rise, thus bringing a strain on the elevating-gear. This strain is relieved by (1) *spring-buffers* or by (2) *friction-disks*.

In the first method, a *worm* which is indirectly secured to the carriage gears with an *arc* which is part of the slide; this worm works on its shaft by a feather, being capable of longitudinal motion along it, and is supported from one end by a spiral spring surrounding the shaft. When the jump occurs, the worm is forced along its shaft and the spring takes up the shock without injury to the mechanism and returns the gun to its first position.

In early turret-mounts, the same principle is applied in a different manner, and a hydraulic cylinder called the *dash-pot* is associated with the spring. The dash-pot supports the lower end of the elevating-shaft. In later turret-mounts the dash-pot is omitted.

The second method is the one now in general use, and operates as follows (see Plate I): An *elevating-arc* (or arcs, one on each side) is secured to the slide. This arc has teeth on its forward concave side. Into these teeth gears a *pinion*, carried on a horizontal shaft which has bearings in the elevating-bracket of the carriage. On the other end of this shaft is the *elevating worm-wheel*. This worm-wheel gears with a *worm* on the elevating-shaft. By turning the elevating hand-wheel, the shaft and worm are turned. This turns the worm-wheel and pinion. The pinion, gearing in the elevating-arc, moves the gun in elevation. To relieve the strain on the elevating-gear, the worm-wheel is secured to the horizontal shaft by friction-disks, instead of being directly secured. When the jump occurs, the arc causes the pinion and shaft to turn, and these disks permit the worm-wheel to slip around

the shaft, as long as the elevating-arc puts sufficient pressure on the pinion teeth, and thus cushions the shock.

In this latter method the gun will not return to its former position, but will usually be somewhat elevated after firing; this is a disadvantage, but since the spring method violently strains the connecting parts, the friction device is preferred. The training-gear has a friction-disk arrangement also, but of fewer bearing-surfaces. The "multiple-disk" device is used for the elevating-gear, and consists of a number of brass disks, keyed to the shaft, bearing on an equal number of steel disks, keyed to the elevating worm-wheel.

Metals Used in Gun-Mounts.

Gun-metal is commonly used for most parts of 6-pounder and smaller mounts. For larger mounts this metal is not reliable, particularly for the large parts, such as the pivot-stand, saddle, etc., for which parts cast steel of good quality is used. The castings are made by private contractors and, after being tested, inspected, and passed upon by the government inspectors, are sent to the Naval Gun Factory at Washington, D. C., where the parts are machined and assembled. The principle in designing is to avoid having steel on both sides of a working surface. This is accomplished by making one of the parts of gun-metal, if small; or, if both parts are large, by bushing one of them with it. For example, the insides of the sleeve and trunnion-seats are so bushed in recent mounts, and the pistons of gun-metal work inside cast-steel recoil cylinders.

6-Pounder Mount, Mark IX. (See Plate II.)

The **Mark IX** mount is a hydraulic spring-return mount for trunnionless 6-pounders. These 6-pounders may be used as semi-automatic or as R. F. guns. The recoil system is similar to that of pedestal mounts, the gun being attached to the piston-rod, and recoiling through the slide. There is only one recoil cylinder.

The mount consists of the *slide*, including the recoil cylinder; the *carriage*; the *stand*; and the *shoulder-bar*.

The gun fits closely in the slide, which has oil-holes for admitting oil to its inner surface to reduce the friction of the sliding gun. The slide is fitted with trunnions which rest in the trunnion-seats of the carriage and permit the gun and slide to be moved in elevation. Cap-squares and cap-square bolts secure the trunnions.

The carriage, a Y-shaped casting, has its base as a pivot to fit in the socket of the cage-stand, thus permitting motion of the gun in train.

A shoulder-bar, by which the gun is pointed in train and elevation, is fitted to the slide on the left side. It is fitted on its rear side with a hollow rubber *buffer*, or cushion, and at its lower end with wooden handles. The gun-pointer places his left shoulder firmly against the buffer, and grasps the wooden handle most convenient, with his left hand. With his right hand he grasps the pistol-grip. The *deflector* is a curved metal piece attached to the shoulder-bar to deflect the extracted empty cartridge-cases downward and prevent their striking the gun-pointer.

In this 6-pounder mount the sight is fitted far enough to the rear to enable the gun-pointer to keep his eye at the telescope buffer during firing.

The gun may be clamped in any position of its elevation by the *elevating-clamp*, and in any position of its train by the *training-clamp bolt*. The gun is clamped in elevation as follows: A clamp-bolt, with handle, turns through an elevating-clamp bracket attached to the left side of the carriage. This bolt, when set up, presses firmly against the elevating-clamp arc attached to the slide. This pressure holds the gun firmly in any position in elevation. The 6-pounder is the largest gun in the U. S. Navy that is trained and elevated in this manner; that is, without elevating- and training-wheels, gearing, etc.

PEDESTAL MOUNTS.

The term "pedestal mount" is now applied to 3-inch, 4-inch, 5-inch, 6-inch, and 7-inch gun-mounts. The term explains itself. These mounts may be placed close to the side of a ship, thereby giving a greater arc of train for a given size of gun-port. It may be stated here that the yoke-sight fitted to a secondary-battery gun brings the line of sight some distance to the right or left of the gun's longitudinal axis. This reduces the arc of train in which the gun can be properly aimed, as the line of sight is cut off before the gun reaches extreme train. Beginning with the 5-inch mount, Mark XIII, the line of sight leaves directly under the gun, thus permitting accurate aiming at the extreme train allowed the gun.

The pedestal mounts for 4-inch, 5-inch, and 6-inch R. F. guns are similar in their principal features. The method, in general, of training, elevating, checking recoil and counter-recoil is similar in all mounts from 3-inch to, and including, 7-inch. The gearing used in transmitting motion of hand-wheel to gun, in train and elevation, is different in different guns. However, any one having a knowledge of the working of a 3-inch and 6-inch mount will readily understand the operation of any of the broadside mounts in the U. S. Navy. It is not deemed advisable to attempt to give a description of the many different mounts in the service.

The following parts of all broadside gun-mounts, though differing in size, shape, fit, etc., in various mounts, have the same object: (1) *Slide and recoil cylinders* in one, (2) *recoil mechanism*, (3) *carriage*, (4) *stand*, (5) *elevating-gear*, (6) *training-gear*.

In general, mounts have the following similarity: The gun fits closely in the *slide* and recoils through it, the bearing-surfaces being well oiled to reduce friction. To the gun, near the breech, is secured a band, called the *yoke*, by means of which the gun is connected to the two *piston-rods* and *pistons* which work in the *cylinders*. The cylinders are a part of the slide. Thus, the gun, piston-rods, and pistons go to the rear when the gun is fired. The casting composed of slide and cylinders is fitted with *trunnions* which rest in the *trunnion-bearings* of the carriage, permitting motion of gun in elevation. The *carriage* in turn either pivots in, or fits over, the *stand*. This fitting permits motion of the gun in train. Either ball-bearings or rollers are interposed between carriage and stand to reduce friction.

All pedestal mounts were originally trained by gearing. A *training-rack* was fitted to the stand, and a system of shafts and gearing, resting in bearings on the carriage, ran from the hand-wheel and ended in a *pinion* on a vertical shaft. This pinion, gearing in the rack, gave motion to the carriage. This system is still in use on many mounts; but, owing to a great deal of lost motion between the rack and the pinion, an improvement was necessary, and, after various experiments, *worm gearing* was adopted for all mounts of this kind. The worm gearing can be adjusted to take up the lost motion. Friction gearing was tried and extensively adopted, but proved unsatisfactory. (See Plate I, illustrating friction training-gear.)

At the time the first pedestal mounts were designed, it was intended that the gun-pointer should do all the work of pointing, sight-setting, and firing. To this end, the elevating- and training-gears were arranged on several different plans, all of which placed the two hand-wheels within reach of the pointer at the sight on the left side. One plan placed the elevating-wheel on a sleeve around the training-shaft, and the two wheels were concentric and close together, making it impossible to work both at once, and at the same time be ready to fire. It was found, at about the same time, in other services, that the best results are not obtained in this way and that pointing in elevation and firing are quite enough for one man. In the division of duties, the trainer has to do solely with lateral pointing—he may work from the left side, conned by the pointer, or he may use the training-gear and sight on the right side. Good results may be obtained in either way, but we now give the trainer a sight and training-wheel on the right side.

Under the modern requirements, in which the sights are to be held on the target throughout a string of shots, fired while the ship is rolling, the pointer has the most difficult and fatiguing duty, and the elevating-wheel should be placed advantageously for him. The proper place for the elevating-wheel is a little below the pointer's shoulder, with its plane vertical and nearly parallel to the vertical plane through the axis of the bore. All future mounts will fulfill this condition; those pedestal mounts otherwise constructed are being rapidly converted.

Pointers rest both shoulders against rubber buffers and grasp a handle in each hand. These handles are at opposite sides of the

center of the wheels, so that the motion of the hands in training or elevating is similar to the motion of the pedals of a bicycle. An electric firing-connection is made with one handle, so that the pointer does not release his hand in firing. The two-hand drive is an improvement over the one-hand. The installation of the training-wheel is not of so great importance, but any hand-piece which controls the pointing of a heavy gun needs great leverage to obtain the delicate movements required. Some mounts are fitted for train and elevation on both sides; some have train and elevation on the left side and train only on the right side; the late mounts have elevation to left and train to right.

The principle and general arrangement of the elevating-gear of the various pedestal mounts are similar.

All modern pedestal mounts are fitted with yoke-sights which are capable of movement in two planes.

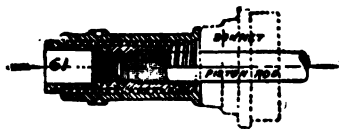
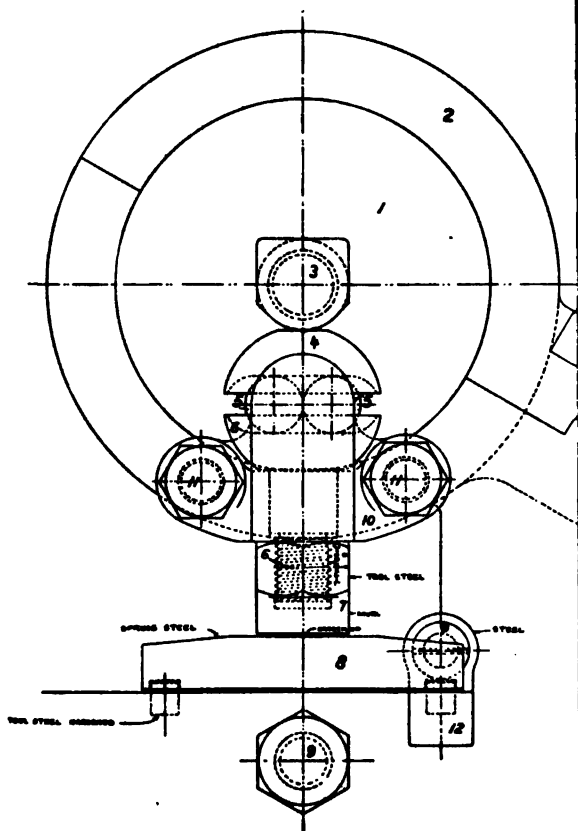


FIG. 1.—COMPRESSOR.

A **compressor**, for use in dismounting or assembling recoil cylinders, is supplied to all ships. (See Fig. 1.) In dismounting, detach the gun from its piston-rods and run it in out of the way. Screw the compressor on the end of the piston-rod until it brings up against the rear bonnet of the cylinder. Then an inner sleeve, which has engaged the thread on the rod, is screwed to the rear by a threaded shaft and brings the rod with it, compressing the springs. When the piston is clear of the forward cylinder-bonnet, the latter may be removed. The compressor is then worked backward, easing the piston-rod through the cylinder until the springs are fully extended, whereupon the compressor is removed and the recoil mechanism is withdrawn.

Gun-shields.—In addition to the stationary armor around the gun-emplacment, the gun is protected by a 3-inch cylindrical shield secured to the carriage by U-shaped brackets. These are arranged to give as much cushioning under a blow as possible. The shield, training with the carriage, is concentric with the mount and completely closes the gun-port. The only opening is

CHAPTER IX. PLATE III.



Side View.

FRictionless

the port through the middle of the shield, which is only sufficient to permit the gun to be elevated through its prescribed arc, and give the pointer an opening to see through.

Shields of various forms, designed to protect the mounting and gun-servants from small projectiles, are in many cases supplied to unarmored ships as well. They are built on the deflective system, with the thickest portion normal to the line of fire. Obviously, shields must be attached to the carriage.

In the latest 14-inch turrets the guns are fitted with shields. When periscopic sights are used on turret-guns, the port opening in the face-plate of the turret can be kept small. In the latest 14-inch turrets a form of yoke-sight is used which necessitates a larger port opening, to accommodate the line of sight, which is under the gun. For this reason shields are used on the guns. They make virtually a complete protection, as the only vulnerable point is the small opening in the shield for the line of sight.

Frictionless trunnion-bearings (see Plate III).—Friction in training is greatly reduced by suitable bearings; the same weight, less that of the carriage, has also to be moved in elevation and, since a great deal of elevating is required in maintaining a “continuous” aim, an arrangement that will minimize friction at the trunnions is also needed. A device which utilizes spherical rollers has been adopted.

A small supplemental *trunnion* (3), with rounded lower side, is screwed into the *slide-trunnion* (1), which is held to the carriage by an ordinary *cap-square* (2). The small trunnion bears on a *shelf* (4), which in turn rests on two hard steel *balls* (5) in a shallow *trough* (6), which is supported from the carriage. While the gun is being worked, its weight is to rest on the shelf (4), which is moved back and forth on the rollers by the motion of (3), the lower side of which is *not* at the center of rotation of the trunnion—as may be seen in the plate. The carriage and cap-square embrace the slide-trunnion closely and, when the gun is fired, the elasticity of the parts of the frictionless device permits most of the shock of recoil to be received by these heavier parts.

The trough (6) rests on an elastic steel bar (8) which is secured to the carriage by *lugs* (12) and *tap-bolts* (9). The trough is held from turning or falling outward by a *bracket* (10) secured to the carriage by *bolts* (11).

The height of the shelf must be such that all the weight rests upon it; the adjustment is made by the *nut* (7), which raises or lowers the trough by its support. In making the adjustment, the rule is to raise the shelf until a thin piece of paper can be inserted under the slide-trunnion—about the same space should be left all around it. In the first mark of the device, the adjusting-nut is often somewhat inaccessible. In the latest form a part of the trunnion (3) is the adjustable part; the troughs are longer and four balls are employed in place of two.

In the latest turret-mounts, a wedge device is fitted which permits the frictionless trunnion to be adjusted for parallelism. Previously to this, turret-guns had no way to compensate for initial faults in the installation of the guns. For this reason almost every pair of turret-guns either converged or diverged; rarely were they exactly parallel. For instance, the forward-turret guns of a ship might converge at 5000 yards range, while the after-turret guns diverged 50 yards at this range. There was no way to overcome this defect, except to rebore the trunnion-seats and true the guns up with trunnion-seat bushings. With this late device, the guns of a turret can be adjusted for parallelism with each other as well as for parallelism with their sights. This device being confidential, no description of it can be given.

5-Inch Mount, Mark XIII, Mod. II.

The 5-inch Mount, Mark XIII, Mod. II, embodies all the late improvements in pedestal mounts. Like all other mounts of this class, it consists essentially of stand, carriage, slide and recoil cylinders, elevating and training systems, yoke-sight and shield. Its distinctive features are as follows:

(1) Prismatic telescopic day sights for both pointer and trainer, whereby the line of sight is deflected through two right angles. By this device the eye-piece lens of the telescope is at the side of the gun and at the normal height of a man's eye, while the objective lens is under the gun. This sight overcomes the old fault of the yoke-sight, in which either the pointer's or the trainer's line of sight was obscured by the edge of the gun-port long before the gun itself had reached the extreme limit of train as determined by the gun taking against the edge of the port. It also greatly reduces

the opening in the gun-shield, and therefore adds to the protection of the crew.

The sight-brackets are massive and well designed to stand service use.

(2) Two-hand drive-wheels are used for both elevating and training. These wheels are installed at such a height and in such a position as to enable the pointer and trainer to operate them with a minimum amount of exertion and movement of the body. This feature aids in good pointing and training, as the operators can hold their eyes steady at the telescopes. The drive-wheels are each provided with two handles on spindles, so that it is never necessary to shift the grip as the wheels rotate. The inner handle on each side contains an electric firing-key which makes it possible to fire without ceasing the motion of pointing or training. Two firing-keys are provided, though that of the pointer is ordinarily used.

(3) Body-rests for both pointer and trainer enable them to assume a comfortable and well-braced position when sighting and operating their respective gears.

(4) One heavy elevating-arc and pinion under the center of the gun is provided. The elevating-arc has a longitudinal rectangular section cut out of the center of the threads. This section is fitted with a toothed feather of the same shape as the section cut out. By means of an adjusting-screw, this longitudinal section can be moved to take up the lost motion between the arc and the pinion.

(5) The training-gear operates through a system of worms and worm wheels. This system has been found best for overcoming lost motion. These systems are enclosed in metal casings to keep out dirt from the gears and to hold lubricators.

(6) The training- and elevating-gears are each provided with variable-speed clutches which can be operated by the throw of a lever placed where the operator can easily reach it.

(7) Improved frictionless trunnion supports, or "knife-edges," encased to protect them from sea and weather.



1

CHAPTER X.

12-INCH TURRET-MOUNTS.

The following description of a 12-inch turret-mount is general. On account of the transitory stage in the development of turrets, no special mount has been taken in its entirety. As far as possible in the descriptions of the various parts of the mounting, those types have been taken which at this date have proven most satisfactory.

Plate I is a vertical longitudinal section between the guns, showing the left gun in profile, of a 12-inch turret provided with two-stage shell-hoists, and for passing powder by hand. Plate II is a transverse section, showing general arrangement of the recoil system in profile, of a Mark VII mount. Plate III is a plan of the upper handling-room of the turret shown in Plate I. Plate IV is a plan of the lower handling-room of the same.

The principal parts of the mounting are:

(1) The *gun* and *gun-slide*, (2) the *recoil cylinders*, (3) the *deck-lugs*, (4) the *elevating-gear*, (5) the *ammunition-hoist*, (6) the *rammer*.

All machinery of a modern turret is electrically operated and controlled.

The electrical gear of a modern turret consists essentially of the following:

Two *training motors* with (1) series armature resistances, (2) field-regulating resistance, (3) controller, (4) such overload relays, circuit-breakers, etc., as may be required.

When the Cutler-Hammer system is used, there are two sets of two motors each. The system now in general use is the Waterbury Tool Company's system. Both systems will be explained later.

Two *gun-elevating motors*, constant-speed shunt motors connected to the Waterbury Tool Company's universal-speed oil motor, are the only motors now installed. The motor has an ordinary starting-panel with armature resistance in series. An overload will throw the circuit out, but there is no voltage release on the recent designs of starting-panel.

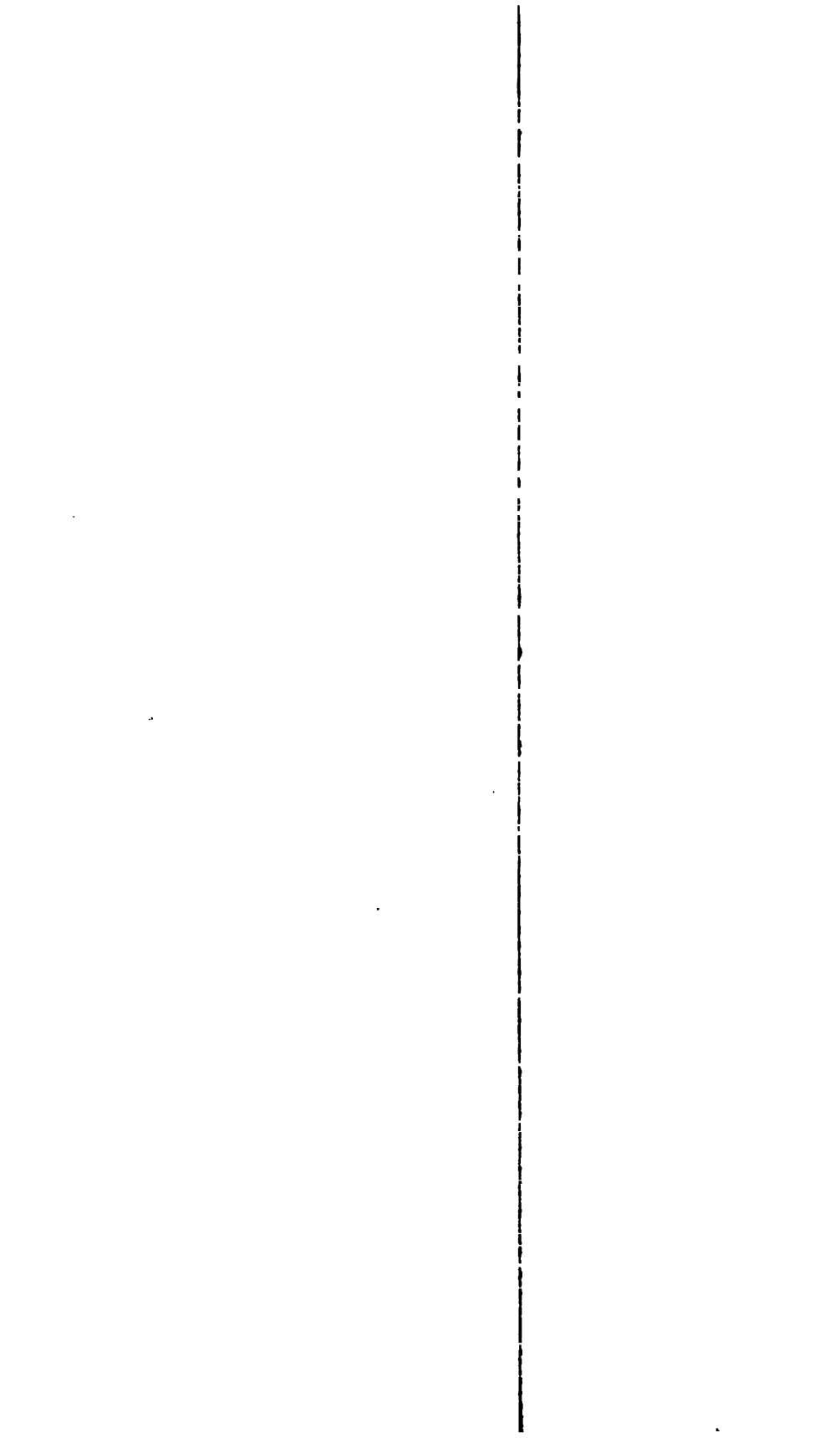
Rammer motors, compound-wound, with hand controller. When used to ram both shell and powder, an automatic limit switch is provided to limit the extension of the rammer in loading the powder-bags.

Breech-operating motors, continuously running shunt motors with starting-panel and rheostat. The motor is thrown into engagement by a mechanical clutch. These motors are installed on only a few ships, and are no longer provided.

Ammunition-hoist motors, continuously running, compound-wound motors operating through mechanical clutches and provided with controller and rheostat, are the latest type in use with fixed length of hoist. When guns are loaded in any position, the following are used: (1) Shunt-wound motor; (2) contactors for opening and closing the main circuit, connected at proper places with (3) grid resistances for controlling the armature current; (4) brake resistance, which may or may not be a part of the armature resistance, (5) master controller for opening solenoid magnets of contactors; (6) limit switch on the cable drum to cut off current automatically at proper point and control car independently of motor controller; (7) interconnecting switch for throwing in heavy balancing current when gun is depressing; (8) control panel, containing switch, fuses, voltage relay, overload relay, watching relay, etc.

The turntable, to which the turret armor and all revolving parts of the mounting are secured, is built up of steel plates and angle-irons, and rotates on live rollers which travel on a roller-path built up inside the barbette framing. The cone-shaped rollers are spaced by two floating rings which are secured to their axles; the weight of the revolving parts of the installation rests upon the rollers, and the horizontal thrust of the guns in recoiling is transmitted to the ship by their flanges. The circular barbette extends from the armored deck well above the turntable, while the guns and upper parts of their mountings are protected by the turret, which rests upon the turntable and joins with the barbette armor.

The turntable is revolved by two 25 horse-power to 50 horse-power motors, driving universal-speed oil motors which, through worms and worm-wheels, operate vertical shafts at the top of which are pinions engaging in a rack. In the turret shown, the rack is on the barbette framing, while the motors (not shown)



are attached to the base of the turntable. In some turrets this installation is reversed, the rack being on the turntable, while the motors are installed on the barbette structure.

The worm-wheel is attached to the vertical shaft by heavy friction-disks similar to those used in elevating systems of pedestal mounts. These friction-disks yield to the twist given the turret on firing one of the guns and prevent the training-gear from being deranged by it. In the Ward-Leonard system, the training-shafts are cross-connected by shafting and bevel gearing, which insures that the two motors shall turn at the same rate, and enables one motor to turn both shafts, should it become necessary. Suitable hand-gear, which may be thrown in by a clutch (at the same time disconnecting the motor), is installed at each motor.

The deck lugs, which bear the trunnion-seats and cap-squares, are heavy steel castings bolted to the turntable.

The gun-slide (Plate I), in which the gun rests, is a sleeve built up of several steel castings bolted together. It is bushed with bronze, giving the gun a bearing at the trunnions 5 feet in length and a shorter one near the breech. The trunnions are parts of the slide, and are placed at the center of gravity of gun and slide combined. Frictionless trunnion-bearings are shown.

Recoil cylinder.—The 12-inch mount, Mark VII, of the U. S. S. *Michigan*, *South Carolina*, *Delaware*, and *North Dakota*, the 12-inch mount, Mark VIII, of the U. S. S. *Florida* and *Utah*, and the 14-inch mounts have only one recoil cylinder, in which two throttling-rods are fitted. The piston reciprocates through a travel of approximately 33 inches during the recoil of the gun; two holes are bored in the piston which travels over the throttling-rods, which are secured in the cylinder-head and rear end of the cylinder. These rods are nearly the same size at the end as the holes in the piston, and the diameter is reduced in a gradual curve, increasing the area around the rods until the maximum amount of area is reached; after this point is reached, the diameter is increased by a gradual curve, diminishing the area around the rods until the end of recoil.

The cylinder is filled with 80 per cent glycerine and 20 per cent water; and from the beginning of the recoil until the maximum area is reached, the flow of liquid through this space increases in proportion to the amount of area between the rim of the hole in the

piston and the throttling-rods, thereby causing the speed of recoil to increase rapidly until the maximum amount of flow is reached. During the last part of the recoil, these conditions are reversed, and the flow of liquid through this space diminishes in proportion to the diminished area between the rim of the hole in the piston and the throttling-rods; this retarding of the flow of the liquid causes the speed of the recoil to decrease rapidly. This method of checking the recoil, in conjunction with the recoil springs, reduces to a minimum the shock on the elevating-gear, the different parts of the mount and the ship.

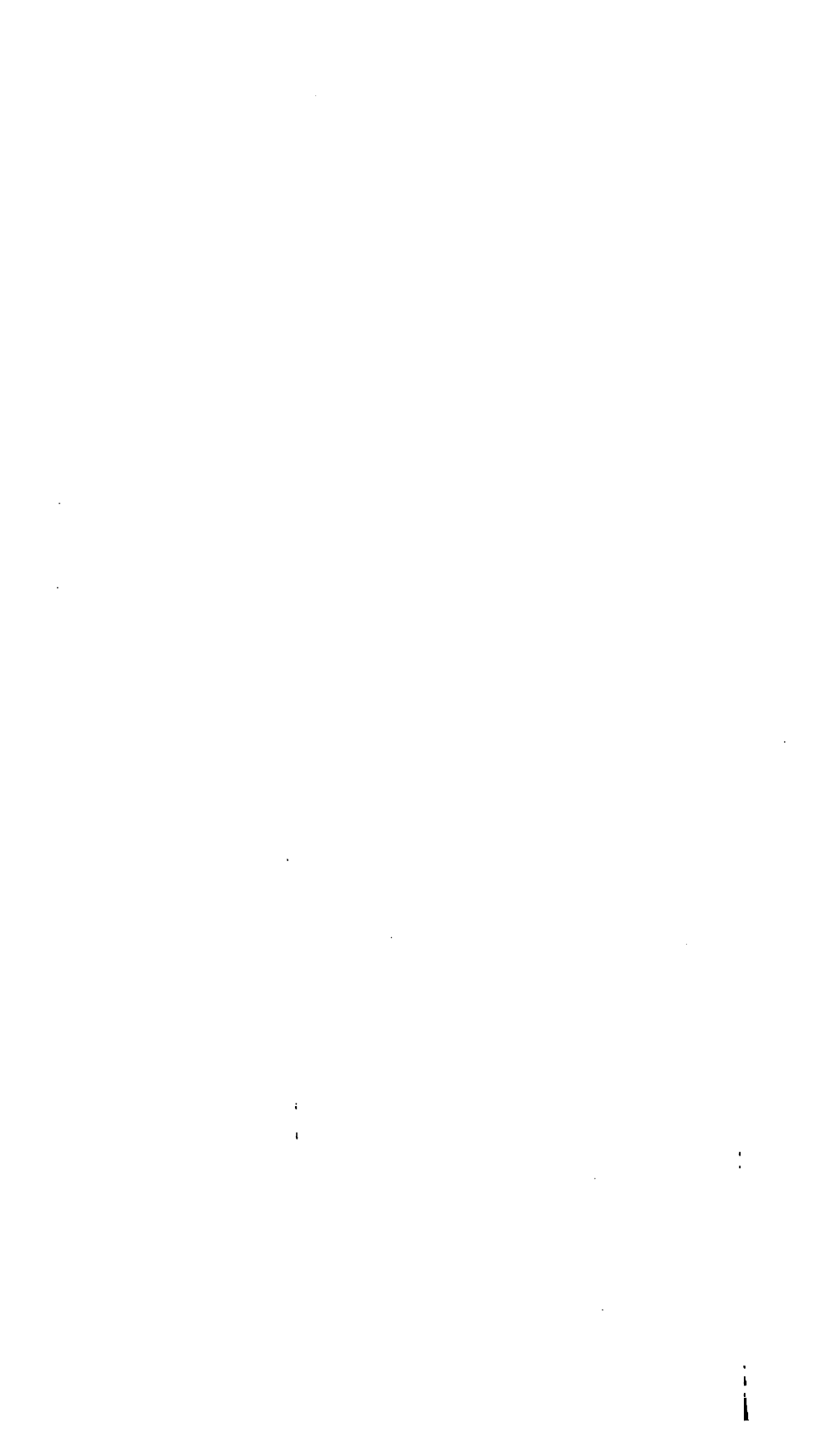
During the counter-recoil, the throttling-rods work under the same conditions as in the recoil, except that they are reinforced by the counter-recoil plunger.

In addition to the recoil cylinder, there are four counter-recoil cylinders, each containing nine sets of double springs.

The arrangement of the recoil cylinders, Mark VII mount, is shown in profile in Plate II. The recoil system of the "grass-hopper" mount of the *Connecticut* and class, the *Mississippi*, *Idaho*, *Virginia* and others, consists of four longitudinal metallic bars arranged in pairs, each having nine sets of triple springs with metallic disks between adjacent sets. These springs are not enclosed in cylinders, but are placed under the gun in the gun-pit. Heavy metallic pieces are placed over the rear face of these springs, and these are cross-connected by a yoke directly under the gun and forward of the elevating-worm. Connected to this yoke are arms, one on each side, which are connected to bottom end of a vertical arm. This vertical arm is pivoted about the middle and is very heavy. At the upper end of this arm, a horizontal bar is hinged, one on each side. These bars run aft and are secured to the yoke on the gun. As the gun recoils, the pull exerted by the force of the gun compresses the springs forward and gradually checks the gun. Then the tendency of the springs to return to their original form forces the gun quickly, but not violently, back to battery.

Directly underneath the gun are two cylinders containing the usual cylinder mixture. These, as usual, are cross-connected by an equalizing-pipe. There are no springs in the cylinders, but the inner surfaces are grooved so as to check both the recoil and counter-recoil in the usual way. The cylinders are rigid with the





gun-slide, but the piston-rods are secured to a yoke which is rigidly secured to the gun itself.

This type of mount makes it possible to do away with the old dash-pot method of absorbing the jump, the mount itself absorbing it.

The elevating-gear is actuated by a 15 horse-power motor operating a Waterbury variable-speed gear. These motors and variable-speed gears are placed beneath the guns and are fitted with hand controls operated by the pointers. The motor is connected through the variable-speed gear to the *bevel-wheel*, held by a feather to the *elevator-shaft* in such a manner that the elevator may have a slight downward motion through, but must turn with, the bevel-wheel; this mechanism is carried on a heavy bracket bolted to the turntable. By turning the elevating-motor in either direction, the elevator-shaft is revolved and, it being practically restrained from a motion of translation, the *travelling nut*, to which the lower ends of the *connecting-rods* are secured, is moved along its guides, and the breech is raised or lowered.

Ammunition-hoists have undergone frequent changes during the past ten years, but have finally assumed the closed-tube, bucket type in practically all modern ships.

The Mark IV turrets which originally had ammunition-cars carrying both shell and powder direct from the handling-room to the turret are now provided with single-tube shell-hoists for each gun, while the powder is passed up by hand. The turret is entirely closed off from the handling-room, the bucket in the hoist closing that path while the powder-bags are passed through a powder-box in the turret floor. This powder-box is provided with two doors, so connected that only one can be open at a time.

The next type is the two-stage hoist in which the cars carry both shell and powder. From the lower handling-room the lower hoist raises the ammunition to the upper handling-room, where both powder and shell are rammed by hand through flap-covered openings into the upper hoist car, which conveys them to the turret.

In two-stage hoists, the cars are balanced like buckets in a well. In single-stage hoists where only one bucket is used, the bucket is usually lowered by gravity.

Another type has two-stage shell-hoists, while the powder is passed up by hand.

A later type has single-stage shell hoists, while the powder is passed by hand. In this type the shells are stowed in an upper handling-room, whereas the powder-magazines are on the lower platform deck and open into a powder-passing room, whence the powder is passed up. Wherever hand-passing of powder is used, powder-passing boxes are provided in the turret floor.

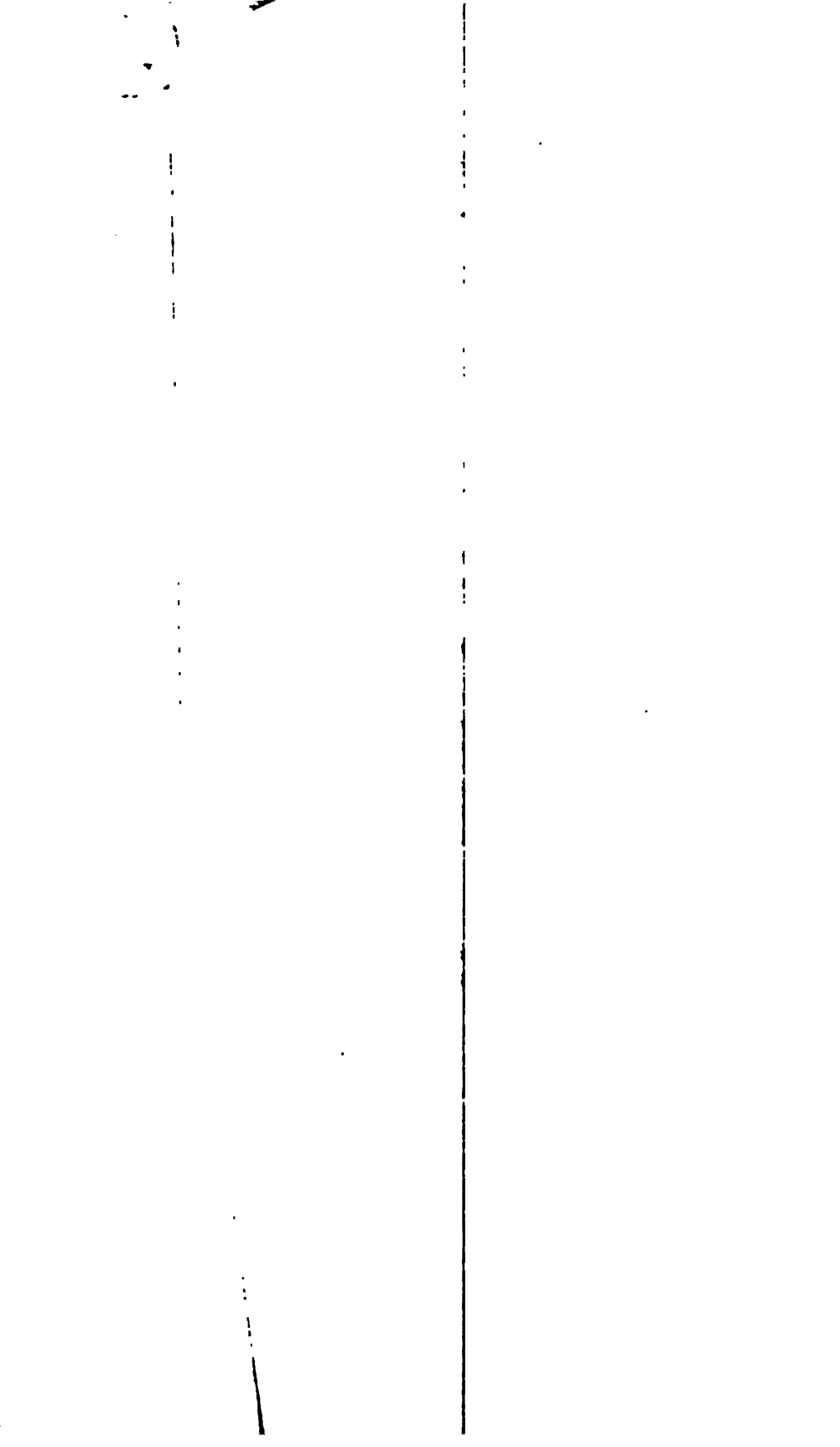
There are other combinations of shell-hoists and hand-passing of powder, but they are variations of the systems above described.

Rammers have been abolished in some ships where the shells are rammed home by hand. Both speed and simplicity are claimed for this system, especially the latter, since there is no machinery to break down or get out of order.

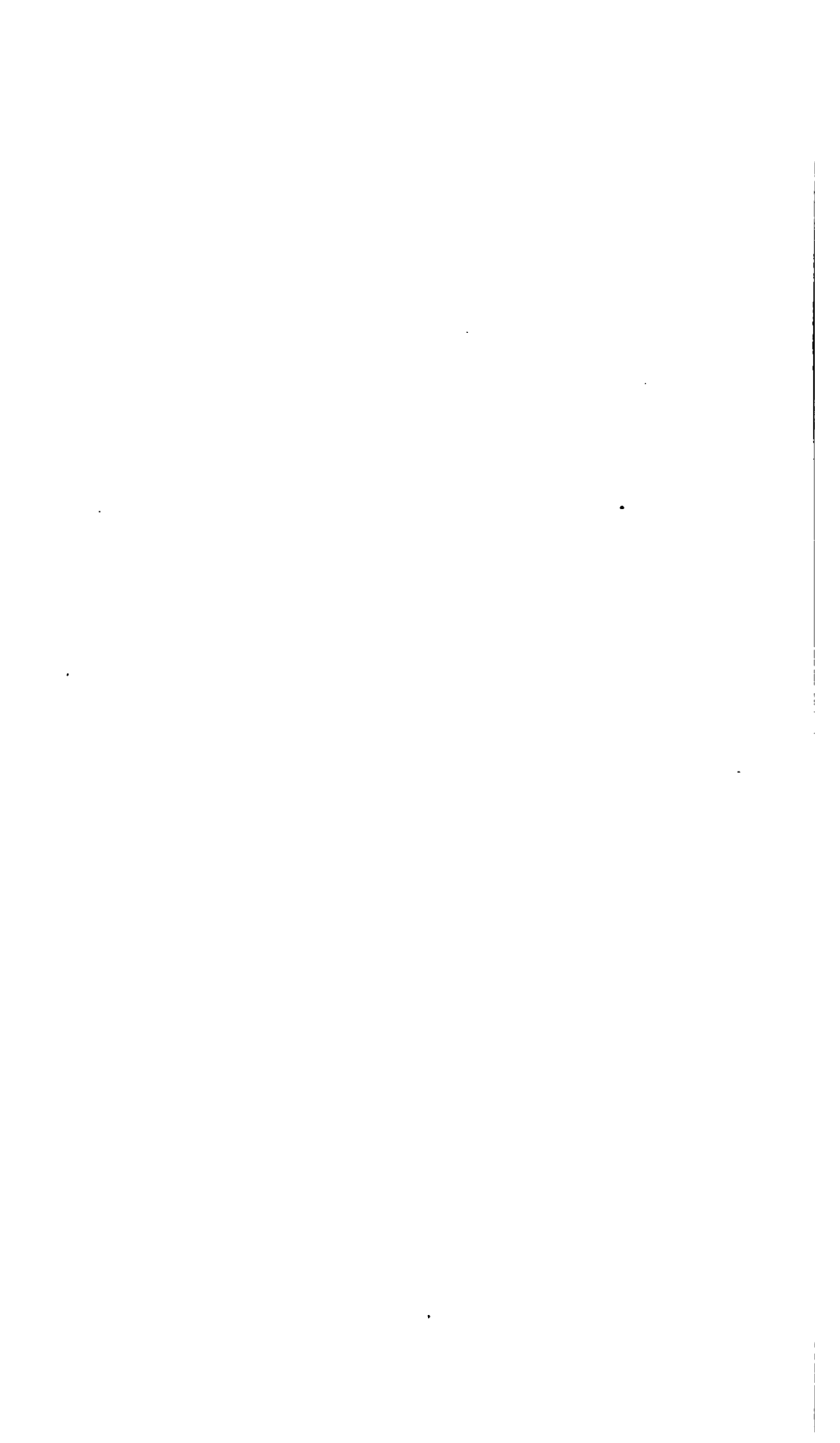
A few modern ships have mounts designed to permit loading the guns in any position of elevation. This system has, however, again been abandoned for the fixed loading position. When the universal loading position is used, the rammer must be carried on a platform which is supported on two girders bolted to the slide and extending down and to the rear. The retracted rammer is housed under the gun.

When the fixed loading position is used, the rammer is secured to the turret floor in line with the axis of the gun. The retracted rammer is housed under the turret roof (Plate I).

The telescope rammer, Mark VII, U. S. S. *Michigan* (Plate V), consists of a single heavy chain carried in a tube of rectangular cross-section, which is made fast to the slide underneath the gun, brought to the rear, and curved upward so that the rammer-head is in line with the bore of the gun. The rammer-head is supported until it reaches the gun by a telescopic carrier of square section built in four sections, which stops on bringing up against the face of the breech. On entering the gun, the rammer-head rides on two beveled hardened-steel rollers which take on the bottom of the bore. As the rammer is secured to the slide, and hence moves up and down with the gun, it follows that some means must be employed which will permit its being operated in any position by the rammer-motor, which is stationary. This is accomplished by means of a long keyed shaft, which is free to move in a perpendicular plane through the axis of the bore, and which is geared, and consequently pivoted, at the bottom to the motor. The bevel-gear on this shaft, which gears to the cross-shaft at the rammer-







head that actually moves the chain, is carried by a gear-case which is pivoted to the rammer-head and is free to turn.

Plate VI shows a 12-inch rammer, Mark IX. The Mark IX rammer differs from the Mark VII in that it has no telescopic support for the rammer. Since it is used for fixed-position loading, it is installed on the turret floor instead of the loading platform; and hence the most convenient place for it in the retracted position is under the turret roof. As it is used to load only the shells, no limiting switch is needed.

This rammer is driven by a 10 horse-power motor operating a large sprocket-wheel which engages the links of the rammer. These links are box-shaped, and are so hinged together at the top of the links that the rammer is self-supporting when extended.

Securing the turret for sea.—The turret is secured for sea by: (1) The *locking-bolt*, operated inside the turret, the principal use of which is to fix the securing position of the turret, and which passes through the turntable to a socket near the top of the bar-bette, and will go in place only when the turret is accurately placed in the securing position; (2) *wedges*, four in number, setting up between the upper inside edge of the bar-bette armor and the lower outside edge of the turret armor, and preventing any severe strain on the roller-flanges as the ship is listed; (3) outside *turn-buckles*, which secure the turret to the bar-bette armor. (None of the securing-gear is shown on the plates.) The *apron* rotates with the turret and, when lowered, bears on a gasket on the bar-bette and makes a water-tight joint; it must be raised before turning the turret.

Miscellaneous fittings.—Each gun is fitted with a gas-expelling device, and blowers are installed in the turrets for forced draft. Speaking-tubes, bells, buzzers and fire-control instruments are also in each turret.

The Cutler-Hammer Differential System.

This type of turret train has been installed on the *Indiana*, *Iowa*, *Minnesota*, *Connecticut*, *Louisiana*, *Delaware* and some of the larger ships under construction. The system is very practical and efficient, and a detailed description is given.

This differential system consists of a differential set of spur-gears entirely enclosed in an oil-tight casing. The differential is

operated by two variable-speed motors which always run in the same direction; and as the motors are not reversed, one motor always carries the turret load, and the second motor can, in consequence, be made about one-third the horse-power of the motor which does the driving. The smaller motor acts as a speed-regulator and brake upon the differential. The reversal of the turret is accomplished by a double magnetic clutch operating a set of reversing-gears; and in the "off" position of the turret controllers, both sides of this clutch are demagnetized, thus disconnecting the driving-gears from the turret, and also preventing any possibility of the differential gears causing the turret to "creep" when running in the balanced condition with controllers on the "off" position.

The motors have a three-to-one speed-variation by field control, and the differential gearing has about a three-to-one ratio. Consequently when one motor is running at 900 revolutions, and the other at 300 revolutions, there is no resultant motion of the differential shaft which transmits the motion to the reversing-gears. This is the state of affairs when the turret is ready for training and the controller is in the "off" position.

The field-leads of both motors go to the training-controllers. The first movement of the controller throws in one set of the reversing-gears. Then, for slower speeds, the controller in moving around cuts resistance out of the small motor field, thus strengthening the field and slowing the motor. This gives a gradual increase in the speed of the differential, and gives the turret a training-speed of about 25° per minute.

At this point both motors are running at about 300 revolutions per minute; now, to speed up still more, the controller gradually cuts resistance in the large motor field, weakening the motor field and speeding up the motor. This speed may be gradually increased until the speed of the larger motor is about 900 revolutions per minute, and the small motor is still running at 300 revolutions per minute. This will give the turret a speed of about 100° per minute.

The double magnetic clutch used for reversing is especially constructed to prevent cutting the faces, should slipping occur, and to prevent the grounding of the clutch wires from moisture or the breaking down of coil insulation.



FIG. 1.—Exterior View.



FIG. 2.—The Two Ends partly Separated.



FIG. 4.—Internal Parts.

The motor armatures are in parallel and are started by simply throwing in the switch of a self-starting panel. The armature resistance is gradually cut out as the motors speed up, and no precautions are necessary, except to see that the controller is in the "off" position. The motors are protected from injury by an overload relay, by fuses, and by the line circuit-breakers. Any lost motion due to wear in gears will not make lost motion in train. All gears and pinions, up to the worm at the base of the vertical shaft of the turret, turn in the same direction at all times. Ordinary wear of gears will not affect the efficiency of the apparatus, and as long as the motors are kept in good condition and the controller is occasionally examined, no troubles need be expected.

THE UNIVERSAL SPEED GEAR.

(Waterbury Tool Company.)

The Universal Speed Gear is a machine for transmitting rotary power at variable speeds and in either direction without steps or abrupt gradations, while the source of power rotates continuously in one direction without any necessary change of speed. This source may be an engine of any kind, an electric motor, a shaft or any rotating mechanism from which it is desired to transmit power. The medium of transmission is oil; this being practically incompressible, the driving is very positive, except to the extent of the very slight leakage necessary for lubrication.

A end and B end.—Functionally, the machine consists of two separate mechanisms designated respectively the A end and the B end.

The A end is an oil-pump operated by the driving-power, whatever that may be. Its function is to deliver oil to the B end at any required pressure and receive it back again, thus keeping up an oil-circulation. The A end contains a controlling device by which the quantity of oil delivered to the B end is regulated exactly to meet the speed requirements of the B end. The shaft of the A end is supposed to rotate continuously in one direction.

The B end is a hydraulic engine. Its rotating parts are almost exactly like those of the A end. In its capacity as an engine, its shaft rotates at any speed and in either direction in exact obedience to the quantity and direction of the oil it receives from the A end.

Arrangement of the ends.—When conditions permit, the two ends are united into one machine, a middle partition, or *midplate*, separating the two parts. If the two shafts are to stand in a straight line, the midplate is a flat disk with parallel faces. If, however, the shafts are to stand in any other position than a straight line, the shape of the midplate may be varied to meet the requirements.

Moreover, it may be desirable to separate the two ends, locating them at some distance from each other. In this case, the midplate becomes two *endplates*, and the oil is circulated through pipes connecting the two ends. Since the chief function of the midplate is to furnish two passages for the circulation of oil between the ends, it is evident that the variety of arrangements possible is unlimited.

To simplify the description let us consider only the unitized or C type of machine, wherein the shafts are in line with each other.

The Fixed or Non-Rotating Parts.

The principal parts which do not rotate with the shafts in the transmission of power are the *cases*, the *midplate*, the *tilting-boxes* and the *control shaft*.

Cases.—All the working parts of the machine are enclosed within cylindrical shells, called *cases*, one for each end of the machine. The open or large ends of the cases are securely bolted against the opposite faces of the midplate by long bolts passing through the cases and the midplate. The other ends of the cases are closed in to form hubs through which the shafts extend. Legs cast on the cases provide means for securing the machine to its support.

Thus combined, the cases form an oil-reservoir, within which the active parts rotate. The greater portion of the oil is not under pressure, but is in communication with the air through the *oil expansion-box* on top of the case. The only active oil, which is directly used in transmitting the power, is enclosed within the port passages of the midplate and within the cylinders ahead of the pistons.

Midplate, or valveplate.—The *midplate* is a very important element of the machine. Its faces are carefully prepared with contact-surfaces against which the face of the cylinder barrel slides in its rotation. Through these surfaces are two semi-

annular passages, called *port passages*, one in each half of the plate, extending from the A face to the B face, through which the oil is circulated when transmitting power. Between the port passages both at the top and at the bottom are flat faces called *lands*, broken only by short oil-grooves for purposes of lubrication. As the cylinder barrel rotates, the cylinder ports pass in succession across these lands, and the contents of each cylinder are for the moment imprisoned within the cylinder, while being carried across from one port passage to the other. At the center of the midplate are bearings for the inner ends of the *shafts*. Several valves are also located in the midplate, which will be described further on.

Tilting-box.—The purpose of the *tilting-box* is to carry a thrust-ball track against which the *socket-ring* may rotate in a plane at any desired angle to its shaft. In the earlier designs there were two tilting-boxes, one in each end of the machine; but later the B tilting-box was displaced by a wedge-shaped casting containing the B thrust-ball track and screwed securely to the end of the inside of the B case, carrying its ball track at an angle of about 20° from a perpendicular. It is even possible to do away with this casting and insert the ball track into a recess in the end of the case itself, at the proper angle.

These substitutes for the tilting-box are possible for the B end, since the angle is not changed after once being set. But in the A end the tilting-box must be retained, for the reason that the speed and direction of rotation of the B end are controlled by the tilting of the A box. The A box is suspended and may be oscillated on two trunnions, which are screwed in from each side of the case and extend inward far enough to penetrate the sides of the box. The greater portion of the bottom of the box is cut out, so as to give a free passage for the main shaft, even when the box is tilted to its maximum angle.

There are two methods employed for tilting the box. The older method is by a *worm-screw* and *worm-segment*. Here the worm-segment forms a part of the bottom of the box, and its teeth engage the worm-threads of the control shaft.

In the later method (see Fig. 5), the worm-segment is displaced by forked *fingers* in which a pair of *guide-blocks* slide. These blocks are carried on the trunnions of a nut, which is prevented from turning by another pair of trunnion guide-blocks sliding in

guide-grooves in the case, but is moved up and down by the screw-threads on the control shaft.

Control shaft.—The purpose of the *control shaft* is to tilt the A tilting-box on its trunnions either way from a neutral or perpendicular position, according to the direction and speed required of the B shaft.

The later screw-and-nut type of control shaft illustrated in Fig. 5 is free from difficulties of thrust-adjustment and packing. It needs no adjustment for the threads, and so dispenses with the bronze ball; and the stuffing-box is of the ordinary type. The downward thrust is against a fiber disk in a plug at the lower end of the shaft, and the upward thrust is against a fiber washer set in the control-shaft bearing. As great care is necessary to secure perfectly tight joints in order to prevent the suction of air into the machine, it will be noticed that a special packing-band of leather is provided at the junction of the nut, the bearing and the case. This will need no attention when once properly fitted.

The Rotating Parts.

The rotating parts of the A and B ends are alike. We may, therefore, confine our attention to one end only. These parts are so assembled to the shaft as to form what may be called a *shaft group*, comprised of the *shaft*, the *cylinder barrel* with the *keys* that connect it with the shaft, the *socket-ring* with the intermediate *universal-joint ring* that connects it with the shaft, and the *pistons* and *connecting-rods*.

Shaft.—The inner portions of the A and B shafts are alike, although the outer ends may be of any desired length to meet requirements. The main bearings are in the hubs of the cases, while the inner ends bear in the midplate. The two shafts are separated in the midplate by a fiber disk called the *inter-shaft disk*. All the other rotating parts are connected with the shafts by *pins*, which are inserted through the shafts under press fits.

The *shaft barrel nuts* serve no other purpose than to keep the cylinder barrels from slipping off of the shafts. When the machine is completely assembled, the nuts perform no function.

Cylinder barrel.—The *cylinder barrel* contains nine cylinders. It is keyed to the shaft by two keys pivoted on a pin passing through the shaft. The loose fit of the barrel on the shaft, together

with the pivoted keys, gives it a slight freedom of motion, so that its face can rest squarely against the face of the midplate. Moreover, it can slide freely endwise along the shaft. This endwise motion is aided by two barrel-springs backing against a spring-pin which passes through the shaft. The purpose of the springs is to hold the barrel against the midplate lightly. When the oil is under pressure, the barrel is held against the midplate automatically by reason of the fact that the cylinder ports are smaller than the pistons, giving an excess internal pressure forcing the barrel towards the midplate.

Socket-ring, connecting-rods and intermediate ring.—The *socket-ring* is so called because it contains the sockets in which one ball end of each connecting-rod rests. There are nine *connecting-rods*, one for each of the nine pistons, in each end of the machine. In earlier designs the connecting-rods are made up of a stem with the balls screwed on to each end, and the socket in the socket-ring is a case-hardened integral part of the ring itself. In all later designs the stem and the balls are made in one piece, and the socket in the socket-ring is formed by the insertion of a bronze block, in a spherical depression of which the ball of the connecting-rod bears. In all cases a hole is drilled entirely through the rod from end to end to provide lubrication for the sockets.

The socket-ring is provided with two inwardly extending trunnions which bear in holes in the *intermediate ring*. Two other holes in this ring, at right angles to the ones first mentioned, receive the ends of the *shaft-pin*. This combination forms a universal joint between the socket-ring and shaft, and permits the socket-ring to rotate with the shaft, while being held at the same time in a plane at any desired angle to the shaft.

For assembling reasons the *intermediate ring* is of peculiar construction. Two of its trunnion-holes can be opened at the side by removing blocks which are secured in position by headless screws fitting half into the blocks and half into the ring.

An examination of the pistons and socket-ring connections shows that the entire thrust of the oil-pressure is communicated to the socket-ring and to the main thrust-ball bearing on which it floats. *The entire torque is transmitted through the intermediate ring to the shaft. No torque is transmitted through the cylinder-barrel connections.*

Minor Parts.

Replenishing-valves.—There is necessarily a small amount of leakage of oil from the active portion into the inactive body of oil enclosed in the cases. Provision must be made to replace this leakage as fast as it occurs, otherwise there would be a vacuum in the cylinders and port passages. For this reason there are two check-valves in the lower part of the midplate, called *replenishing-valves*. One of these is connected with each port passage, and permits the oil to flow freely from the case space into the port passage, but prevents its flowing in the opposite direction.

The valve itself is a steel ball. The seat is a bronze piece screwed in from the outside. The hole in the midplate through which the seat was inserted is closed by a plug called the *replenishing-valve cap*. The ball is prevented from lifting too high above the seat by a pin inserted through the midplate. In some of the later types this pin is displaced by a plug screwed into the upper part of the valve chamber.

Relief-valves.—In the transmitting of power at very low speeds in the B end, it is possible that the oil-pressure may rise to thousands of pounds per square inch should the resistance to be overcome be correspondingly great. It is therefore necessary to provide safety-valves, to be set at any desired maximum pressure, say 800 or 1000 pounds. Should the pressure exceed this amount, the oil will escape from the high-pressure port passage through a *relief-valve* into the case space and flow back again through a replenishing-valve into the low-pressure port passage.

The relief-valve group consists of a *valve*, a *spring*, a *plug* and *adjusting-washers*. The plug forms the backing for the spring, whose compression is adjusted by the use of more or fewer copper washers under the head of the plug.

Air-valves.—At the highest points in the two port passages are needle-valves. The purpose of these is to allow any air that may be imprisoned in the passages to escape into the case space, whence it can rise through the oil expansion-box. It is only necessary to open these valves one or two turns during the filling process, after which they are to be closed tight, and perform no other function.

It may be found advisable to screw thimble-caps over the ends of these valve screws, to prevent oil from leaking out or air from being sucked in.

Oil expansion-box.—As the proper functioning of the machine requires that the medium of power-transmission be practically incompressible, it is important that no air be allowed to mix with the oil. The case must therefore be entirely full of oil. To fully meet this requirement it is desirable to have the oil in the machine connected with an external supply that will always be in communication with the interior and yet not permit the entrance of air. The oil expansion-box serves this purpose. In the illustrations the box is represented as connected directly with the top of the case. In practice, however, the box may be located in any convenient place nearby and connected with the case by a pipe. The connections should always be such as to allow the easy escape of air from the case.

In the lid of the box will be noticed a *baffle*. Immediately above this are holes in communication with the outside air. The baffle prevents the splashing of the oil in the box from stopping the air-holes, should there be a sudden rush of oil from the case into the box. This is an interesting and important phenomenon. Should the machine become overloaded, the flow of oil through the relief-valve is more rapid than the supply through the replenishing-valve, for the reason that the relief-valve is acting under high pressure, while the replenishing-valve is acting only under atmospheric pressure. A momentary vacuum is produced in the active body of oil, which is the same in effect as if the whole volume of oil had suddenly increased.

Stuffing-boxes.—Where the shafts pass through the cases there are stuffing-boxes. These are of the ordinary type, and need no special comment further than to call attention to the kind of material used in packing. Thin leather washers are used, the holes in which are cut very round and smooth so as to fit the shaft nicely.

Plugs.—The various plugs need only to be mentioned. In the midplate are two gauge-plugs. These close holes connected with each port passage for the attachment of pressure-gauges where desired. In the cases are plugs for drainage, escape of air, equalizing-pipes, etc.

How the Gear Operates.

In order that the functioning of the various parts of the machine may be understood, before attempting the study of special instruc-

tions about filling and operating let us assume that the gear is assembled and filled with oil ready for running.

The entire space within the cases and midplate not actually occupied by metal parts is filled with oil. No air-pockets exist; and in order that no air may enter the case, the oil is made to fill the expansion-box about half full. A definite portion of the oil is enclosed within the cylinders ahead of the pistons and within the port passages of the midplate. This is the really active portion of the oil, and if there were no leakage this is all the oil that would be used in transmitting energy. The inactive oil which fills the space within the cases is never under pressure. It is simply a supply for lubrication, and into which leakage from the active oil may flow and from which this leakage is replenished through the replenishing-valves, the total quantity remaining constant.

With our attention directed to the A end of the sectional views, let us first assume that the A tilting-box, with its socket-ring, is set at the neutral position; that is, perpendicular to the shaft. Under these conditions the shaft in rotating will carry around with it the socket-ring and the cylinder barrel, together with the pistons and connecting-rods; but the pistons will have no tendency to reciprocate, or move to and fro in the cylinders. There will, therefore, be no drawing of the oil in or forcing it out through the midplate. The only work done will be the stirring of the oil in the case by the revolving parts and the light friction of the shaft bearings and the sliding of the face of the cylinder barrel against the face of the midplate. The B end will not be disturbed.

If the control shaft be turned a little, so as to move the top of the tilting-box away from the midplate, and the A shaft be rotating over towards the observer, all the pistons, as they move up on the far side of the machine, will draw in oil through the port in the far side of the midplate; all the pistons as they move down on the near side will slide in towards the midplate and force the oil through the near midplate port. The near port will thus be under pressure, while the far port is in suction.

It should be noticed that when a piston reaches the top or higher position in its revolution, it for an instant makes no end movement and the oil in that particular cylinder is carried across the *land*, or space between the two midplate ports, from the suction side to the pressure side. The same condition exists when a cylinder is

passing its lowest position, except that the piston is then at the inner end of its stroke and is passing from the pressure side to the suction side.

The quantity of oil transferred from one side to the other depends upon the angle at which the tilting-box stands, and consequently upon the length of the piston-stroke.

We have spoken of the transfer of oil, but this cannot take place unless there is some means acting to receive the oil and carry it back again. This is the function of the B end. The B socket-ring always stands at an angle of about 70° to the B shaft, and when the B shaft rotates, the B pistons will make their full stroke as they pass between the top and bottom positions. Now, when the A cylinders are moving down on the near side, as described above, oil is forced through the midplate port of this side into the B cylinders of the near side. But they cannot receive the oil unless their pistons move back to give space. In doing this, the near side of the B cylinder barrel must move up together with the socket-ring. This rotates the B shaft in the opposite direction to the rotation of the A shaft.

The speed of the B rotation depends upon the quantity of oil it must take care of. The B socket-ring, being always set at its maximum angle, gives the pistons their full stroke. If each cylinder has a capacity of, say, 3 cubic inches, the revolving of all nine of the B cylinders would transfer 27 cubic inches of oil from the near side to the far side. If now the control shaft of the A end be turned so as to tilt the A socket-ring only a little, say enough to reciprocate each piston to the extent of $\frac{1}{100}$ of a cubic inch, all nine of the cylinders will together transfer $\frac{1}{100}$ of a cubic inch of oil from the far side to the near side at each rotation of the shaft. Since the capacity of the B cylinders per rotation of the B shaft is 27 cubic inches, 300 rotations of the A shaft will be necessary to rotate the B shaft once. If the A socket-ring be tilted still further, the B shaft must rotate proportionately faster. The speed of the B shaft is thus dependent upon the turning of the control shaft.

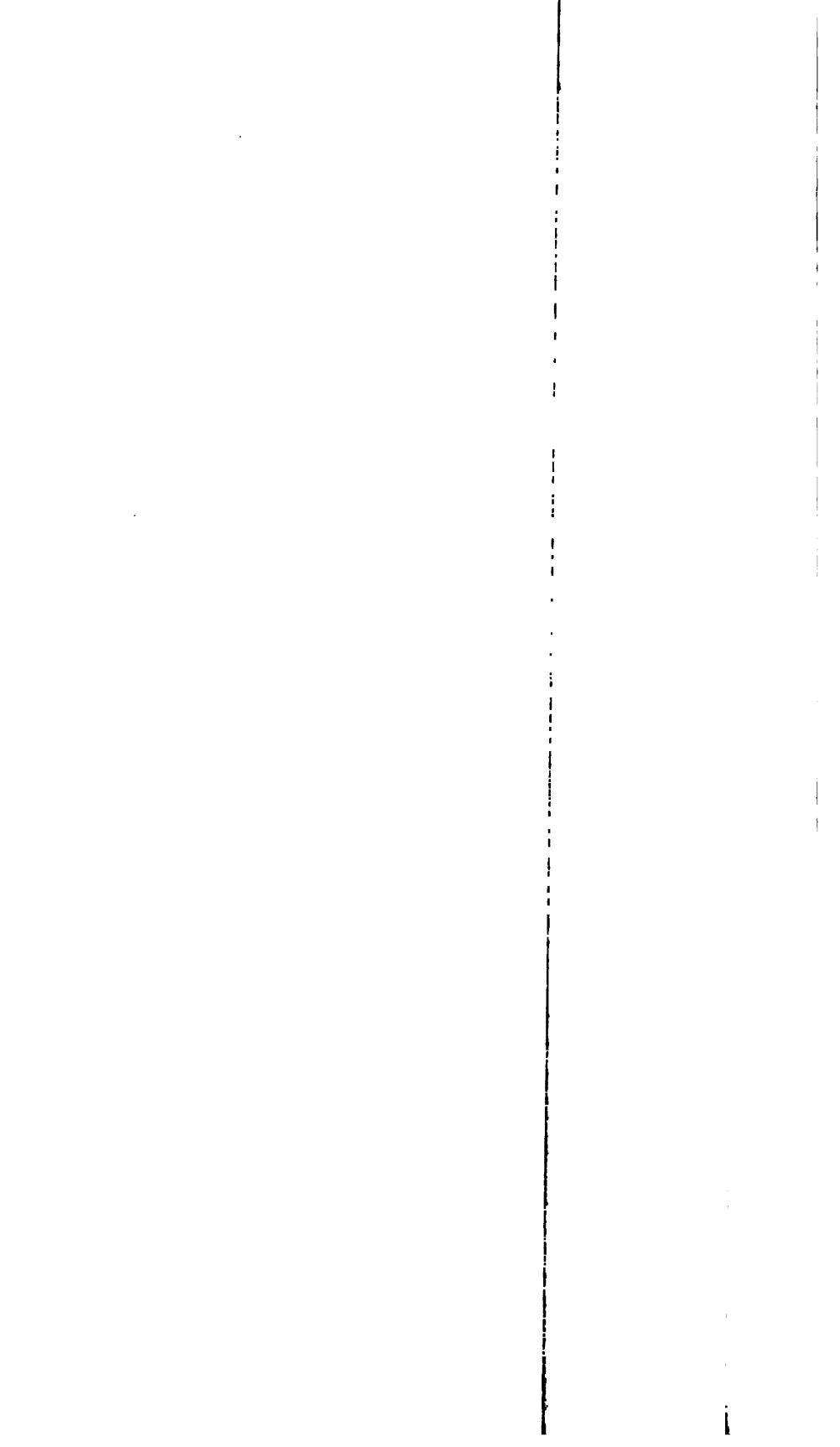
We have thus far spoken of the A socket-ring as tilted in one direction only. If it be tilted in the opposite direction, that is, with the top towards the midplate, and the A shaft still rotates in the same direction as before, the oil will be sucked in from the near

port of the midplate and be carried under across the lower land to the far side. This will, of course, cause the B shaft to rotate opposite to its former direction, that is, in the same direction as the A shaft.

The oil-pressure.—The pressure of the oil in the midplate passages depends upon the resistance offered to the turning of the B shaft, and not upon the speed. The pressure rises instantly to meet any resistance up to the capacity of the driving motor. If the A socket-ring stands almost perpendicular to the shaft, only a very small quantity of oil is transferred per rotation, which has the effect of giving a very great leverage, and a very small motor may produce a pressure of several hundred pounds, and of course, a corresponding torque or turning effort in the B shaft. The actually permissible pressure in any particular machine is limited by the setting of the relief-valves.

NOTE.—The old oil should be drained off and the machine be filled with a fresh supply at least every six months.

ALL
LAD



CHAPTER XI.

FIRING-ATTACHMENTS AND GAS-EXPELLING DEVICE.

In U. S. naval guns the term "*firing-mechanism*" is used to designate that part of the breech-mechanism which directly explodes the primer and thus fires the gun. The "*firing-attachments*" comprise those appliances, fitted to the gun and mounts, which put the firing-mechanism in operation. The lock-lanyard, electric firing-battery, wires, terminals, firing-key, etc., are attachments.

Guns are fired by percussion and by electricity. Percussion-primers are used for guns of 4-inch caliber and below, while guns of larger caliber use combination-primers which may be fired either by percussion or by electric current.

For large guns electric firing is considered preferable, percussion firing being used only as an alternative. Electric primers shorten the *firing-interval*, or the time that elapses between the instant the gun-pointer wills to fire and the instant the projectile leaves the muzzle. This interval, which on the average is three-tenths of a second, has two factors: (1) The *personal factor* (which is much the greater), depending on the pointer's quickness and nerve, and (2) the *time consumed by the travel of the projectile along the bore and by the mechanical action of the firing-devices*. With electric firing, the pointer's muscles act through less distance than when using percussion firing-mechanism, and the passage of the current is more nearly instantaneous than is the action of the lock-lanyard, sear, hammer, etc.; and this part, at least, of the firing-interval is reduced.

Current for electric firing is furnished by batteries and by motor generators, connections being made so that either may be used as desired.

Primary batteries composed of dry cells have been used for some time, but they are now being replaced by storage batteries charged from ship's circuits.

Motor generators or rotary transformers are used to furnish a low-voltage current for the ship's interior communication system, and are located in the dynamo-room. In some ships special motor generators delivering 10 volts at the guns are being installed for firing and sight-lighting.

The storage batteries are carried in battery-boxes attached to the gun-mounts.

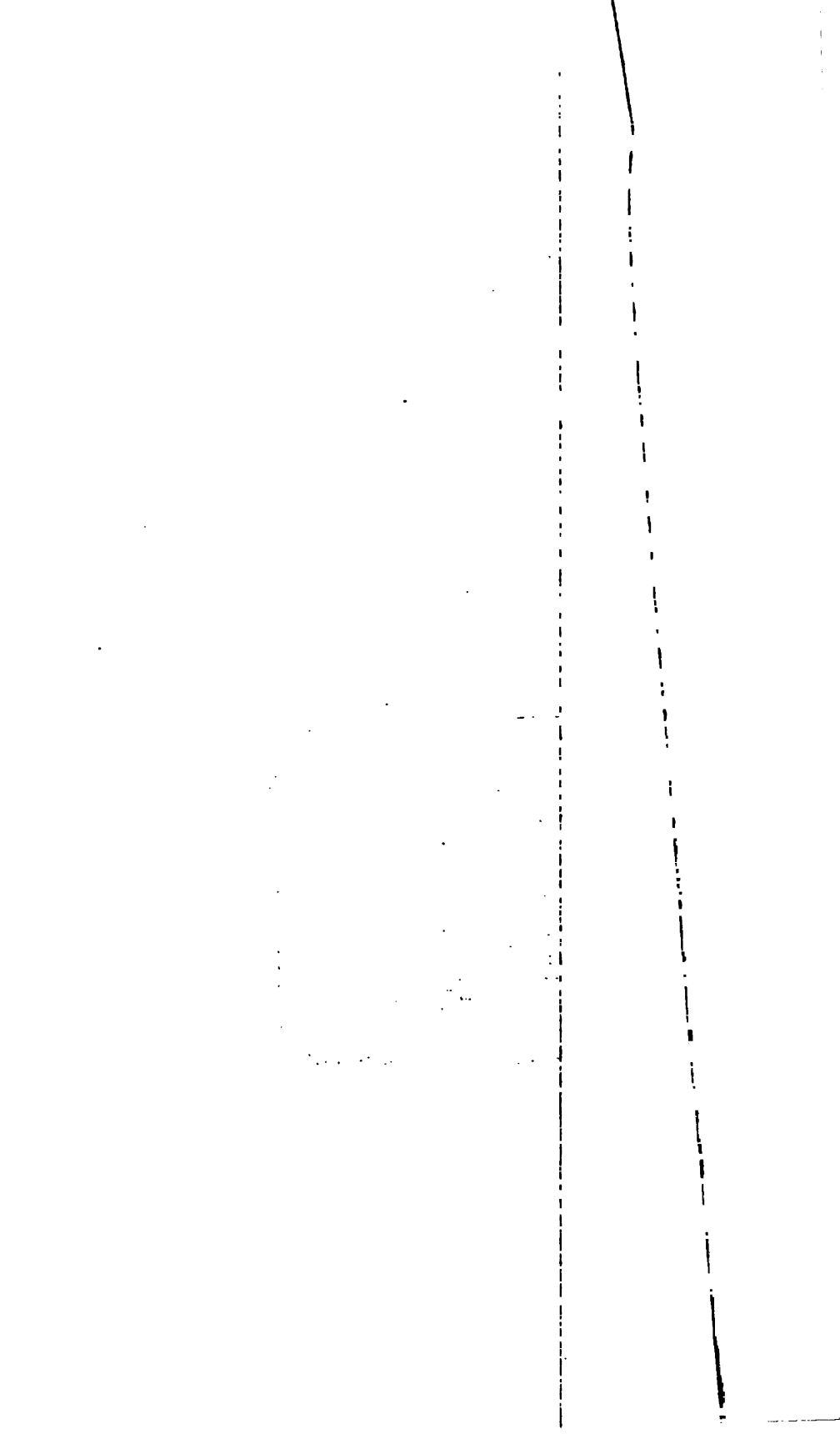
It is the present practice to have batteries and motor generators, which furnish current for firing, also furnish the current for sight-lighting. The latest practice is to use 1-candle-power 10-volt lamps for illuminating the sights.

Firing-keys.—The pistol-grip firing-key is used for guns having a one-wheel drive for the elevating-gear. Plate I, Fig. 1, shows pistol-grip firing-key, Mark IV, used for secondary-battery guns. It is attached to the mount by the hanger shown, and its operation is self-evident in the drawing.

Pistol-grip firing-key, Mark VIII, shown in Plate I, Fig. 2, is used for turret-guns having Mark VII firing-mechanism. The cables enter the butt of the grip, the forward end being secured to apparatus for firing by percussion. For electric firing, press the trigger in the usual way. To fire by percussion, the whole grip is pulled upward, thus operating the firing-mechanism by a lanyard leading over two sheaves and attached to a system of rods and levers.

Figs. 3 and 4, Plate I, show the firing-key for a two-hand drive. The two brass rings *A* and *B* are insulated from each other, but may be connected through the pins *C* and *D* by pressing the trigger, thus completing the circuit for firing. It will be seen that the grip and trigger turn together freely on the steel handle *E*, by which the wheel is rotated. The trigger is a bell-crank, the lower part of which forms a fork straddling the handle *E*. Lugs *F* on the ends of the fork press against the ring *G*, which is insulated from *H* by the ebonite piece *J* (attached to the ring by the pin *K*) working in a slot in the handle *E*.

Plate I, Fig. 5, shows the form of firing-handle now generally used on two-handed drive-wheels. It is simply a push-button carrying on its lower end a metal bridge to close the gap between the insulated firing-circuit terminals, and held clear of the terminals by a spiral spring.



Firing and sight-lighting switch-box.—In order that the same circuits may be used whether taking current from the motor generator or from the battery, a switch-box or transfer-switch is used to shift from one to the other. Fig. 1 shows this switch-

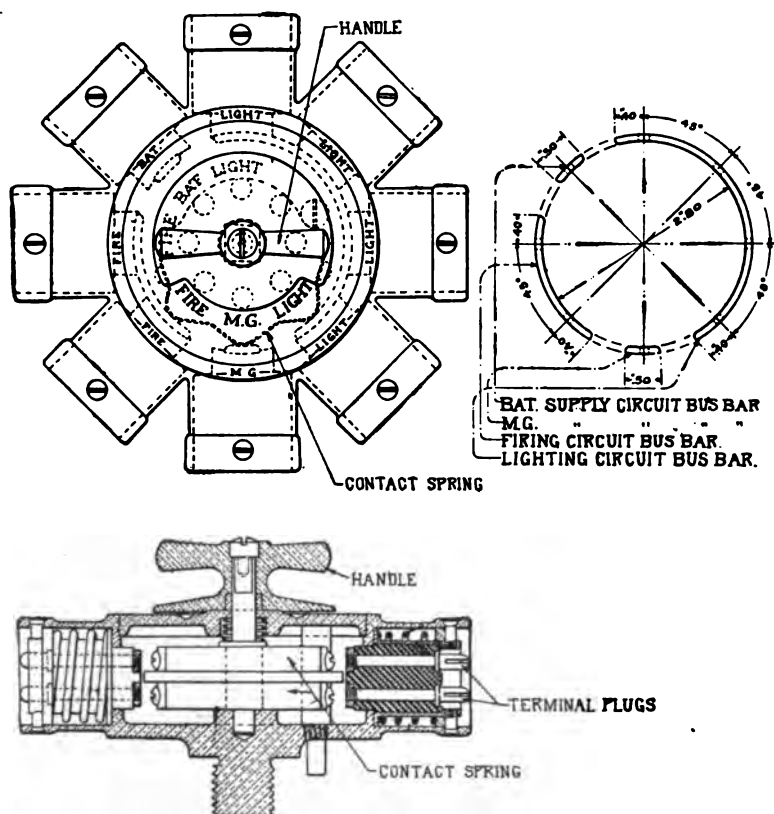


FIG. 1.—FIRING AND SIGHT-LIGHTING SWITCH-BOX, MARK II.

box in plan and section, and Plate II, Fig. 1, shows the switch in place on a 5-inch gun.

The switch-box consists of a number of sockets, two sets of bus-bars, two contact-springs, and a handle. The upper set of bus-bars connects to the upper terminals of the sockets, and the lower set to the lower terminals. Each socket has two terminals,

one for supply and the other for return. One terminal of the firing-circuit socket is grounded to the mount.

It will be seen from the sketch that, by turning the handle, we may use either the motor generator or the battery for firing and sight-lighting, or for firing alone.

The firing-circuit.—Plate II, Fig. 1, shows the firing and sight-lighting connections for a 5-inch mount, Mark XIII, Mod. I, and Plate II, Fig. 2, shows the firing-circuit for a turret-mount, 12-inch, Mark VIII.

As stated above, one terminal of the socket in the switch-box, which carries the single conductor cable leading to the firing-key, is grounded to the mount. When the firing-key is pressed, current passes from the battery to the switch-box, through the battery bus-bar, to the contact-spring, where it divides itself, part going to the firing bus-bar, and part to the lighting-circuit bus-bar. That part from the firing bus-bar goes on to the firing-key, thence to the eye firing-terminal on the gun, through lock-primer, bridge, primer-case, gun-mount, ground terminal, back to the other firing bus-bar; thence through contact-spring to battery bus-bar, back to battery.

The lighting-circuit goes from one lighting bus-bar through lights back to the other lighting bus-bar, thence by contact-spring to battery bus-bar and back to battery.

When the contact-springs are opposite the points *A, D, C*, Fig. 2, the firing and lighting are done by the battery. When they cover the points *D, B, C*, the firing and lighting are done by the motor generator.

Eye firing-terminals are used to connect the cables to the breech-plugs and firing-locks. This type of terminal gives greater flexibility and security against jarring out. An eye firing-terminal is a form of binding-post having a bolt which passes through an eye in a brass palm attached to the cable. The eye is secured to the bolt by two nuts and a split-pin.

The 5-inch gun shown in Plate II, Fig. 1, may be fired by percussion by pulling the lever shown, which is connected to the firing-mechanism. The 12-inch gun shown in Plate II, Fig. 2, may be fired by percussion with the Mark VIII pistol-grip, as heretofore described.

In some cases, in order to avoid the use of a switch or switch-box, separate circuits with separate firing-keys have been fitted for motor-generator firing and battery firing.

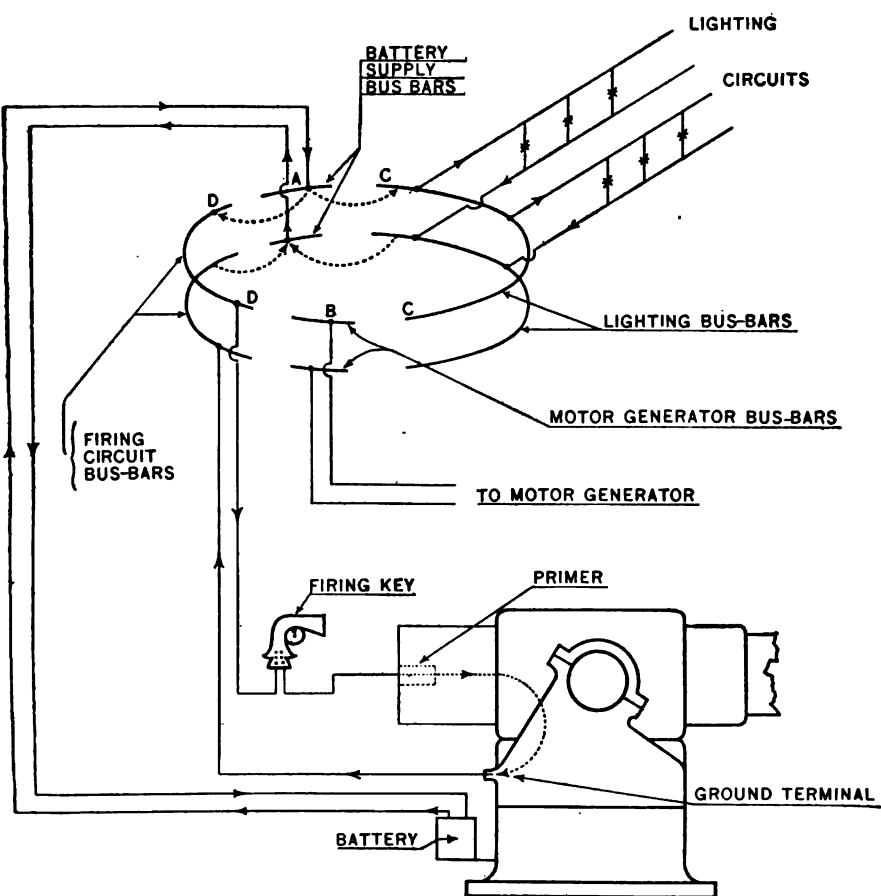


FIG. 2.—DIAGRAM OF FIRING- AND LIGHTING-CIRCUITS.

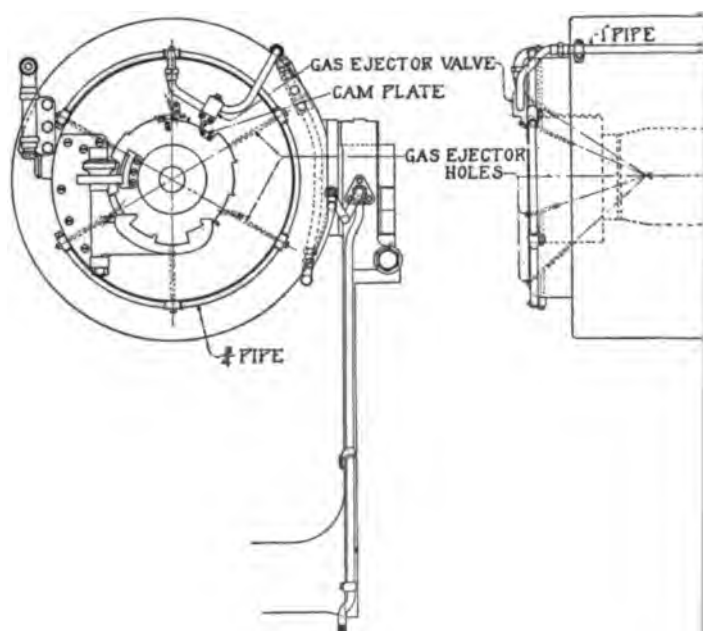
Care of electric firing-attachments.—(1) The batteries should be frequently tested with a volt-meter, the various parts of the circuit with a battery-tester, and the circuit as a whole with an ammeter, or by firing a primer. Unless the electric firing-connections are perfect and securely held in place, there will be fre-

quent failures to fire, due to insufficient current passing through the primer.

(2) The best test (and the only sure one) of electric firing-connections and battery strength is the frequent firing of primers. The battery-tester, ammeter and volt-meter are mainly useful in locating faults.

(3) The faults most frequently found in the circuit are broken wires, or grease or other foreign matter in the connections. The firing of the gun will sometimes jar out the plugs; and as it is important that this should not occur, they must be well secured. Particular care must be taken to see that the primer-seat, the primer, and all contacts are perfectly clean and free from grease or oil. Whenever there is danger of a short-circuit, the parts should be covered with insulating-tape. The failure of the primer to fire when using electric firing is generally due to poor contacts.

CHAPTER XI. PLATE III.



12-INCH GAS-E

Gas-Expelling Apparatus.

Flare-backs.—The smokeless powder used in the U. S. Navy leaves in the bore, after firing, an inflammable gas which sometimes becomes ignited on opening the breech-plug, causing what is called a “flare-back.” With B. L. Rs. this flare-back is very dangerous, as the powder charges may be ignited in loading, as happened in the after 12-inch turret of the U. S. S. *Missouri* with such disastrous results on April 13, 1904.

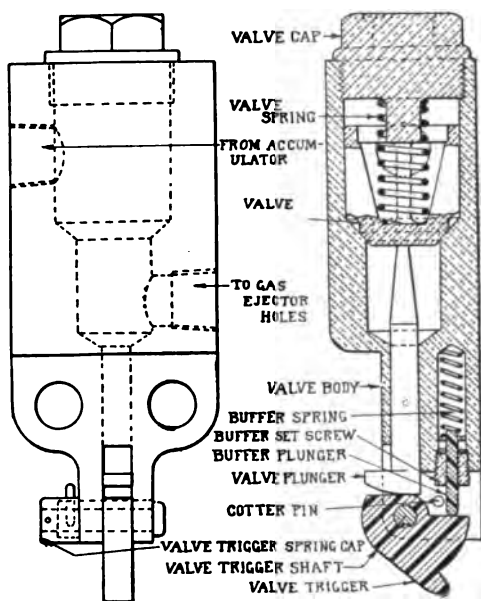


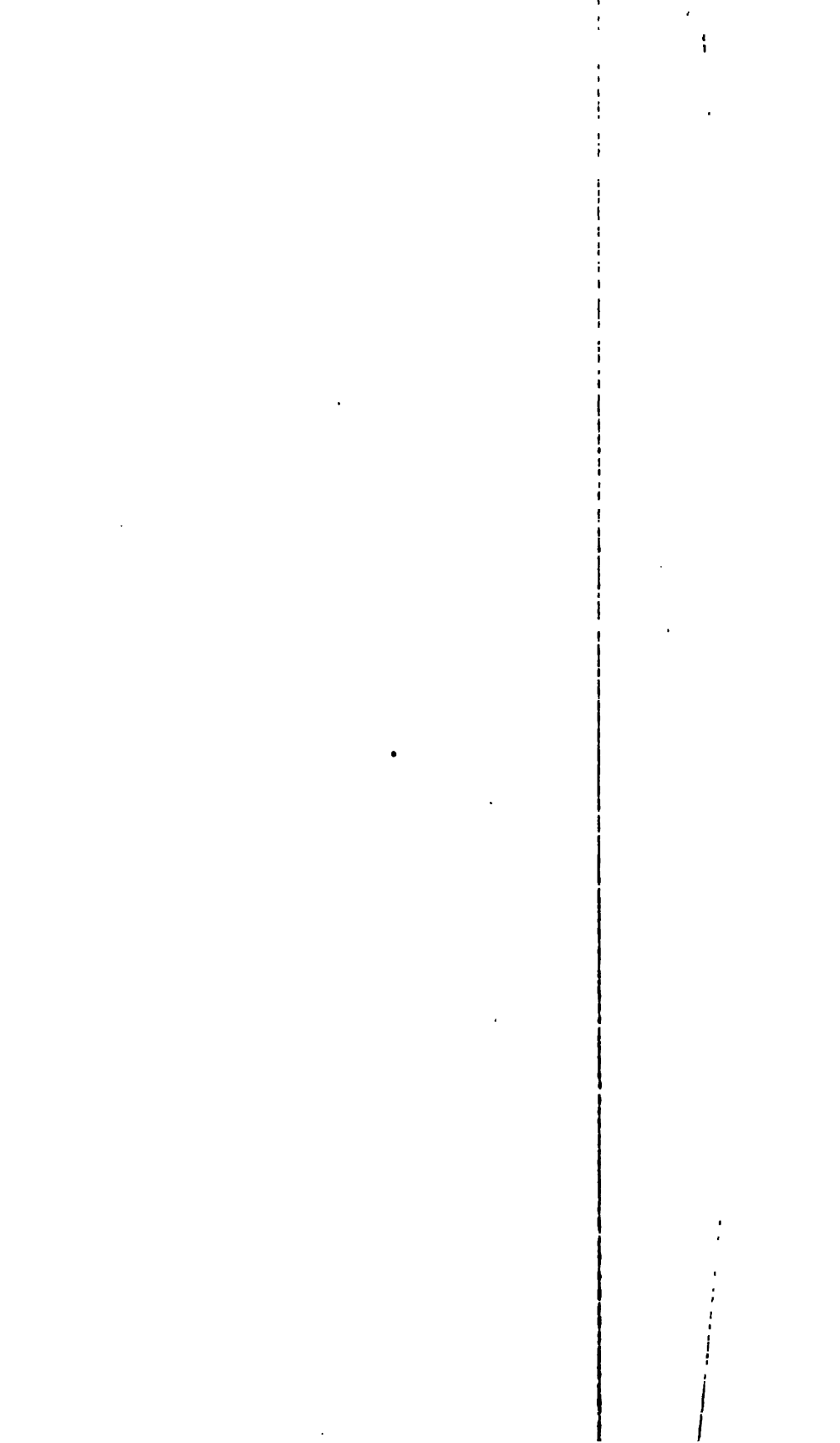
FIG. 3.—GAS-EJECTOR VALVE.

Gas-expelling device.—To guard against flare-backs, an air-blast is now fitted to all B. L. Rs., in order to blow out through the muzzle the gases remaining in the gun after firing. Plate III shows the gas-expelling device fitted to a 12-inch turret-gun. Air is taken from the *accumulator*, through the pipe shown, at a pressure of about 150 pounds. This air is led through the *gas-ejector valve* to a circular pipe surrounding the breech of the gun, and thence through six holes leading to the screw-box. Fig. 3 shows the gas-ejector valve.

Operation.—The first motion of withdrawal of the plug in opening causes the cam-plate attached to the plug to open the gas-ejector valve, thus admitting air to the screw-box. When the gas-check is unseated, the air is forced out through the muzzle, taking with it the gases lingering in the bore. When the plug is fully opened, and the bore is seen to be clear, a member of the crew touches the trigger of the gas-ejector valve, thus shutting off the air. The ends of three of the holes are turned at an angle, as shown, to give the air a whirling or spiral motion. During the firing, air-pressure is kept turned on and maintained on the piping up to the gas-ejector valve.

The two lengths of flexible hose allow the gun to elevate and recoil without disturbing the connections.

Air-pressure in turrets.—Some ships close the openings to the turrets and maintain the turret chamber under a low air-pressure from the ship's ventilating system. This is done as an auxiliary, and in addition to the above-described gas-expelling device, but never replaces it.



CHAPTER XII.

FIELD-ARTILLERY.

The field-artillery, or guns carried by U. S. ships for operations on shore, is composed mainly of 3-inch field-pieces and machine-guns or automatic guns of rifle caliber, on field-carriages.

Automatic Machine-Rifle, Caliber .30, Mark II.

General description.—The gun comprises a single *barrel*, *receiver*, *guard*, and *stock*, rigidly assembled. Guided in the receiver, parallel to and below the barrel, is the *actuator*, which by its reciprocating motion assures the automatic action of the gun. This reciprocating motion is brought about as follows: When the bullet, in its passage through the bore, has passed a port connecting the bore with the gas-nozzle, a small portion of the powder gas issues from the nozzle and, impinging in the cup-shaped forward extremity of the actuator, throws it to the rear. The *actuator-spring*, compressed by the actuator in its rearward movement, now returns the actuator to its initial position.

In its movement to the rear, the actuator, which is accompanied by the breech-block, opens the breech, extracts and ejects the spent cartridge-case, and brings a fresh cartridge to the loading position. In its forward movement, a cartridge is pushed into the chamber, the breech is locked, and the shot is fired.

The cartridges are fed into the gun on flat, tempered-steel strips of 30 rounds each.

A folding *barrel-rest* is provided for steadying the barrel when firing in the prone position, which will ordinarily be taken.

The operation of the gun requires but one man, who loads and fires. If a second operator loads, the speed of fire is increased from 250 to 400 rounds per minute.

Action of mechanism.—In order to load, the breech must be opened by means of the *cocking-handle*. As the actuator is drawn

back, cams on its upper face turn the *breech-nut* a partial revolution, disengaging its interrupted threads from corresponding threads on the nose of the *breech-block*. This unlocks the breech. Under the action of its springs, the *feed-piece* engages with a shoulder on the actuator and locks in its rearmost position.

To permit the introduction of the *feed-strip*, the feed-piece must be lifted to its highest position by pressing up on its lower end. This frees it from the shoulder of the actuator, which latter moves forward slightly under the action of its spring and engages with the *sear*. The feed-strip may now be introduced into the guides, cartridge side down, and should be pushed forward until the *parrel* forming part of the *feed-spring* engages with it, so as to prevent any backward movement.

When the trigger is pulled, the actuator, accompanied by the breech-block, is propelled forward by its spring; the breech-block pushes a cartridge from the feed-strip into the *chamber*; the *cams* on the upper face of the actuator act on the breech-nut, locking the breech; the *firing-pin* is driven against the *primer*, and the shot is fired.

When the bullet, in its passage through the bore, has passed the port leading to the gas-nozzle, a small portion of the powder gas, conducted by the port and the gas-nozzle, impinges in the cup-shaped forward extremity of the actuator and drives it to the rear. As already explained, the breech is now unlocked by the action of the actuator cams on the breech-nut, the breech-block is withdrawn, along with the *extractor* holding the spent cartridge-case, which latter, when entirely extracted, is ejected when its head strikes the *ejector*.

Toward the end of the backward stroke of the actuator, a cam on its side imparts a slight rotary movement to the feed-piece, which advances the feed-strip sufficiently to bring the following cartridge to the loading position.

Its last cartridge having been fired, the exhausted strip is ejected from the gun. Under the action of its spring, the feed-piece, which has been held up by the strip, now descends and, engaging with the shoulder of the actuator, locks the breech open. All is now ready for the introduction of another strip.

The firing-gear may be set for continuous firing, single shots, or safety, by turning the cocking-handle to the positions marked *A*, *R*, and *S*, respectively.

When set at *A* (automatic), so long as the trigger is held back, the actuator is free to move forward again under the action of its spring. As a result the gun fires continuously until the strip is exhausted or the trigger is released.

When set at *R* (repetition), a separate pull of the trigger is required for each shot, as the sear engages with the actuator each time the latter recoils, thus stopping the firing.

When set at *S* (safety), the trigger is locked, and cannot be pulled back so as to release the sear from the actuator. As a result the gun cannot be fired.

Points to be attended to before firing.—If the rifle has never been used since issue, or not used for some time, all cosmic or vaseline should be carefully removed from the chamber and all moving parts, and the parts should be lightly oiled as outlined below.

(1) Cock the gun.

(2) Pass the cleaning-rod down the bore to make sure that the barrel is clear.

(3) See that the regulators of all available barrels are properly set. The normal setting is 25.

(4) Oil the mechanism. A moderate quantity of oil will suffice. It is useless to flood the mechanism. As the essential parts are sufficiently accessible through the ejection slot and by opening the feed-piece cover, dismounting is not necessary.

(5) Test the action of both ejector and cartridge-stop by pushing on their points. They should work freely, their springs being elastic but without stiffness.

(6) Test the action of the mechanism by rapidly opening and closing the breech several times. It should work freely and smoothly.

Operating the gun.—In firing, the prone position will be taken ordinarily, the barrel-rest being used to steady the gun. In high grass or under conditions where more height is desirable, ammunition-boxes may be placed under the barrel-rest so as to increase the height. In short, any sort of rest available may be used, the top of a parapet or the limb of a tree, for example.

In going into action, the following operations must be performed:

- (1) Set the barrel-rest.
 - (a) Free the legs from their catches.
 - (b) Turn the legs forward until at right angles to the barrel.
 - (c) Open the legs with a sharp movement such that the separators catch in one another.
 - (d) Place the feet in the desired position and force the points into the ground.
- (2) Free the elevating-mechanism.
 - (a) Draw the elevating-mechanism feet straight to the rear, disengaging the forward end from its socket in the back of the pistol-grip.
 - (b) Place the elevating-mechanism feet on the ground in such position that the guide-rod joining them is at right angles to the axis of the gun.
 - (c) Bring the gun to approximately the required elevation by turning the hand-wheel.
- (3) Take the firing position.
 - (a) Take the prone position, resting on the elbows.
 - (b) Grasp the pistol-grip and trigger with the right hand, pressing the stock well into the hollow of the right shoulder.
 - (c) Grasp the elevating-screw hand-wheel with the left hand.
 - (d) In case the elevating-mechanism is not used, the left hand grasps the stock to the rear of the receiver and pulls the butt-plate hook down solidly against the shoulder.
- (4) Cock the gun.
 - (a) Throw the cocking-handle knob to the left to a stop.
 - (b) Draw the cocking-handle to the rear as far as possible with a sharp, quick movement.
 - (c) Return the cocking-handle to its original position and set at *R* for single shots, *A* for automatic, and *S* for safety.

(5) Loading is ordinarily performed by a second operator who takes the prone position to the right of the gun with the ammunition conveniently at hand.

(a) Raise the feed-piece to its uppermost position by pushing on its lower extremity with the left hand, placing the thumb on the feed-piece housing cover.

(b) With the right hand introduce a feed-strip into the guides, cartridge side down, and push home until the pawl catches.

NOTE.—If the gun is operated by but one man, loading will be found more convenient if the elevating-mechanism is not used.

(6) Firing. The gun is fired by pulling the trigger.

NOTE.—The trigger must be released at the end of each strip so that the sear will hold the actuator at the cocked position during the introduction of the following strip. Otherwise, as soon as the feed-piece is raised, preparatory to loading, the breech will close, necessitating recocking the gun before continuing firing.

(7) Unloading. In order to remove a partially exhausted strip, proceed as follows:

(a) See that the breech is open, cocking if necessary.

(b) Hold the claw of the pawl free from the strip by pushing up on the lower extremity of the feed-piece with the left hand.

Use of the regulator.—In order that the working of the gun may be regular, sufficient power must be available to insure complete recoil of the actuator. The amount of power necessary may vary because of insufficient oiling, dust, or fouling in the mechanism, etc. Then, again, the pressure of the powder gases may vary because of the temperature, deteriorated powder, or badly worn rifling. The *regulator* affords means of varying the power which works the gun. Under normal conditions it should be set at 25.

To test the automatic action, fire several shots with the regulator set at 25 and the cocking-handle at *R*, and observe:

(1) One shot should be fired at each pull of the trigger. If more than one shot is fired at a time, it shows that the actuator does not recoil sufficiently after each shot to catch on the sear.

(2) The claw of the pawl should catch in the opening in the strip at each shot. If the pawl rides on top of the strip instead of catching, it shows that the actuator does not recoil sufficiently to throw the feed-lever through a complete stroke.

(3) The ejection should be regular and energetic.

If these three points are not satisfactory, it may be concluded that there is a lack of power, and the regulator should be screwed up from 5 to 10 divisions. On the other hand, too much power is not desirable, as the vibration due to the violent action of the mechanism necessarily affects the accuracy.

Accidental stoppages in the automatic action of the gun.—In case of a jam, always proceed as follows:

(1) Open the breech completely by means of the cocking-handle.

(2) Remove the jammed cartridge through the ejection-slot by using the hand ejector or rammer; as the case may be, and see that the chamber is clear.

(3) Withdraw the strip if some remedy is to be applied. Otherwise push it forward, bringing the next cartridge to the loading position.

Most frequent stoppages and their remedies.—(1) *Jam on the first round of a strip.*—The strip was probably not pushed completely home before the trigger was pulled. Always push forward the strip until the pawl catches so that both strip and cartridge are positively held in the loading position.

NOTE.—A loose primer falling into the mechanism may cause repeated misfires. Dismount the actuator and breech-block so as to remove the primer, which will usually be found either in the actuator-cams or in the ferreture-nut near the entrance to the chamber.

Misfires may also be due to a weakened actuator-spring. In this case replace the spring with the spare.

(2) *Misfire.*—Eject the defective cartridge by cocking the gun, and continue firing.

(3) *Bad introduction.*—The cartridge jams at the entrance to the chamber when being pushed forward by the breech-block. The bullet of the cartridge in question may have been imperfectly seated, due to defective crimping, or the cartridge may have been insufficiently held by the clips of the feed-strip. In the latter case the strip should be laid aside for resizing. Another cause of bad introductions is incomplete feeding forward of the strip, due to lack of power. In this case screw up the regulator 5 to 10 divisions.

(4) *Incomplete ejection of the spent cartridge-case.*—This is due to lack of power. Screw up the regulator 5 to 10 divisions.

(5) *Jam due to ruptured cartridge*, the head of the case having been pulled off, the remainder sticking in the chamber, as may sometimes occur through defective ammunition. In this case try first to remove the ruptured case by inserting another cartridge, allowing the mechanism to come down to drive it into the ruptured case; then by drawing the mechanism to the rear the cartridge will usually bring the ruptured case with it. Coating the bullet and end of the cartridge with dust will help to make it stick to the ruptured case. If this fails, the defective-cartridge extractor must be used.

NOTE.—Extreme care must be observed in using the defective-cartridge extractor, as it is made of steel and is hardened, and if not used carefully will injure the rifling and bore. In inserting it, it should follow the rifling and not be forced across the lands, as little force as possible being used to force out the defective case.

Replacing broken extractor or firing-pin.—Continued rapid firing tends to crystallize the firing-pin and sometimes causes it or the extractor to break. When practicable, it is desirable to shift the firing-pin and extractor after 1000 or more rounds have been fired without interruption. In case of breakage from any cause:

- (1) Close the breech.
- (2) Remove the cocking-handle.
- (3) Remove the guard and stock.
- (4) Withdraw the actuator-spring.
- (5) Remove the recoiling-mechanism.

Replace the defective part by a spare and mount by reversing the operations.

Ammunition.—The ammunition used in this rifle is the same as that provided for the U. S. rifle, caliber .30, model of 1903. It is fed into the rifle by means of feed-strips, holding 30 cartridges each. The cartridges are located in the feed-strips by means of a loading-tool.

Feed-strip.—With each rifle are furnished 100 feed-strips made of sheet steel, steel-spring tempered, by means of which the cartridges are fed into the rifle. Each feed-strip is designed to hold 30 cartridges.

On each strip are punched three rows of large clips, which hold the cartridges longitudinally, and one row of small clips, which align and hold the cartridges transversely. Ten feed-strips are packed in each ammunition-box.

Automatic Machine-Rifle, Caliber .30, Mark I, Mod. I.

Description and operation of the Colt automatic gun.—This arm consists of a detachable *barrel* connected with a *breech-casing*, in which the mechanism for charging, firing, and ejecting is contained.

The cartridges are automatically fed to the gun by means of *belts* from left to right. As the belt (looped in horizontal layers) lies in a box attached to the breech-casing, the supply of cartridges is not disturbed by the vertical or horizontal movement of the gun. The boxes contain 100, 250, or 500 cartridges each, and are so constructed that they can be quickly attached or removed.

The automatic action of the gun is effected by means of the pressure of the powder gases in the barrel. As the projectile has already received its maximum velocity, the range and penetration are not affected.

There is a small radial *vent* in the barrel near the muzzle, opening downward from the bore. This vent is closed by a *piston* which fits in the *gas-cylinder* surrounding the outer edge of the vent. The piston is pivoted to the *gas-lever* so that it adjusts itself to the gas-cylinder, while the lever swings in a vertical plane.

To operate the automatic gun: The feed-belt is entered. The lever is thrown downward and rearward (by hand) as far as it will go. This opens the breech and feeds the first cartridge from the belt to the carrier. The lever is then released, and the spring causes it to swing forward, close the vent, and transfer the cartridge from the carrier to the barrel, also cocking the hammer and closing and locking the breech.

On pulling the trigger, the cartridge is discharged. After the bullet has passed the vent, and before its exit from the muzzle, the powder gases expand through the vent upon the piston and gas-lever, which in turn act on the breech-mechanism, opening the breech, ejecting the shell, and feeding to the carrier another cartridge. The gas-lever, returning, forces home the cartridge in the barrel, closing and locking the breech. If, instead of releasing the trigger, it is held back, the same operation will be repeated as long as cartridges are supplied, producing a continuous fire at the rate of 400 shots or more per minute.

As the automatic action of this gun is due to the pressure of the gases through the vent upon the lever, the delicacy of the parts

necessary in some classes of automatic arms is avoided in this gun; therefore the barrel and the storage springs are of greater strength, and yet effective with even small charges.

A *safety-lock* is provided which securely locks the hammer and prevents it from striking the firing-pin. It is to be used only when a loaded cartridge is left in the chamber. The hammer of this gun is also used as a piston for an air-pump, which forces a strong jet of air into the chamber and through the barrel, removing all residue or unburnt powder after the empty shell is extracted. The necessity for such a device has been shown by experience.

The mainspring, firing-pin, and extractor can be replaced as easily and as quickly as in the ordinary bolt gun, all these parts being removable from the rear of the arm without displacing a single screw.

The barrel of the gun is of such strength that it will withstand the heaviest charges of nitro-powder, and its accuracy is not disturbed by the vibration incident to rapid firing.

Elementary instructions for operation.—Attach box in firing position on left side of mount.

To load: Push brass tip of belt through opening above the box and draw it out on other side of gun as far as it will go. Let go of the belt. (Never pull on the belt while the gas-lever is being operated.) Swing the gas-lever downward to the rear until it strikes the bottom plate of the gun. Release gas-lever, when it will resume its normal position. The gun is now ready to fire.

To fire: Hold back trigger. The firing will continue until the trigger is released or until all the cartridges in the belt are fired. To hold the gun ready for firing, push the safety-latch on right side of gun below rear sight from "Fire" to "Safe."

To draw belt and cartridges from gun: Push forward the knurled head on the right side of the gun near the belt exit, and draw the loaded belt out to the left. Then operate the lever once by hand, as in loading, ejecting the loaded cartridge that remains in the chamber.

Misfires.—Wait a moment in order to make sure that it is a misfire and not a hangfire. Then operate the gas-lever by hand, as in loading, which will eject the unexploded cartridge and will reload the piece, ready for continued firing.

Stoppage from any cause.—Whether the stoppage occurs from the jamming of a cartridge, misfire, or breakage of a part of the gun, operate the lever once by hand before making any effort to free the mechanism. If the stoppage occurs when the lever is partially retracted, push it backward until it strikes the bottom plate. Never push it forward. This will generally free the mechanism, unless a broken part stops it. If not freed, draw belt and cartridges from the gun and examine for breakages. In case of jamming, due to failure to eject empty shell and pushing of a live cartridge against shell in the chamber or in the receiver, draw back the lever until it strikes the bottom plate, letting the live cartridge and carrier descend into the bottom position and remove shell with wiping-rod. The lever is now free to resume its normal position. In this case, examine the extractor, and if it is broken or chipped, or if the spring does not work well, replace it.

Precautions to be observed.—After dismounting mechanism and before firing is begun, a belt of cartridges (preferably dummies) should be placed in the gun and the lever should be operated several times by hand, as in loading, to see if the mechanism is in proper working order.

Target-practice.—The center of impact is lower in case a number of shots are fired one at a time, with pause between shots, than it is when the same number are fired continuously. Firing from tripod, the first few shots tend to settle the trail into the ground, increasing the elevation and causing shots to go high. This settling is slight in heavy, compact soil. In light, sandy soil the shots should be fired in groups of 10 and 20, and the elevation should be frequently verified.

Caution.—With the gun hot from rapid firing, a cartridge should not be allowed to remain in the chamber longer than six or seven seconds, as it may be discharged by the heat. In case it is not possible, from any cause, to withdraw the cartridge within this time, and the lever is in its normal position, no harm will be done; but if the lever is partially retracted, the bolt is then withdrawn, and a "blow-back" may occur. In either event, keep away from in front of the muzzle until satisfied that the danger from the explosion of the cartridge by heat is passed. After firing, the piston, and also piston-hole in gas-cylinder, must be carefully

cleansed and wiped with a cloth or waste, but emery cloth must not be used. After wiping thoroughly, grease or oil the piston.

Care and management.—The rate of fire of the guns as now issued to the service is fixed at a minimum of 400 shots per minute, and each gun is required to maintain this rate for one minute without stoppage before being accepted from the manufacturers. The rate of fire depends on several points in the construction of the gun, as follows:

(1) It is obvious, since the energy required for the operation of the gun is derived from the pressure of the gases escaping through the gas-vent, that the interval between shots cannot be less than the time consumed between the explosion of a cartridge and the passage of the bullet over the vent. This, of course, depends in the main on the initial velocity of the bullet, and can be regulated by changing the powder charge.

(2) The second condition governing the rate of fire is the location of the vent in the bore in a longitudinal sense. This affects the rate of fire in two ways: (a) By the time consumed by the bullet traversing the bore to the vent, and (b) by the amount of pressure obtained through the vent.

(3) The third governing condition is the size of the vent, which regulates the amount of gas taken from the barrel, and consequently the available force for operating the gun.

(4) The weight of the moving parts is an element affecting the speed, the gas-lever itself being the most important. Small changes in the weight of this part effect considerable alterations in the rate of fire.

(5) And dependent on the second and fourth, the length of the various levers and connecting-rods, and the consequent time consumed in completing one motion, affect the rate of fire.

(6) The rate of fire may be altered by changing the point of firing. The gun, as has been before explained, is fired when the *trip*, operated by the *slide*, releases the sear from the hammer. The point in the motion of the slide at which this takes place can be altered by changing the length or location of the cut which operates the trip. As at present made, the gun fires when the gas-lever is about $1\frac{3}{8}$ inches open; if it were so arranged as to fire with the lever entirely up, it is evident that more gas-pressure would

be utilized and the speed would be correspondingly increased. Conversely, the speed may be reduced by causing the gun to fire with the lever more open. The limits of variation due to an adjustment of the firing-instant are, of course, narrow, as the bolt must be fully closed and locked before firing.

(7) The point of firing can be slightly delayed by flattening the lower side of the trip-pin which operates on the sear; this will allow the lever to close further before the hammer is released, and the rate of fire will be slightly increased.

It will be noted that the operation of the various parts of the gun is so timed that, if they perform their work properly and the ammunition is good, no jams can be caused (the personal equation of the operator being eliminated by the automatic action). The gun cannot be fired until the bolt is fully closed and locked; no other operations can begin until the gun has been fired and the bullet has passed the vent; the next cartridge cannot be fed up until the fired case has been extracted and ejected. Jams can, then, occur only as the result of the failure or breakage of some part.

A jam or breakage of any kind causes an instant stoppage of the gun; and immediate examination should be made to ascertain and remove the cause if possible.

The following accidents have occurred in experimental firing and may occur again, though the causes, so far as they have been discoverable, have been removed:

(1) *Hangfires*.—These are due to the slow ignition of the powder, and may be expected to be eliminated when increased experience with these powders enables the manufacturers to produce primers which will make ignition as sure and as rapid as with black powder. Ordinarily the hangfire is of only just perceptible duration and will scarcely attract attention; they have been known, however, to last several seconds, and they then become dangerous. The automatic gun will, of course, wait for the explosion; and if the operator will do the same, there is no trouble to be apprehended.

(2) *Misfires*.—These will not be frequent with good ammunition, but may sometimes occur, and of course stop the action of the gun.

(3) *Incomplete action of gun, causing bolt to close on empty case.*—This results from firing a cartridge with a reduced powder charge, and will be a very rare accident. The effect is to throw the gas-lever partly down and then allow it to close again without ejecting the fired case, which may either be returned to the chamber by the closing bolt or may be jammed in the receiver, due to partial ejection, in which case the lever will not be entirely closed.

These three accidents have the common feature of stopping the gun with the gas-lever up, while in others to be mentioned the lever is left in some intermediate position. Consequently this general rule must be observed:

Whenever the gun stops firing in the midst of a belt, keep the finger on the trigger and look at the gas-lever. If this is entirely up, maintain the trigger pressure for two or three seconds, in which time, if the stoppage was due to a hangfire, the gun will be discharged and the firing will be resumed. In case the gun does not fire, the difficulty is probably attributable to the second cause, a misfire, and the trigger should be released and the lever operated once by hand. Upon then pulling the trigger, the firing will recommence. The method of handling a misfire serves also for the third accident mentioned above.

In case the gun stops with the lever open, one of the following conditions may have arisen:

(1) *"Following up" of a sear.*—This is due, in a new gun, to too great thickness of the nib of the sear, so that the bolt does not push the hammer back sufficiently far for the sear to engage it; this difficulty is usually evidenced by a faint impression of the firing-pin on the primer. To remedy it, release and draw out the feed-belt and empty the chamber of the gun by operating the lever by hand twice. Then remove the handle from gun, take out sear and replace it, or, if the same one is to be used, file the inner face of the nib slightly with a flat file. A very slight reduction in thickness of the nib will remedy the defect.

The same effect of "following up" may be caused by wear of the notch around the head of the hammer. The remedy for this is obviously to turn the hammer and present a new portion of its circumference to the sear.

(2) *Non-extraction or non-ejection.*—This will be shown by the presence of an empty case in the receiver, partially drawn out or

partially ejected, or by a new cartridge jammed over the empty case in the chamber. This accident is generally due to a broken extractor, or it may be due to the third of the causes above enumerated, the energy of the discharge being insufficient to bring the empty case into contact with the ejector. The remedy is to clear the jam, remove the empty case, and examine the extractor. If it is broken or chipped on the nib, or if the spring fails to work well, replace it.

(3) *Jam of cartridge in carrier.*—This accident has been of rare occurrence, and it is not at present possible to say with certainty what causes it, but it is probably due to faulty action of the carrier dog and spring. The cartridge is in this case engaged by the bolt and pushed forward before it has been raised to the correct loading position, and is thus jammed between the two sides of the carrier. To clear it, do not attempt to push it forward or to cant it, but work the mechanism gently a few times without allowing the bolt to touch the cartridge; this will loosen the cartridge and allow it to be removed.

(4) *Jam in feed.*—This may be due to uneven loading of belts or to a cartridge fitting too tightly into its pocket, so that the cartridge-extractor cannot draw it out. It can be cleared through the hole in the right side plate.

In general, when a jam or stoppage occurs, due to any cause, the first thing to do, after waiting long enough to see that it is not a hangfire, is to release the trigger, then to work the gas-lever gently by hand, observing the mechanism meanwhile to see what the cause of the stop is. Jammed cases or cartridges may be removed through the ejection opening with the blade of a knife or the point of a screw-driver; a combination operating-handle and screw-driver is sent out with remodeled guns. The only cautions that need be observed are these:

(1) If the gun stops with the lever closed, wait two or three seconds to see if a hangfire has occurred.

(2) If the gun is very hot, as after continuous firing for three or four minutes, release the belt and draw it out an inch or two to the left; then work the gas-lever, emptying the chamber.

(3) Always, in operating the lever by hand, do so slowly, observing the action of the mechanism meanwhile, and do not attempt to clear any jams by force.

(4) In loading belts, see that the cartridges are all pushed well home in the loops, and that their bases are perfectly even, if possible lining them up with a straight-edge.

Directions for dismounting and assembling.—(1) Take hold of the *gas-lever pin* (30) and throw the *gas-lever* (29) rearward until it strikes the *bottom plate* (91). Then release the gas-lever, when it will fly forward to its original position. This movement cocks the *hammer* (6).

(2) On the right-hand side of the gun, forward of the trigger, is the *handle-lock* (2), which is a pin with a small projecting lever resting in a horizontal position. Turn this lever upward and backward as far as possible. Withdraw the handle-lock. This releases the *handle* (1), which then can be removed rearward. The handle contains the *mainspring* (7), *hammer* (6), *sear* (10), *sear spring* (11), *trigger* (8), and *trigger spring* (9). To remove the hammer and mainspring from the handle, pull back the trigger, release the sear by pulling the nose down, when the hammer and mainspring will fly out, as the sear holds them in place.

(3) To remove the *bolt* (13), throw the gas-lever (29) rearward as far as possible; and while holding it in that position, insert the small end of the handle-lock (2) in the hole on the right-hand side of the gun, pushing the handle-lock in as far as it will go. This removes the *bolt-pin* (14) from the bolt. Withdraw the handle-lock pin, but leave the bolt-pin in the position in which it now is, *i. e.*, projecting from the left side. The bolt is now free to be removed from the rear of the gun.

(4) The *extractor* (15) and *firing-pin* (18) can be removed from the bolt by pushing out the small pins (17) and (20) that hold them in place.

Assembling the Colt automatic gun.—To assemble the Colt automatic gun:

(1) Insert the bolt (13) and push forward as far as it will go.

(2) Place hand on gas-lever (29), holding it up against bottom plate (91).

(3) Push in bolt-pin (14) from left-hand side as far as it will go.

(4) Then release the gas-lever (29).

(5) Replace handle (1), locking it in position with handle-lock (2).

To remove the interchangeable barrel: Take hold of the gas-lever pin (30) and throw the gas-lever (29) rearward until it strikes the bottom plate (91), and hold in this position. Withdraw handle-lock (2) and insert its small end in the small hole in rear end of gun and on right side, pushing handle-lock in as far as it will go. This causes the bolt-pin (14) to lock slide to receiver and to hold gas-lever back. Bolt-pin will then project from left-hand side. Leave in this position. Replace handle-lock.

Attached to the *gas-cylinder* (27) will be found the *barrel-lock* (A); place small end of combination-wrench (C) under point of barrel-lock (A), and press down and out until it clears the barrel. Engage combination-wrench in slot (B) in under side of barrel, just forward of gas-cylinder, and unscrew; then pull barrel forward and out.

To replace the interchangeable barrel: Push the barrel in as far as it will go, and turn a few times by hand to engage the threads; complete this operation with the combination-wrench until lines on top of barrel and receiver coincide. Swing barrel-lock up into slot. Release gas-lever by pushing in bolt-pin from left-hand side as far as it will go with handle-lock. Replace handle-lock. Do not attempt to remove or replace the barrel until the gas-lever has been thrown to rear and locked in that position.



e-Box Attached. (Left side.)



riage, Ammunition-Chests Open,
s, etc., are carried.)

ALIBER .30, MARK I, MOD. I,

The 3-inch Landing-Gun, Mark IV, with Carriage and Limber.

This gun and mount are made by the Bethlehem Steel Company. The weight of the gun is 576 pounds; weight of carriage, 1141 pounds; weight of limber, 620 pounds. The total weight of gun, carriage and limber is 2337 pounds; total weight of gun, carriage, limber, accessories, and ammunition, 3446 pounds. It is supplied to all battleships.

The recoil system of this gun is unusual, and will be described in detail.

There are two hydraulic *recoil cylinders* (2) in one with the *barrel* of the gun (1), located on either side of and below the axis of the bore of the gun. There is no recoil rifling in the cylinders. Each cylinder is fitted with a *filling-plug* and a *drain-plug*. The cylinders are connected by an *equalizing-pipe*. The gun rests on the top plate of the *slide* (3), with two gibs which fit under the edges of the slide to hold the gun to the slide during recoil.

The *piston-rods* (4) are 66.5 inches long and have a cylindrical hole called the *throttling-bar socket* (5), bored in 32.5 inches from the rear face of the piston (7).

The *piston* (7) carries the *throttling-ring* (8), screwed into its rear end. Forward of the throttling-ring is a recess called the *piston throttling-chamber* (9), which is connected by means of 14 *port-holes* (10) to the *piston annular groove* (11).

The *spring collar* (12) retains the recoil springs, and is smaller than the bore to allow recoil liquid a free passage to the ports and throttling-chamber. The piston fits with .005 inch clearance, and has a shallow annular groove around it to give the effect of liquid packing during recoil. At rest, the piston is against the rear end of the cylinder.

The *throttling-bar* (13) bears the *throttling-bar nut* (14), which screws into the rear end of the recoil cylinder. The throttling-bar is 32 inches long and tapers gradually to a point 29.47 inches forward of the nut, then jumps to a slightly larger diameter in a quick slope, and is cylindrical to its end. The throttling-bar passes through the coned throttling-hole in the throttling-ring (8), then through the throttling-chamber (9), and slides in the throttling-bar socket (5). There are 90 *throttling-bar socket escape-holes* (15) drilled through the piston-rod. These holes allow the free

passage of liquid to and from the socket and serve also to check the counter-recoil. At full counter-recoil, the forward end of the throttling-bar is .2 inch forward of the last escape-hole, and the rest of the socket serves as a *dash-pot* (16). The checking of the gun-recoil is accomplished by forcing the liquid from the cylinder through the piston port-holes into the throttling-chamber, and then through the tapered hole of the throttling-ring around the throttling-bar. The clearance is large at first, and allows an easy recoil. The tapered throttling-bar, however, gradually closes the hole in the throttling-ring and, with the help of the recoil springs, checks the recoil.

There are three sets of *springs* (17) in each cylinder, consisting of an outer and an inner spring in each set. The sets of springs are separated by *spring-separators* (18). The piston-rod passes through the front *cylinder-head* (19), and the recoil liquid is prevented from escaping by annular V *packing* (20).

The pressure of the recoil-cylinder liquid is admitted to the V packing through four holes in the cylinder-head. This pressure serves to set the V packing in against the piston-rod during recoil and prevents leakage of the recoil liquid.

The V packing is backed by an annular *packing-ring* (21) sliding in the bore of the cylinder-head. This is followed by a ring of hemp packing (22), which is pressed in place by the *cylinder-head gland* (23).

The forward ends of the piston-rods secure to the front enforcement (24) of the slide by nuts and taper pins. The gun can recoil slightly over 30 inches before the throttling-bar socket escape-holes reach the V packing.

Slide and turntable.—The *slide* rests on and is pivoted to a *turntable*, which in turn pivots on the axle and is movable vertically.

Elevating-gear.—The *elevating-gearing* is contained in the *gear-case* (33), pivoted on the cheek of the *trail* (34). By turning the *elevating-wheel* (35), the *shaft* (36), *pinion* (37), and *screw-case* (38) are turned. This transmits motion to the *inner screw* (39) and *outer-screw* (40), raising and lowering them, and with them, the gun. The bottom of the screw-case is closed by a disk to keep out dust and moisture.

Traversing-gear.—The gun has 10° total train. The *traversing-screw hand-wheels* (41) operate the *traversing-screw*, which gives lateral motion to the slide.

Trail-plates.—The *trail* (34) is built up of steel plate and has bearings for the axle in its forward end. At the rear end is the *spade* (47), with the *trail-eye* cast in it. The trail handles and drag-rope snap-hook loop are riveted on. The combination-handle with rammer and sponge is secured to the right side of the trail. In action, the *trail-wheel* (48) is removed and the spade is bedded.

Ammunition-boxes.—Two ammunition-boxes are carried on the carriage. They contain 12 rounds each. Below them are the tool-boxes.

The sight.—The *sight* consists of a peep-sight with cross-wires in the front sight and an auxiliary finding-sight, consisting of a notch on top of the peep-sight and a point on top of the front sight. The sight-radius is 39.8 inches.

The front sight-bracket is secured to the left side of the slide.

No allowance is made on the deflection-scale for drift.

To dismount the gun.—(1) Remove the sight-bar; depress the gun; remove the breech-mechanism; remove the nuts that secure the piston-rods to the front enforcement. Four men, two at each end of the gun, insert strong bars in the muzzle and breech, and lift and slide the gun off to the rear.

(2) Remove the traversing-screw and drop out the traversing-nut and block. Remove the nut on the end of the pivot-pin. Knock out the hinge-pin that holds the clamp-plates together.

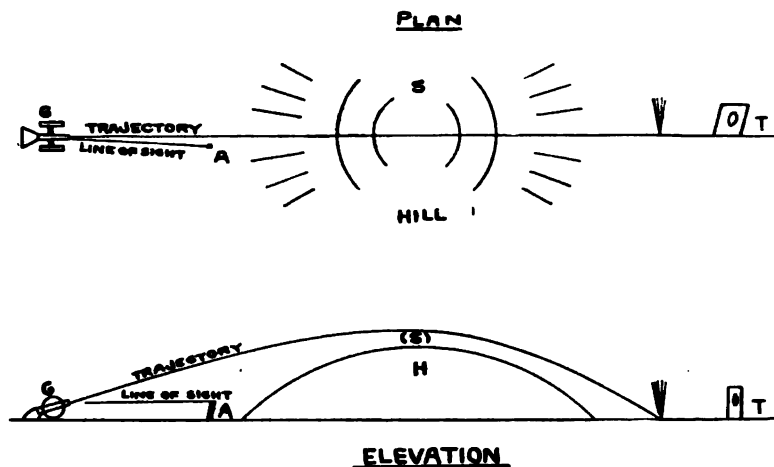
(3) Turn the slides clear of the rear end of the turntable and lift the slide off the turntable. Remove linch-pins from the axle and pull off the wheels. The turntable, trail, and axle cannot be further dismounted.

(4) Remove the cylinder-head nuts and stand clear of the recoil springs as they jump out.

It would be better in disassembling, however, to slack off the cylinder-head nuts until they bear against the front enforcement, and then gradually ease them off together until tension on the springs is removed; then the gun can be hauled off the slide.

Assemble the gun and carriage parts in the reverse manner.

Care and handling.—Be careful to keep the recoil system overhauled and clean. The recoil liquid should be renewed when dirty. It should always be strained to keep out grit. Be careful not to dent the recoil cylinders, as there is not much clearance between cylinder walls and piston. If the piston does not fit freely, scrape down the high spots in the cylinder. It is advisable to test the recoil system by hauling the gun back to its position of normal recoil against the action of recoil springs and liquid by hooking a whip to a strap around the gun; then release the whip to see if the gun



returns freely and fully to battery. If not, overhaul recoil mechanism until it does.

Keep all bearings properly oiled and the bearing-surfaces on the turntable and slide free from grit and sand.

The spade should be properly bedded before firing, as the carriage has a heavy recoil and is not provided with wheel-brakes.

Use of the Mark IV landing-gun for indirect fire.—Supposing it is desired to fire over the hill **H** (shown in sketch). **G** is the position of the gun. **A** is the point of aim, the top of a rod. **S** is the spotter on the top of the hill, having the target **T** in view.

The rod, which is the point of aim, is put up in line with the estimated bearing of the target, and at a distance of not less than 200 yards from the gun, to avoid parallax.



3-INCH LANDING GUN.

The spotter *S* then gives the gun such an elevation by the spirit level on the sight-bracket (or by the range readings in yards on the sight-bar) as he thinks will insure the shell clearing the top of the hill and coming near the target. Deflection, zero (0).

A trial shot is fired. Supposing it falls short of the target and to one side, the spotter gives the gun such an increase of range or degrees of elevation as he judges will insure reaching the target, and such a deflection right or left as will bring the next shot on in deflection. The sights are set again.

The point of aim, the top of the rod *A*, is again sighted on. Another shot is fired and spotted. Each time the gun is aimed and fired, the end of the rod is used as the point of aim.

This is a rough method, as the sights cannot be accurately leveled up, and spotting may not always be possible—for instance, when the enemy is in dense undergrowth or in woods.

A hard-bottomed gun-pit, with bottom level, will do much towards insuring accuracy. The transverse level on the sight-bracket should be used to level up the wheels and axle of the piece.

The 3-Inch Landing-Gun, Mark VII, for Marines.

For marine detachments on shore, the 3-inch. Mark VII landing-gun is supplied. This is a heavier gun than the Mark IV. It is fitted with a shield, and a *panoramic sight* for use with indirect fire. The breech-mechanism is the Ehrhardt horizontal-wedge breech-block.

The opening and closing of the breech is effected by one movement of the breech-block handle.

The panoramic sight is a vertical telescope so fitted with reflecting-prisms that the pointer, with his eye at the eye-piece, which is fixed in a horizontal position, may bring into the field of view an object situated at any point in a plane perpendicular to the axis of the telescope.

CHAPTER XIII.

EXPLOSIVES.

SUBSTANCES USED IN THE MANUFACTURE OF EXPLOSIVES.

Regarded from the point of view of their composition, explosives may be divided into two classes; namely: (1) *Explosive mixtures*, (2) *explosive compounds*.

Explosive mixtures consist of an intimate mixture of distinct substances, properly prepared and conglomerated mechanically in varying proportions. Such explosive mixtures must have at least some *oxygen-supplier*, such as a nitrate or chlorate, and some *combustible*, such as carbon or sulphur. Black and brown powders and the new explosive called *ammonal* are typical examples of such mechanical mixtures.

Explosive compounds consist of substances whose molecules contain within themselves the oxygen, carbon and hydrogen necessary for combustion. Any substance whose molecule contains oxygen, carbon, and hydrogen in the proportions to give CO or CO₂ and H₂O, may become an explosive. One which is so constituted and at the same time has weak molecular bonds, due to the presence of the radical NO₂ or other weak-bonding radical, is an explosive compound.

Mechanical mixtures can be graded by varying the proportions of the ingredients. The elements constituting an explosive compound are always present in the molecule in the same quantities, according to the law of fixed proportions; therefore the nature of the explosive cannot be graded by varying the quantities of the constituent elements as in the case of mechanical mixtures. The substances used in the manufacture of these two classes of explosives may be considered conveniently in the following order:

(1) The nitrates and chlorates, used as *oxygen-suppliers* in explosive mixtures.

(2) The *combustibles*, charcoal and sulphur, used in explosive mixtures.

(3) The *hydro-carbons and other compounds of organic origin*, used in the manufacture of high explosives, and of the more recently developed nitro-powders. These include hydro-carbons proper, alcohol, ether, acetone, phenol, glycerine, cellulose, and certain nitro-derivatives of some of these, including the nitro-benzines, nitro-naphthalene, nitro-phenol.

The Nitrates.

Potassium nitrate (KNO_3).—This salt, known also as “niter” and “saltpeter,” is found in nature as an incrustation on the surface of certain soils in hot countries, especially in East India. This incrustation is caused by the moisture of the air or rain soaking into the soil, and by the effervescence of niter salts in dry weather, through the capillary action of the soil. These effervesced salts are collected, extracted and evaporated by heat.

It may be produced artificially by the niter-bed.

Process.—Liquids from stables are poured on heaps of vegetable and animal matter, limestone, wood ashes and other alkaline materials. Decomposition follows, and a chemical action takes place in which the soluble nitrates percolate through the mass to the side where it is exposed to the winds. Evaporation leaves on the surface an incrustation of nitrate mixed with other salts.

Sodium nitrate (NaNO_3).—This salt, known also as “Peruvian saltpeter” or “Chile saltpeter,” cannot be used for explosive purposes on account of its hygroscopic qualities. Its chief connection with explosives is as a source from which KNO_3 is obtained by chemical reaction. Almost all the niter used in the manufacture of gunpowder is obtained by the conversion of NaNO_3 into KNO_3 by means of potassium chloride. When these two are mixed and the solution is boiled down, sodium chloride is deposited and KNO_3 remains in the boiling liquid.

Ammonium nitrate (NH_4NO_3).—This salt, which was formerly used in the manufacture of gunpowder, has been eliminated from use on account of its excessive hygroscopic properties. It is an ingredient in the new explosive *ammonal*, which has given excellent results as a charge for shell and for disruptive purposes. It is also used in certain blasting powders and dynamites.

Barium nitrate.—This is the least hygroscopic of all the metallic nitrates used in explosives. It is an ingredient of some of the modern military and sporting smokeless powders.

The Chlorates.

The chlorates are oxygen-carriers like the nitrates. They act more readily than the nitrates as oxidizers, and at lower temperatures.

Potassium chlorate is the oxidizing ingredient in signal and pyrotechnic compositions and in firecrackers. It is used with sodium nitrate to obtain potassium nitrate for gunpowders.

Combustible Elements.

Sulphur.—Sulphur (S) is found in the uncombined state in nature in certain volcanic districts. It is refined by melting down the crude sulphur and distilling it from the molten state.

As an ingredient of gunpowder, sulphur is valuable on account of the low temperature (500° F.) at which it ignites, thus facilitating the ignition of the mixture. Its combination with the oxygen of the niter gives also a higher temperature than would obtain if charcoal alone were used. This higher temperature has the effect of increasing the rate of combustion and the pressure of the gases evolved.

Carbon (charcoal).—Carbon (C) is the combustible element of most explosive mixtures, and is present in combination with hydrogen in most explosive compounds. Its function in all cases is to combine with oxygen, producing either CO or CO₂.

The charcoal used in the manufacture of powder is obtained by the destructive distillation of certain woods and woody fibers, such as willow, alder, European dogwood, and rye straw. The lighter woods are used because they give a charcoal more easily combustible than charcoal from heavier ones.

Compounds of Organic Origin.

Most of the recently developed explosives are derived from organic substances. The organic substances enumerated below

may be regarded as the most important ones in connection with explosives:

- (1) The hydro-carbons (compounds of C and H only).
 - (a) The paraffins, derived from mineral oil.
 - (b) The olefins, found in the products of distillation of coal, wood, etc.
 - (c) The acetylenes, found in the products of distillation of all substances rich in carbon and hydrogen.
 - (d) The benzenes, extracted from coal tar.
- (2) The alcohols.
- (3) The ethers.
- (4) The ketones.
- (5) The phenyls.
- (6) The quinones.
- (7) The carbohydrates.

The Benzene Series.

Benzene itself (C_6H_6) is not used as an explosive, but lately certain of its derivatives have come into prominence as disruptive explosives, particularly as charges for shells.

Mononitro-benzene, produced by adding one part of benzene to three parts of a mixture of nitric acid and sulphuric acid in the proportion of 4 to 6, is an ingredient of *indurite*, a smokeless powder invented by Professor C. E. Monroe.

Picric Acid and Derivatives.

Picric acid, or **trinitro-phenol** ($C_6H_2 \cdot HO(NO_2)_3$), has recently found use not only as an explosive itself, but more particularly as an ingredient of special explosive mixtures. It and its salts (the picrates) find application in detonating or disruptive explosives only. *Lyddite* (England), *melinite* (France), and *shimose* (Japan) are examples of shell-fillers of picric acid or its derivatives.

Trinitro-toluol ($C_6H_2(NO_2)_3 \cdot CH_3$)—also known as *trotol*, *tritone*, *trinitro-toluene*, *trinitro-methyl-benzene*, *tolite*, *trilite*, *trinol*, *trotyl*—is a by-product obtained in the manufacture of illuminating coal gas. As it does not form sensitive compounds

by combination with metals, it is valuable as a shell-filler and also for mines.

Alcohols, Ethers, Ketones.

Alcohol and alcohol derivatives are used either in the manufacture or as ingredients of modern explosives. Only two of the alcohols proper are important in explosives; namely, *monohydric ethyl alcohol* (C_2H_5HO) and *trihydric propenyl alcohol* (glycerine, $C_3H_5(OH)_3$).

Ethyl alcohol is an ingredient of the solvent used in making nitro-cellulose.

Propenyl alcohol forms nitro-glycerine when treated with nitric acid.

The following compounds are allied in structure to the alcohols:

Ethyl ether, $(C_2H_5)_2O$, a mixture of ethyl ether and ethyl alcohol in the proportion, by volume, of 2 to 1, is used as a solvent for nitro-cellulose of medium nitration.

Cellulose, $(C_6H_{10}O_5)_2$, is used in the manufacture of nitro-cellulose.

Acetone, or dimethyl ketone ($CH_3 \cdot CO \cdot CH_3$), is the solvent for cellulose that has been nitrated to contain a high percentage of nitrogen, say 12.9 per cent or above.

Acetone is found among the products resulting from the distillation of wood.

Glycerine is a trihydric alcohol. When acted upon by nitric acid, it forms nitro-glycerine.

Cellulose, by far the most important substance used in explosives, is now classed as hexhydric alcohol.

GENERAL REMARKS ON EXPLOSIVES.

As a matter of practical military interest, explosives may be divided into three classes; namely:

(1) *Progressive or propelling explosives (low explosives)*. These include all classes of gunpowder used in firearms of all kinds.

(2) *Detonating or disruptive explosives (high explosives)*, used in shells and torpedoes, and for demolitions of all kinds.

(3) *Detonators or exploders (fulminates)*, explosives used to originate explosive reactions in the first and second classes.

Explosive phenomena may be divided into three corresponding classes; namely:

(1) *Explosions proper* (explosions of low order, progressive explosions, combustions).

(2) *Detonations* (explosions of high order).

(3) *Fulminations* (the characteristic type of explosion produced by the fulminates, possessing exceptional brusqueness).

Explosion proper (explosion of low order, progressive explosion).—This class of explosion is marked by more or less progression; the time element is involved as a controlling factor, the time required to complete the explosive reaction being large compared with that in the other forms of explosives. In this class of explosion the time consumed in the reaction is to some extent under control by varying the physical characteristics of the explosive. The explosion, indeed, is in the nature of an ordinary *combustion*. The mass is ignited at one point, and the reaction proceeds progressively on the exterior surfaces, and then perpendicularly to these surfaces, until the entire mass is consumed. The explosion of a charge of black, brown, or smokeless powder is not different in principle from the burning of a piece of coal, wood, or other combustible; there is a progressive change of state from particle to particle, from the solid state to the gaseous state, accompanied by the heat due to the chemical change.

Detonation (explosion of high order).—The second class of explosion is of different nature. This explosive reaction is not confined to the surfaces exposed, but appears to progress in all directions throughout the mass, radially, from the point of initial explosion; it appears to pass from the molecules at the initial point to those adjacent, and so on throughout the body, at a very rapid rate. Apparently the atomic bonds of the initial molecules are disrupted by the molecular energy or blow at the initial point. This breaking up of the initial molecules is transmitted by a wave-like action known as the *explosive wave*, extending throughout the body, the initial disruptive energy being transmitted from molecule to molecule, and these in succession giving way, the nascent atoms thereof combining according to the newly existing affinities which yield mostly gaseous substances. The effect is to transform the explosive in an almost inappreciably brief time from the solid or liquid state to the gaseous state, the gases being

greatly increased in volume and pressure by the heat of combination attending the reaction.

Fulmination.—This class of explosion is still more brusque than the last. It is like the last in that the initial molecule is broken up by the crushing effect of the blow due to the exciting cause, and the molecular energy thus applied is transmitted by the disruption of the first molecules to those adjacent, and these to the next, and so on throughout the mass. The characteristic feature of this form of explosion is the *absence of dissociation*. The gases are evolved in such a simple form that there is little or no dissociation and the new affinities do not invite chemical combination. The explosive blow is thus not prolonged by these phenomena, and is therefore relatively much sharper than in the last class. The heat of the first phase of the explosion is also very great, tending in itself to increase the sharpness and energy of the blow on the initial molecules.

PROGRESSIVE EXPLOSIVES.

Progressive explosives may be considered under the two headings: (1) Charcoal powders, and (2) nitro-cellulose powders.

Charcoal Powders.

These may be divided into (1) black charcoal powder, or *black powder*; (2) brown charcoal powder, or *brown powder*. Brown powder is now obsolete. Black powder is used chiefly for saluting purposes and as an igniter for nitro-cellulose powders, also in fuses and as mealed powder in primers.

Black powder.—The proportions in which pulverized charcoal, sulphur and niter are mixed are about as follows:

- 75 parts by weight of niter.
- 15 parts by weight of charcoal.
- 10 parts by weight of sulphur.

Explosion of gunpowder.—The phenomenon of explosion of gunpowder may be divided into three parts, viz., *ignition*, *inflammation*, and *combustion*. By ignition is understood the setting on fire of a particular part of the charge; by inflammation, the spread of ignition from grain to grain; and by combustion, the burning of each grain from its surface to its center.

Ignition.—Ordinary gunpowder may be ignited by the electric spark, by contact with an ignited body, or by a sudden heat of 572° F. A gradual heat decomposes powder without explosion, by subliming the sulphur. Flame will not ignite brown powder unless it remains long enough in contact with the grains to heat a small portion to the ignition-point. Thus the flame from burning paper may be touched to grains of brown powder without igniting them, owing to the slight intensity of the flame and the cooling effect of the grains. It may be ignited by friction or a shock between two solid bodies, even when they are not very hard. Experiments show that gunpowder may be ignited by the shock of copper against copper, copper against iron, lead against lead, and even lead against wood; in handling gunpowder, therefore, violent shocks between all solid bodies should be avoided.

The time necessary for igniting powder varies according to circumstances. For instance, damp powder requires a longer time than powder perfectly dry, owing to the loss of heat consequent on the evaporation of the water. A powder, the grain of which has an angular shape and rough surface, will be more easily ignited than one of rounded shape and smooth surface; a light powder more easily than a dense one.

Smokeless powder is not ignited as easily as black or even brown powder, and for this reason an *ignition-charge* of the former is used for each charge of smokeless.

Inflammation and combustion.—When grains of powder are united to form a charge, and fire is communicated to one of them, the heated and expansive gases evolved insinuate themselves into the interstices of the charge, envelop the grains, and ignite them one after another.

The propagation of ignition is called *inflammation*, and its velocity, the *velocity of inflammation*. This velocity is much greater than that of combustion, and should not be confounded with it. When powder is burned in an open train, fine powder inflames more rapidly than coarse; such, however, is not the case in fire-arms, owing to the diminution of the interstices. If a charge were composed of mealed powder, the flame could no longer find its way through the interstices, and the velocity of inflammation and combustion would become the same. The ignition-charge used with

smokeless powder serves not only to ignite the powder but to increase the velocity of inflammation.

Now, supposing one grain or particle alone be ignited, it will first be inflamed over its whole surface, and the progressive combustion will take place from the exterior to the interior. Its *rate of combustion* will therefore depend upon both its shape and size, leaving out entirely, for the present, the question of density and hardness. A grain of spherical or cubical form will expose less surface to ignition in proportion to its volume than one of an elongated or flat shape, and will consequently require a longer period for the combustion of its entire mass; the larger the grain also, the longer will be the time required for its combustion.

Looking, then, at one grain of powder by itself, we may say that the larger it is, and the more nearly its form approaches a sphere, the longer will its combustion take and the slower will be the evolution of the gas. When, however, we come to regard the action of an aggregation of such particles, as in the charge of a gun, the *rate of ignition* of the whole charge is also affected by the size and shape of the grain.

The part of the charge first ignited is that near the vent, and the remainder is inflamed by contact with the heated gas generated by the combustion of this portion, so that the rate of ignition of the whole mass will be regulated by the greater or less facility with which the gas can penetrate throughout the charge, which is itself dependent upon the shape and size of the interstices between the grains. If the grains be spherical and regular in form, the interstices will be comparatively large and uniform, and the gas will penetrate the mass with facility; again, the larger the grains, the larger the interstices between them. If, on the other hand, they be flat or flaky and irregular in shape, the passage of the gas will be more difficult, and the rate of inflammation of the charge will be reduced.

We see, therefore, that the considerations which affect the more or less rapid combustion of an individual grain of gunpowder, also affect the rate of ignition of a charge of such grains, but in an opposite direction; so that a form of grain which will individually burn rapidly, may offer an increased resistance to the passage of the heated gas through the charge, and thereby retard its ignition; while a grain which will burn more slowly may allow the charge

to be more rapidly ignited. In the case of perforated grains, however, the rates of ignition and combustion are both increased by the perforations.

By varying the size and shape of the grain alone, a powder may therefore be obtained, a charge of which shall be ignited rapidly throughout, but burn comparatively slowly; or one which will be ignited more slowly, but, when once inflamed, will burn very rapidly. It is necessary to draw a clear distinction between a rapidly igniting powder and a quickly burning powder.

Velocity of combustion.—The *velocity of combustion* is the distance passed over by the surface of combustion in a second of time, measured in a direction perpendicular to this surface.

The velocity of combustion varies with the purity, proportions, trituration, or incorporation of ingredients, density, and condition of the ingredients, as also with the pressure and temperature under which the powder is burned.

Effect of temperature on combustion.—The heat developed increases with the charge, and as the velocity of the gases increases with their temperature, it is therefore evident that a large charge is consumed proportionately quicker than a small one. It is also true that the quantity of heat absorbed by the surface of the bore is much less sensible when the charge is great than when it is small; that is, the heat absorbed is *proportional to the surface*, or the *square* of the caliber of the gun, and the heat developed *increases as the cube* of the caliber.

The resistance of the projectile.—When the projectile offers a great resistance, its motion in the bore is less rapid; and it evidently follows that the inflammation takes place in a space which diminishes as the resistance increases. The smaller this space, the more heat is generated, the higher the temperature of the gases, and the greater their velocity; and there follows from all these causes a train of effects which accelerates the inflammation and combustion of the charge.

The point of ignition.—When a quantity of powder is contained in a closed space all the sides of which offer an equal resistance, it is evident that the complete inflammation will be quickest when the fire is applied to the center of the charge.

In cannon, however, the force developed does not meet with the same resistance in all directions; the projectile yields as soon as sufficient force acts upon it; and as the combustion of the powder

requires a definite interval of time, it follows that a great part of the charge is not consumed until after the displacement of the projectile.

The position of the interior orifice of the vent may influence the time required to displace the projectile, and this influences the inflammation of the charge. For example, with the regulation vent it is the rear part of the charge which first takes fire; the inflammation is communicated to the adjacent parts and promptly reaches the projectile; the gases expanding displace it, and the inflammation takes place in a larger space than that at first occupied by the charge.

Density and hardness.—The density and hardness of the grains of powder are of quite as vital importance as their size and form, in determining the rate of ignition and combustion of a charge.

By *density* is meant the quantity of powder actually present in a given bulk. It is important that this quality should not be confounded with *hardness*. A substance may be very hard and yet be of a low density. A powder with a very hard surface may be really less dense than another, the surface of which is softer. Of course, very high density cannot be communicated without producing a considerable degree of hardness; but powder can be made hard without rendering it very dense, by pressing the dust in a comparatively dry state.

Hardness seems to bear a direct relation to the power exerted in compressing, while density does not. Black-powder dust at a high degree of moisture, say 6 per cent, can be made very dense by application of moderate pressure, while that at 1 per cent can only be brought to the same point in density by the exertion of enormous force. Of the two, the latter will be the harder powder.

Nitro-Cellulose Powders.

Nitro-cellulose may be considered the base of all forms of smokeless powders. According to a noted scientist, Vielle, there are eight varieties of nitro-cellulose, as follows:

Cellulose tetra-nitrate.

Cellulose penta-nitrate.

Cellulose hexa-nitrate. . . Only slightly attacked by acetic ether and ether alcohol.

- Cellulose hepta-nitrate . . . Becomes gelatinous in acetic ether and ether alcohol.
- Cellulose octa-nitrate . . . Soluble in ether alcohol; inferior colloid.
- Cellulose ennea-nitrate. . . } Highly soluble in ether alcohol;
 Cellulose deca-nitrate. . . } superior colloid.
- Cellulose endeca-nitrate. . . Insoluble in ether alcohol, soluble in acetone. (Gun-cotton.)

Colloidization.—After cellulose has been dipped in nitric acid ("nitrated"), and purified of the free acid and nitro by-product by boiling and washing in water, it possesses a property it did not have before; namely, solubility in certain liquids in which it was not soluble as cellulose. The two most important of these liquids are *acetone* and a mixture of *ether* and *alcohol*, in the proportion, by volume, of 2 to 1.

If an excess of the liquid be used, a true solution is formed; and if the liquid be evaporated off, the nitro-cellulose will remain as a horn-like, compact mass, called *colloid*, in which all evidences of cellular structure have disappeared. If the quantity of solvent be reduced sufficiently, the solid nitro-cellulose will soften and take the form of a paste-like mass.

This process of dissolving nitro-cellulose and producing the colloid form of it, is called *colloidization*.

In connection with nitro-explosives there are two important series of colloids: one, the *acetone* series; the other, the *ether-alcohol* series. Acetone dissolves the nitro-cellulose of highest nitration, and gives colloids which are characterized by brittleness. This renders such colloids dangerous when used alone for powder; the shocks due to handling and the pressure in the bore of a gun would cause grains to be disintegrated and the rate of combustion to be enormously increased, and hence would cause excessive pressures. The ether-alcohol colloids, on the other hand, are tough and elastic. It is from this class of colloids that most smokeless powders now in use are made.

General Remarks on Smokeless Powder.

Powder such as that just referred to is a pure cellulose or colloid powder. Sometimes nitro-glycerine or certain metallic nitrates are added to the colloid in the mixing, with a view to giving a better ballistic effect. These substances, when added, are to be

considered as distributed throughout the mass of the colloid—the nitro-glycerine like water in a sponge, the metallic nitrates like particles of sand or earth in ice made from muddy waters. They are not *essentials*; they are added to modify the character of the explosion in the bore of a gun.

The ballistic efficiency of a powder may be represented by the ratio

$$\frac{\text{Velocity given to projectile in f. s.}}{\text{Pressure in tons per square inch in bore}}.$$

It is desirable that this ratio shall have a maximum value. The strength of guns now in use limits the denominator to about 16 to 18. With this limitation, muzzle velocity for a given projectile is dependent on the rate of burning of the powder, its quantity, and the length of bore.

It is lately thought that the best results with progressive explosives are to be had when the carbon is burned to CO instead of CO₂, for the reason that a given weight of carbon will give double volume of CO compared with CO₂ at the same pressure and temperature; and this will be more efficient in a gun than the increase of volume due to the increased temperature in burning to CO₂. Furthermore, the higher temperature of the products of explosion when C is burned to CO₂ is so destructive to the metal of the bore of guns, by erosion, as to make such explosives less desirable.

For example, military gun-cotton has insufficient oxygen to burn all of its C to CO₂, and nitro-glycerine has an excess of oxygen. By mixing these two substances in proper proportion, the excess of oxygen in the explosion of the latter supplies the deficiency of oxygen in the explosion of the former, and the products of explosion of the mixture are CO₂, H₂O, and N. The English smokeless powder is an illustration of such a combination. It is composed of

Gun-cotton (acetone colloids).....	37 parts.
Nitro-glycerine	58 parts.
Vaseline	5 parts.

It gives high muzzle velocities, with low pressures, but the temperature of its explosion is very high comparatively, and has caused thereby such rapid erosion of the bores of English guns as

to cause it to be discarded in favor of a powder with less nitro-glycerine, about 38 per cent.

The celebrated French B. N. powder contained barium and potassium nitrate.

The explosion of such powders, containing an oxygen-carrier disseminated throughout the mass of the colloided nitro-cellulose, appears to be more prolonged and increasing in its effect than that of the pure colloid powders.

Based on the foregoing considerations, nitro-cellulose powders may be classified as follows:

(1) Pure colloids.

(a) Acetone colloids.

(b) Ether-alcohol colloids.

(2) Composite colloids.

(a) Acetone colloid for matrix with nitro-glycerine.

(b) Acetone colloid for matrix with metallic nitrate.

(c) Ether-alcohol colloid for matrix with nitro-glycerine.

(d) Ether-alcohol colloid for matrix with metallic nitrate.

(e) Acetone colloid for matrix with organic nitrate.

(f) Ether-alcohol colloid for matrix with organic nitrate.

EXAMPLES OF POWDERS.

PURE COLLOIDS.

ACETONE.

Maxim-Schupphaus.

Poudre B.

Rifleite.

Indurite.

Swiss normal powder.

ETHER ALCOHOL.

Mendeléef.

Powder for U. S. Army and Navy (great guns). Nitro-cellulose.

For U. S. Army and Navy (small arms). Pyro-cellulose.

COMPOSITE COLLOIDS.

METALLIC NITRATES.

Plastomenite.

Poudre B. N.

Schultze.

E. C. Powder.

NITRO-GLYCERINE.

Ballistite.

Cordite.

Maxim-Schupphaus (practically the acetone powder with 9 per cent nitro-glycerine).

DETONATING EXPLOSIVES.

Detonating explosives may be classified as follows:

- (1) Gun-cotton.
- (2) Nitro-glycerine.
- (3) Dynamites.
- (4) Explosive gelatin.
- (5) Picric-acid derivatives.
 - (a) Melenite (French).
 - (b) Lyddite (English).
 - (c) Explosive D (United States).
 - (d) Shimose (Japanese).
 - (e) Ecrasite (Austrian).
- (6) Trotyl.

Trotyl is manufactured extensively in Germany, and is used by the German government and other European governments for mine and torpedo charges. It is neither difficult nor dangerous to make. It behaves in a very stable manner when exposed to the air under varying conditions of temperature. It is unaffected by contact with metals even in the presence of moisture, and forms no sensitive compound due to such contact. It is a very powerful explosive when detonated, but cannot be exploded by flame or by strong percussion. It can be cast into any form desired.

In 1863, Noble discovered that the highest type of explosion could be initiated in nitro-glycerine by a small cap of *fulminate of mercury*. This introduced an epoch in explosives, in that it for the first time established the fact that *the character of the explosion is dependent upon the character of the initial disturbance*.

General Requirements of High Explosive for Shells.

- (1) Should be reasonably safe to manufacture, and free from any injurious effects to the operators.
- (2) Must show a safe degree of insensitiveness in the impact-machine.
- (3) Must withstand the maximum shock of discharge under repeated firings in the shell for which it is intended.
- (4) Must withstand the shock of impact without explosion when fired in fused shells against the strongest plate that the shell alone will perforate without breaking up.

(5) Must be uniformly and completely detonated with the service detonating-fuse.

(6) Should possess the greatest strength compatible with other necessary requirements.

(7) Must not decompose when a dry or wet sample is hermetically sealed and subjected to a temperature of 65.5° C. for one week.

(8) Should be non-hygroscopic, and must not have its facility for detonating affected by moisture that can be absorbed under ordinary atmospheric conditions of storage and handling.

CHAPTER XIV.

SMOKELESS POWDER AND GUN-COTTON.

A description of the military gunpowders of to-day would, so far as they relate to the propulsion of projectiles, exclude all but smokeless powder. Black powder, which has been in use for nearly six centuries, is little used except for igniting smokeless-powder charges, for explosive shell, for primers and fuses, and for saluting-charges. Brown, or cocoa, powder—so named from its peculiar color—came into extensive use some twenty years ago, but is no longer manufactured.

Black powder is an intimate mixture of 75 parts of saltpeter, 15 parts of charcoal and 10 parts of sulphur. The proportion of ingredients has been varied from time to time during the history of gunpowder, but it is a notable fact that we are using to-day the same relative quantities that were in use at the earliest times.

The ingredients, after being incorporated in a suitable mill, are caked and then broken up into granules. Shell powder and powder for fuses and primers are very fine-grained; ignition-charges for guns are made up of similar powder. Saluting-charges are made up of irregularly shaped grains considerably larger than the shell powder.

Brown powder has played such an important part in the development of the modern gun that it merits a word in passing. Its composition is similar to that of black powder, except that the proportion of saltpeter is increased and the amount of sulphur is decreased to 2 or 3 per cent; a small amount of sugar, about equal to that of the sulphur, is also incorporated. The light color is due to the fact that the charcoal used is underburnt.

Advantages of smokeless powder.—When black or brown powder is exploded in a gun, only about 35 per cent of its weight is converted into gas, the remaining 65 per cent being mainly dissipated in dense smoke, while a portion of it remains in the bore as solid residue. The smoke and residue are entirely inert and,

instead of aiding in the propulsion of the projectile, actually reduce its initial velocity by taking away from the expanding gases sufficient force to eject the solid particles from the gun. Thus, taking the 6-inch gun, firing a projectile of 100 pounds with a charge of 50 pounds of brown powder, 17.5 pounds of gases are formed, which must not only do the work of expelling the projectile at a velocity of 2100 f. s., but must also expel 32.5 pounds of solid material, making the projectile weigh, for the moment, virtually 132.5 pounds. Now if the propellant were of a material that could all be turned into a gas of equal force, we would have gained: (1) The considerable advantage of a less weight of ammunition to stow and handle, (2) a greater velocity, (3) no fouling of the bore, and (4) no smoke and an unobstructed view of the target after firing each shot.

These advantages were recognized quite early in the last century, when attempts were made to obtain a substitute for black powder, and gun-cotton was the first material extensively used for the purpose. In order to control its rate of burning, the gun-cotton fiber was spun into threads and then twisted or braided. Considerable success attended these attempts, but owing to irregular ballistic results and other accidents, the use of gun-cotton in this form as a propellant was finally abandoned.

Gun-cotton.—Gun-cotton is of several varieties, *depending upon the degree of nitration the cellulose attains in the process of manufacture.* A fairly sharp dividing-line may be drawn between the grades of “*high and low nitration*” in that the latter are soluble in a mixture of ether and alcohol at ordinary temperature, while the former are not. In general, this division occurs when the percentage of nitrogen amounts to 12.75; above that point gun-cotton is insoluble. Gun-cotton containing less than 12.75 per cent nitrogen may be perfectly dissolved into a jelly-like substance, which, after the solvent is evaporated off, becomes a hard, tough, translucent mass. In this condition it burns regularly in parallel layers without smoke; it may be pressed into any desired shape, and it cannot be detonated. This material, pressed into grains of the required form, constitutes the U. S. Navy smokeless powder.

NOTE.—A clear distinction must be made between the gun-cotton proper, which is used as a high explosive in mines and torpedoes, and that from which smokeless powder is manufactured.

Mononitro-cellulose represents the lowest degree of nitration and is little used; nitration is stopped at *bi*-nitro for the gun-cotton that is to be used for smokeless powder; if stopped too soon, part of the cotton will be *mono*-nitro, and smokeless powder made from such cotton might be too weak; if, on the other hand, the nitration be continued too long, *tri*-nitro-cellulose (which is regular gun-cotton) will result, at least in part. This part (the high-nitration part) *will not dissolve* in ether alcohol, but will remain mixed in the powder as *gun-cotton*, and the resulting mixture might be too brusque for use in guns. Strictly speaking, therefore, gun-cotton is usually understood to mean *tri*-nitro-cellulose, while the *bi*-nitro cotton from which smokeless powder is made is often called "*pyro-cellulose*," more correctly nitro-cellulose or nitro-cotton.

Smokeless powder.—Smokeless powder is now used for all purposes in the navy except for saluting-charges, ignition-charges, and bursting-charges. The form now issued for all guns is a singly-perforated or multi-perforated cylinder.

Manufacture of Smokeless Powder.

At present the cotton used is Tennessee short-fiber cotton. This cotton is obtained by washing and scrubbing the cotton seeds after the cotton has been ginned. The cotton so obtained is pressed into cakes which are shipped in 65-pound bales, wrapped in heavy paper and bound with iron wire.

Picking.—The cotton as received at the powder works is first picked. In this process it is run between two corrugated-iron drums which are about $\frac{1}{8}$ of an inch apart. It is here ground up, and all lumps are removed.

Drying.—From the picking-house, the picked cotton is sucked by a blower through a large pipe into bins in the dry-house. In this house the cotton is dried by means of hot air drawn by blowers over steam-pipes and blown up through the cotton from the bottom of the bins.

The temperature of the dry-rooms is regulated (1) by speed of blower, (2) by number of steam-coils used for heating the air, (3) by amount of steam-pressure carried in the steam-pipes, (4) by adjusting the amount of air admitted to each bin-room, by dampers in the bottom of the bins. The temperature for drying is 105° C., and it is maintained for eight hours, thereby reducing the moisture from between 4 per cent and 6 per cent to 2½ per cent.

From the dry-house the cotton is sent to the nitrating-house in covered metal cans.

Nitrating.—In the nitrating-house, are arranged batteries of centrifugal wringers driven by motors in adjacent rooms. To nitrate the cotton, 1500 pounds of acid composed of H_2SO_4 , HNO_3 , and oxides at a temperature of $33^\circ C.$ is admitted to a wringer through a pipe from the acid-heating tank. In this bath is immersed, as rapidly as possible, 30 pounds of the cotton. It is allowed to remain in the acid 20 minutes, with the top of the wringer open. At the end of this time the top is closed down, the drain to the wringer is opened, and the wringer is started. In about two minutes the cotton is fairly dry. The charge of 30 pounds of dry cotton has by nitration been changed to about 41 pounds of dry nitrated cotton.

The above operation must be done carefully, as the cotton must contain between 12.5 per cent and 12.7 per cent of nitrogen at the end of the operation.

Drowning.—The nitrated cotton or *pyro* is next quickly taken from the wringers, by means of metal forks, and drowned in fresh-water tanks. These tanks are on trucks and are brought alongside the wringers. After a couple of minutes of drowning, the water is run out of the tanks and the cotton is washed with water from a hose.

From the tanks the nitrated cotton is transferred to fresh-water wringers, where, after five minutes washing, it is wrung as dry as possible.

Boiling.—The nitrated cotton is next taken on cars to the boiling-tubs. These are large wooden tubs with false bottoms, under which are steam-pipes for heating them. Water is admitted through pipes. When a charge of about 1000 pounds of nitrated cotton is placed in a tub, it is covered with water and is then heated to $80^\circ C.$, after which the water is drained off for 15 minutes. Water is again admitted, and the charge is then boiled four hours at a temperature of $100^\circ C.$, after which it is washed and drained.

It is next boiled three periods of 12 hours each at a temperature of $100^\circ C.$, and at the end of each period it is washed and drained. The cotton gets a total of 40 hours boiling at a temperature of $100^\circ C.$, and five washings and changes of water.

At the end of this boiling process it is covered with cold water and allowed to stand until wanted at the poaching-house.

Pulping.—From the boiling-tubs the nitrated cotton is transferred on hand-cars to the upper story of the pulping- and poaching-house, where it is dumped into galvanized-iron-lined bins, the pulpers being on the first floor. There is one bin for each pulper. The charges from 25 wringers, or 1025 pounds of dry nitrated cotton, constitute the charge for one pulper.

A *pulper* is a mill composed essentially of a cast-iron roller containing longitudinal cast-iron strips or knives on its circumference, driven by a 100 horse-power motor. It revolves with very small clearance between two craws situated 180° apart. In addition there is a *beater* or *baler*, consisting of a hexagonal roll covered with fine screen, which can be lowered into the forward end of the machine to skim the water and wash the cotton, fresh water being run in at the same time.

The nitrated cotton and water pass from the front of the mill between the upper craw and roller, where it is first ground. By means of a baffle-plate, the ground cotton is then carried down and back between the roller and lower craw. The revolving roller maintains the circulation.

When the nitrated cotton is sufficiently pulped, the baler is lowered and water is run into the machine. This water finds its way out through the screen of the baler, and thence through its central shaft to the exhaust, thereby washing the pulped cotton. The mesh of the screen is too fine to allow the cotton to pass through.

The pulping process takes from eight to twelve hours, depending upon the condition of the knives.

After washing, a bottom valve is opened and the pulped pyro is pumped to a tank on the second floor, where it is steam-heated and stirred until drawn off.

Next, the pyro is run through a box holding a screen consisting of vertical copper plates with slits .012 inch in width. The water and fine pyro pass in a zigzag path over this screen and through the slits down to another tank. The coarse pyro is scooped up and taken back to be repulped. Water jets keep the pyro moving, and tappers prevent clogging of the slits.

Poaching.—A poacher charge consists of three pulper charges, or 3075 pounds of dry nitrated cotton. A *poacher* is simply a

large wooden tub fitted with paddles for stirrers, steam jets for heating, and the necessary supply and drain pipes and valves.

The treatment received in the poachers is as follows: The pyro is boiled for a total of 12 hours at 100° C., being settled and drained five times in the meantime. It is then washed one-half hour and drained one hour. This washing and draining process is repeated 10 times.

Test.—Upon completion of the poaching, a sample is pressed out dry and sent to the laboratory to be tested. If it fails to pass the heat test, it is re-subjected to heating, boiling and poaching. This is kept up until a sample passes the test.

Wringers.—The pyro is pumped from the poachers to the wringers. These wringers are lined with cotton toweling, and have false bottoms that can be lifted to allow the dry pyro to drop through into a chute leading to the bins. From these bins the powdered pyro is conveyed to the pyro storehouse.

Dehydrating.—Charges of the pyro are placed in the hydraulic dehydrating-presses, in which they are subjected to a 200-pound pressure. Alcohol is then admitted to the pyro cake formed in the press, and the whole is subjected to a 75-pound pressure. The alcohol drives out the water in the pyro. This water escapes through a perforated copper plate at the bottom of the cylinder, and thence to a drain pipe. As soon as alcohol begins to escape through the drain, the pressure is cut off.

The cake of pyro is next subjected to a pressure of 3000 pounds. This pressure is maintained from one to three minutes, depending upon the powder desired.

The pyro cakes are put in metal cans, and are next transferred to the mixing-house.

Mixing.—The *mixers* consist of two worm-paddles on two horizontal shafts driven in opposite directions by a motor, and all contained in a rectangular case surrounded by a water-jacket. A charge consists of 100 pounds of the dehydrated pyro, in cakes. It is first stirred alone for 20 minutes, after which ether, alcohol and diphenylamine, in such quantity as previously determined at the laboratory, are added through a strainer. The charge is now stirred again for 30 minutes.

The mixture, now *nitro-cellulose*, is then taken out into cans and transferred to the press-room, where it is put in a hydraulic

press and is subjected to a pressure of 200 pounds per square inch. Each mixer charge is formed into three cakes, which are placed in air-tight cans and sent to the press-house.

Pressing.—The cakes of nitro-cellulose are first put into strainer presses, where, under a pressure varying between 1000 and 2000 pounds, the nitro-cellulose is forced out through $\frac{3}{8}$ -inch holes in the bottom plate. The macaroni-shaped powder falls into a funnel, and thence down into a blocking-press, where it is again pressed into a cake.

From the blocking-press the cake of nitro-cellulose is taken to the die-press. Two cakes from the blocking-press constitute a charge for a die-press. In the end of the cylinder of the die-press is screwed the die, the size depending upon the size of grain desired. The cake is forced through this die by a hydraulic-driven piston.

A *die* consists of a strainer four inches in diameter, with conical chamber tapering down to a cylindrical hole, the diameter of which is equal to the powder-grain desired. Seven needles, one in the center and a circle of six surrounding it, are fastened to the strainer. These needles project through the conical chamber and extend to the end of the cylindrical hole. The diameter of the needles depends upon the size of the grain formed by the cylinder.

As the powder comes from the die in the shape of a rod, it is cut into grains of the proper length by a cutting-machine.

Solvent recovery.—From the die-house, the powder is sent to the solvent-recovery house, where the powder is placed in galvanized-iron baskets, the baskets being contained in a steam-heated box. Air, after passing over steam-coils, passes down through the baskets of powder, thereby vaporizing the volatiles. The air containing the vapors then passes down over cold-brine pipes, where the vapors are condensed and flow off to a tank.

The charge of powder is kept under a temperature varying from 30° C. to 39° C., for 96 hours, and in this time it loses about 30 per cent of its weight.

Drying.—From the solvent-recovery house, the powder is sent to the dry-house, where it is placed in large bins. The green powder is left from two to two and a half months before air heated by steam is circulated through it. The temperature is then kept at 40° C. from two to four months, depending upon the volatiles.

Blending.—From the dry-house, the powder is taken to the blending-tower, where it is left 24 hours to absorb moisture from the air. On the upper floor of the blending-tower, a lot of powder is placed in a bin of eight sectors, all opening into a common chute leading to the floor below. On this floor, and centered under the chute, is a similar bin of eight sectors. Directly under the chute and above the second bin is a cone-shaped metal deflector, apex up, upon which the powder from above strikes. This deflects the powder equally in all directions, and this blends the powder from the upper bin.

From this bin the powder falls through a chute to the next floor, where it is similarly deflected; but this time it falls into a bin containing four segments, each of which contains floors sloping to the center, where a door opens to a chute leading to the first floor. On this floor the powder is taken from the four chutes, placed in boxes, weighed and marked, and is ready for stowage or shipment.

One blending-charge consists of 100,000 pounds of powder, which is one lot, and this consists of 20 pyro lots.

Summary.—The process of manufacture may be summarized as follows:

(1) *Picking.*—To grind and to remove lumps and foreign matter.

(2) *Drying.*—Dried eight hours at 105° C. to reduce moisture from between 4 and 6 per cent to 2½ per cent.

(3) *Nitrating.*—30 pounds of cotton immersed in H₂SO₄, HNO₃, and oxides for 20 minutes. Weight when dry, after wringing, increased to 41 pounds of nitrated cotton or pyro.

(4) *Drowning.*—To remove free acids.

(5) *Boiling.*—1000 pounds of pyro boiled 40 hours at 100° C. and washed five times to further remove free acids.

(6) *Pulping.*—1025 pounds of pyro, or 25 wringer charges, to one pulper charge. Ground from eight to twelve hours in contact with water, to break up tubular cotton fibers. Water baled off through baler.

(7) *Poaching.*—3075 pounds, or three pulping-charges, of dry pyro for one poaching-charge. Boiled 12 hours at 100° C., and water changed five times. Washed ½ hour and drained one hour 10 times.

(8) *Testing*.—Sample of pyro is chemically tested by heat test in laboratory.

(9) *Wringing*.—Pyro is wrung in cotton-towel-lined wringers.

(10) *Dehydrating*.—Charge of pyro submitted to pressure of 200 pounds per square inch to force out water. Alcohol then forced through charge under 75 pounds pressure, until water is all forced out. Charge then caked by 3000 pounds pressure maintained from one to three minutes.

(11) *Mixing*.—100 pounds of dehydrated pyro in a charge. First ground by knives for 20 minutes. Ether, alcohol and diphenylamine added, and charge again mixed for 30 minutes. Now a plastic mass of nitro-cellulose. Taken out into three cans.

(12) *Pressing*.—Under pressure of 1000 to 2000 pounds, cakes are forced through $\frac{3}{8}$ -inch holes in strainer press. Thence to blocking-press, where it is again caked. Then forced through die-press, from which it emerges of the desired diameter, with seven holes in the rod. The rod is cut into grains of the desired length.

(13) *Solvent recovery*.—Powder submitted to hot air for 96 hours at a temperature of 30° C. to 39° C. It thereby loses 30 per cent of its weight in volatiles. These volatiles are recovered by condensation.

(14) *Drying*.—Green powder dries from two to two and one-half months at air temperature. Then dried at 40° C. from two to four months.

(15) *Airing*.—Left 24 hours in the blending-house to absorb a normal amount of moisture from the air.

(16) *Blending*.—100,000 pounds of powder in one blending-charge. Blended to get all the powder of one index of an even mixture, so that any two bags of equal weight will give the same initial velocity under similar conditions.

(17) *Boxing and weighing*.—Placed in air-tight boxes, weighed, marked and stored ready for shipment.

General Discussion.

General characteristics.—Navy smokeless powder is translucent and varies in color from a light lemon to a deep brown, almost black. These variations in color depend generally upon variations in the process of manufacture, and possibly upon the water used. The material possesses a marked degree of tough-

ness, which operates to render the powder regular and progressive in action and prevents the unconsumed portion of the charge from crumbling or disintegrating in the gun, under the influences of heat and gas-pressure due to those portions of the charge already consumed.

Form and size of grain.—The size of the powder-grain varies with the caliber; the larger the gun the larger the grain. In general terms, the lineal dimensions of grains of similar form are in direct ratio to the calibers of the guns in which they are employed. As compared to the old forms of powder, smokeless powders produce relatively large volumes of gases per unit weight of material, yet they burn away more slowly; the result is that grains of smokeless powder for a given caliber are smaller than those of the black and brown varieties.

The grain in use for the .30-caliber rifle is in the form of short, hollow cylinders; for 1-pounders, 3-pounders, and 6-pounders no perforations are generally used, although the multi-perforated form may be used to give the required ballistic qualities; in all larger caliber guns, the multi-perforated grain is always used. The perforations of cylindrical grains are for the purpose of keeping the burning surface practically constant, thus securing the quality of progressiveness, which is of prime importance.

When smokeless powder is employed in the form of a sphere or a cube, the cube burns smaller in all directions; consequently the surface upon which the flame is operating is rapidly diminished in all directions and the quantity of gas diminishes. If, however, the powder is formed in long strips, the amount burning from the ends is immaterial; consequently the reduction only takes place in one direction—that is, in the thickness—and therefore the reduction of the burning surface is much less rapid than in the case of spheres or cubes. For this reason, powder that is formed in flat strips, or in long tubes, is more *progressive*; that is, it evolves equal quantities of gas in equal intervals of time. In the case of the multi-perforated grain, the burning surface decreases from the outside and increases from the inside. This form is, therefore, the most progressive of all.

NOTE.—Different forms of granulation have been advocated after a study of various erratic and disastrous ballistic results, the three principal forms being the *multi-perforated* grain with seven holes, the *tubular* or *macaroni* form and the *strip*. The former alone is now manufactured for common powder.

Ballistics of smokeless powder.—An example of the ballistic value of smokeless powder is shown in the fact that in a 6-inch, 40-caliber gun, 20 pounds of navy smokeless give a velocity of 2000 f. s. with 10.8 tons pressure, whereas 45.5 pounds of brown powder are required to produce the same velocity, while the resulting pressure is 15 tons. With brown powder, 2100 f. s. is the greatest velocity obtainable in the 6-inch, 35-caliber gun, while the smokeless easily produces a velocity of 2300 f. s. with less pressure and a charge weighing 25 pounds. The 12-inch, 35-caliber gun gives a velocity of 2100 f. s. using 425 pounds of brown powder. Less than half this weight of smokeless will produce the same velocity.

In general, the new-type large-chambered guns of 45 and 50 calibers length require a charge of smokeless weighing about 36 per cent of the weight of the projectile. In the 12-inch, 45-caliber gun this charge gives a velocity of 2700 f. s.; in the 5-inch, 51-caliber gun the velocity for such a charge is 3150 f. s. These velocities would be impossible with black or brown powder.

It is certain that the powder is absolutely progressive in its burning. When small charges are used, with consequent low pressures and rates of burning, it frequently happens that partially burned grains are recovered in front of the muzzle of the gun. In all cases it has been observed that the outside diameter has been reduced and the inside diameter of the perforations increased in exactly equal amounts. The walls may be reduced to the thinness of paper, but the general structure of the grain remains intact.

Ignition-charges.—Smokeless powder ignites at a temperature of about 180° C., and black powder at a temperature considerably higher; nevertheless, the latter is very much more *inflammable* than the former, and a small quantity of it must be used as an *ignition-charge*.

The question of ignition is an extremely important one in modern guns. Owing to the great length of the powder-chamber, inferior ignition will result in having only a portion of the charge ignited, with the result that the gases will be given off from that vicinity and will then expand to the opposite extremity of the chamber with great velocity and *add their dynamic effect to what should be only a static pressure*.

Wave-pressures.—The hurling back and forth of the gases constitutes what is known as “wave-pressures,” and if the ignition of the entire charge is delayed until the shell has moved forward to a considerable distance in the gun, the result may be a high pressure at a point in the bore of the gun where the metal is not thick enough to withstand such pressure. It is a phenomenon similar to the “water-hammer” in hydraulic pipes.

To avoid wave-pressure, the entire chamber should be filled instantaneously with a burst of flame sufficient to ignite the whole charge; and the only way of accomplishing this, is by the use of a considerable quantity of highly inflammable powder (ignition-charge) properly placed in the charge of smokeless.

Erosion.—Erosion is caused by the rush of very highly heated gases, under great pressure, over the surface of the metal in the gun tube, this metal being heated at the time to practically an incandescent state for a very slight depth. The result is a wiping away of a film of the tube each time the gun is fired.

Erosion first starts, and is thereafter most pronounced, at the origin of the rifling, where the temperatures and pressure are at a maximum. The first visible signs of erosion are very fine longitudinal lines or scores in the metal, and a gradual increase in the diameter of the bore. It is increased by the escape of gas around the rotating-band, for the velocity of the gas is enormously increased at such leaks.

From the above, it may be deduced that erosion is *directly proportional* to the temperature of the gas, which in turn is dependent on the pressure, and *inversely proportional* to the hardness of the metal of the tube.

Special gas-checks have been devised abroad, which prevent the escape of the gases beyond the rotating-band of the projectile. This of course preserves the uniformity of the velocity within limits, but does not prevent the ultimate erosion and consequent disabling of the gun.

Disadvantage of gun-cotton powder.—Against the gun-cotton powders must be reckoned the disadvantage of leaving in the gun, after discharge, a large amount of CO, a gas which is both *poisonous and inflammable*.

This is due to the *insufficiency of oxygen* contained in the gun-cotton to unite with the carbon and form CO₂ upon the rearrange-

ment of the molecules. In the earlier powders, barium nitrate was mixed with the colloid in order to provide more oxygen, but it resulted in a lower efficiency ballistically and was abandoned. Nitro-glycerine powders being made of gun-cotton much higher in oxygen, and the nitro-glycerine itself having a very high percentage of oxygen, this fault obtains to a very much less degree in them than in simple nitro-cellulose powders.

NOTE.—Notwithstanding this disadvantage of gun-cotton powder as compared with nitro-glycerine powders, it is almost universally admitted that the disadvantages of the latter (especially as regards erosion) are far more serious, and that none but pure nitro-cellulose powders are desirable.

“Flare-back” is the name that has been given to the burning of the residual gas in the gun when the breech is opened after firing. Two things are necessary to cause a flare-back—a fresh accession of oxygen from the atmosphere and a spark or degree of temperature high enough to unite the oxygen with the CO. Opening the breech will permit the necessary current of air to mix with the CO, and the spark may be easily supplied by a smouldering particle of powder-bag remaining in the bore.

Pressures and velocities.—Both the pressure and the velocity vary directly with the weight of the charge, when the charge is not too small to prevent sufficient pressure from being developed to burn up all the grains before the shell leaves the bore, or when the charge is not so large as to give pressures exceeding 17 or 18 tons. At that point there seems to be a deflection in the pressure curve, and a small increase in the charge may produce a very great pressure. The residual volatiles contained in the smokeless powder act as a deterrent, and if they are permitted to escape after the powder has been proved and a charge has been assigned, excessive pressures will result. It is, therefore, of great importance that the charges be always kept hermetically sealed; and conversely, it is necessary to protect the powder from the deposition of moisture on its surface or it will become “slower” and fail to give the designed velocity.

Tests for stability.—Certain tests for the stability of nitro-cellulose powders are given which depend upon the fact that decomposing powder evolves the fumes of nitrous acid. In these tests the powder is heated above the atmospheric temperature to a point where all powders, no matter how stable, would eventually

decompose. The *time* between the beginning of the heating and the appearance of the first signs of decomposition is taken as a measure of the stability.

In making the test for stability, it is necessary to observe, with the greatest care and accuracy, such directions as are given. All of the tests now known are entirely empirical, and if the standard method is departed from in the slightest particular the value of the test is nullified.

Instability is generally caused by insufficient purification of the gun-cotton of which the powder is made; but subjecting the powder to direct sunlight, or permitting it to sustain an abnormally high temperature for a protracted period, will cause any powder to decompose.

A strong odor of ether in the charge is often erroneously taken as an indication of decomposition. But it may be of no importance whatever, as a very minute quantity of ether is sufficient to strongly impregnate the atmosphere of a large room.

Effect of instability on pressure.—Instability does not manifest itself in *higher pressures* in the gun. On the contrary, one would look for *lower pressures* in a powder that had lost considerable oxygen and nitrogen.

Dangerous Powders.

The purity of the nitro-cellulose from which the powder was made, and the residual volatiles, play the two important parts in the non-deterioration of the powder. It may be stated that from these two features spring the two kinds of dangerous powder, which may be designated respectively as (1) *statically* dangerous and (2) *dynamically* dangerous; and, curiously enough, the quantity of volatiles, or the amount of dryness at which the powder was issued, plays a part in both of these.

(1) A **statically dangerous powder** may become a dynamically dangerous one; but this is not probable, and such powder may, therefore, be considered alone as statically dangerous, giving off nitrous-oxide gases, the cause of deterioration being due to lack of purification or to chemical changes through exposure to heat, etc.

The part the volatiles play in this decomposition is a reflex one. If the powder has a tendency to decompose, the dryness of the powder aids. As decomposition goes on, the residual volatiles are absorbed in uniting with the nitrous-oxide gases, and if the rate of giving off gases is greater than the rate at which the powder can supply volatiles, the evolution of heat is an increasing one. In other words, *loss of volatiles alone renders a powder dynamically dangerous* by drying out the powder. Decomposition may or may not be accompanied by loss of volatiles. It is the giving off of this heat which renders the powder dangerous, from the fact that the process may be so rapid and the radiation of the heat so slow that the ignition-point of the powder (which is in good powders from about 350° F. to 380° F., and in decomposing powder may go as low as 250° F.) may be reached.

Statically dangerous powders may be discovered: (a) *By the surveillance test*; (b) *by acid reaction on litmus-paper*; (c) *by smell*, which should be the *acrid nitrous-fumes smell*. Deterioration is an evidence of the loss of explosive properties, and some statically dangerous powders will not become dynamically dangerous but the very reverse—innocuous.

If the decomposition has proceeded so far that nitrous fumes can be unmistakably smelled, condemnation should not be delayed. Nitrous odors or *visible red fumes* indicate a stage of decomposition much more advanced than the early indications shown by a low surveillance test.

It is known from experience that small-caliber powders are more prone to decomposition than the larger ones, due primarily to the larger percentages of volatiles in the large calibers; and yet an instance was reported from a magazine on shore where Index S. P. 9 and Index S. P. 19, 1-pounder and 3-inch powders, first developed their nitrous odors about five months after the detection of a low heat test.

It is the opinion of the chemist at the laboratory at Indian Head that in case a powder which has been regularly and periodically examined on board ship is suspected of deterioration, it does not become so rapidly dangerous that it need be condemned at once. Nevertheless, precautions should be taken and all directions as to the safety of the ship should be carried out. It is furthermore believed that in the event of a ship being in a position such that it

would be inadvisable to get rid of the powder entirely, a check to this deterioration can be given by cooling the powder in its air-tight cans, allowing none of the volatiles to escape. Of course, the first opportunity should be taken to forward a sample to the proving-ground for analysis.

(2) A dynamically dangerous powder, on the other hand, is one that is very seldom statically dangerous, being merely so from the fact that it is drying out and thereby becoming more violent.

The condition of dynamically dangerous powders may be found in several ways: (a) *By an increase in muzzle-velocity*, as shown in range; (b) *by the chamber-pressure*, obtained by the pressure-gauges; (c) *by the loss in weight of the charge*, always provided the charge had been accurately weighed when first issued, and again when the test is made. In this connection, it is well to state that the charge of smokeless powder as designated by the Bureau of Ordnance means the smokeless powder alone, exclusive of the bag and ignition-charge. Each ship should be provided with a set of accurate and repeatedly checked scales.

The dynamically dangerous powders are becoming less and less in number, from the fact that powders are issued in a drier condition now and are packed in good standard air-tight boxes for the magazines. Nevertheless, from experience it has been found that the curve, whose co-ordinates are (1) *time since manufacture* and (2) *percentage of volatiles* in the powder, resembles very strongly, if it is not exactly, a hyperbola approaching an asymptote. It seems to be borne out in practice that no powder, however old, is entirely devoid of volatiles. But from this fact, also, it must be remembered that powders will always dry out slightly after issue, however long they are kept.

General Suggestions to Ordnance Officers.

Indices.—It would be a good idea for the ordnance officer of every ship to inform himself as to the characteristics of the indices of powders he has on board, and particularly with regard to the chamber-pressure obtained at the proving-ground when the charge was assigned, as the pressure, after all, is the main criterion as to violence.

Ignition and inflammation form very important features in smokeless powders; and these are directly dependent upon the

character of the burning surface of the grains, their contamination in this respect, whether by oil, moisture, grease, or other cause, should be most strictly avoided.

Traces of acid.—In the matter of test it has been found occasionally that an acid reaction, shown by litmus-paper, has been given in powders which afterwards prove to be good, for the reason that slight traces of acetic acid evolved by moisture and solvent (the latter escaping from the powder), together with cellulose material—such as excelsior used for distance-pieces—form what might be called a small vinegar factory. The actual fact as to whether such is the case or whether the powder is really, through deterioration, giving off nitrous acid, may be roughly determined by drying the powder in an exposed vessel at a temperature of about 100° F. for about 24 hours and then making the litmus-test again.

Odor of fumes.—If the odor of ether fumes is detected in the magazine, it is an evidence that the volatiles are escaping from the powder through leaky powder-tanks. The leaks should be found and corrected, and this powder should be watched for increase in pressure. The magazine should also be well ventilated, on account of the inflammability of the ether fumes.

Loss of volatiles.—It has been further demonstrated by experiment at the proving-ground that the loss in volatiles, as determined by chemical analysis, *is almost exactly shown by loss in weight* where the weight is accurately determined at both times. From this it would seem that, after more data have been secured, the connection between increase of velocity and loss of volatiles may be discovered on board ship by weighing the charge, provided, as before, that the charge was accurately weighed when issued.

Drying-out.—In the case of strongly suspected drying-out of powders, as indicated by loss of weight or otherwise, the Bureau of Ordnance should immediately be notified, in order that firing-samples may be sent to the proving-ground for reassignment of charge.

Care in drying powders.—Where the powder, for any cause, requires to be dried or exposed to the air, the greatest care should be taken not to expose it to the direct rays of the sun for any length of time, as it is known that the actinic power of these rays exerts a deteriorating effect upon smokeless powder.

Altering charges.—It is believed that it is not wise, with powders now on board ship, to alter the charge there, not only for the reasons before given in regard to recently manufactured powders, but because all powders of earlier manufacture have had reassignments of charge of late.

Precautions and tests.—For further precautions and tests, see U. S. Navy Regulations.

General Description of the Manufacture of Gun-Cotton.

Gun-cotton is generally made from what is known as "weaver's" or "cop" waste. This form of cotton is preferred to cotton "wool" on the ground that the thready form prevents the material from packing closely together when wet by the alkaline solutions, water, or acids used in the various processes through which it is passed, and thus permits a more uniform and speedy treatment, while it diminishes the chances of fuming during "dipping."

The waste is first carefully picked by hand to remove foreign substances, such as nails, pebbles, bits of wood, metal, and paper, which are sometimes found in it; and then it passes to the first boiling-tub, where about 200 pounds of cotton are placed in the tub, to which 250 gallons of water and 35 pounds of caustic soda are added. The steam is turned on and the whole is maintained at the boiling-point for eight hours. The liquid is then drained from the cotton, which remains thus over night, when the tub is filled with clear water and the boiling is continued for eight hours more, after which the water is again drained off and the cotton is left in the tub over night.

From the first boiling-tub the cotton passes to the centrifugal washer, and from there to the first drying-room, where it is dried by hot air, the temperature of the room being kept at 187° F. and the time of drying varying from three to five days.

From the drying-room the cotton passes to the picker, where it passes between two small horizontal cylinders armed with teeth rotating in opposite directions, and a large wooden drum, which is also armed with teeth. This removes knots and rolls in the cotton, which would produce more or less "firing."

The cotton passes from the picker to the final drying-room, where it remains for eight hours at a temperature varying from 200° to 260° F., at the end of which time it is estimated to contain .25 to .50 per cent of moisture; one-half of 1 per cent is the

largest amount of moisture which cotton may contain at time of dipping.

From the final drying-room the cotton is taken to the dipping-room, or converting-room, where it is dipped in a mixture of 1 part by weight of nitric acid to 3 parts by weight of sulphuric acid. The dipping-troughs are of cast iron, have a capacity of 150 pounds each for mixed acids, and are set in an iron trough in which cold water circulates, which serves to keep the acid below 70° F. during the process of conversion. The cotton is dipped into the mixed acids by means of a steel fork, the separate portions being well stirred about in the acids to prevent any local rise in temperature. The dipping occupies something over ten minutes, when the cotton charge is withdrawn from the acids, placed upon a grating, and squeezed by a lever press as completely as possible, and then placed in the *digestion-pot*, which is an ordinary 2-gallon crock made of coarse stoneware, glazed inside and out and provided with a cover. The mass of partially converted cotton saturated with acid is squeezed down compactly by means of a hand-press, and the pot is then covered and placed in water in the cooling-trough, where it remains over night.

The gun-cotton is then taken to the centrifugal wringer, and after it is wrung it is taken from the wringer by hand, the hands being covered with rubber gloves. It is then taken to the immersion-tub, where it is thoroughly and repeatedly washed to remove any free acid that may be retained by it. It is then boiled in fresh water with caustic soda, and passes on to the *pulper*, which is a large wooden vessel with a cylinder on which are a number of knife-edges. Clean water is kept constantly running in this tub; and as the cylinder revolves, the gun-cotton is forced between the knife-edges and the *craw*, which is a metal casting on the body of the wooden vessel. The cotton is pulped from one to two days, being repeatedly washed during this process, and is cut and ground to the consistency of corn meal. It then goes to the poacher, where it is treated with soda and boiled for a number of hours until samples taken from it pass the required heat test, as follows:

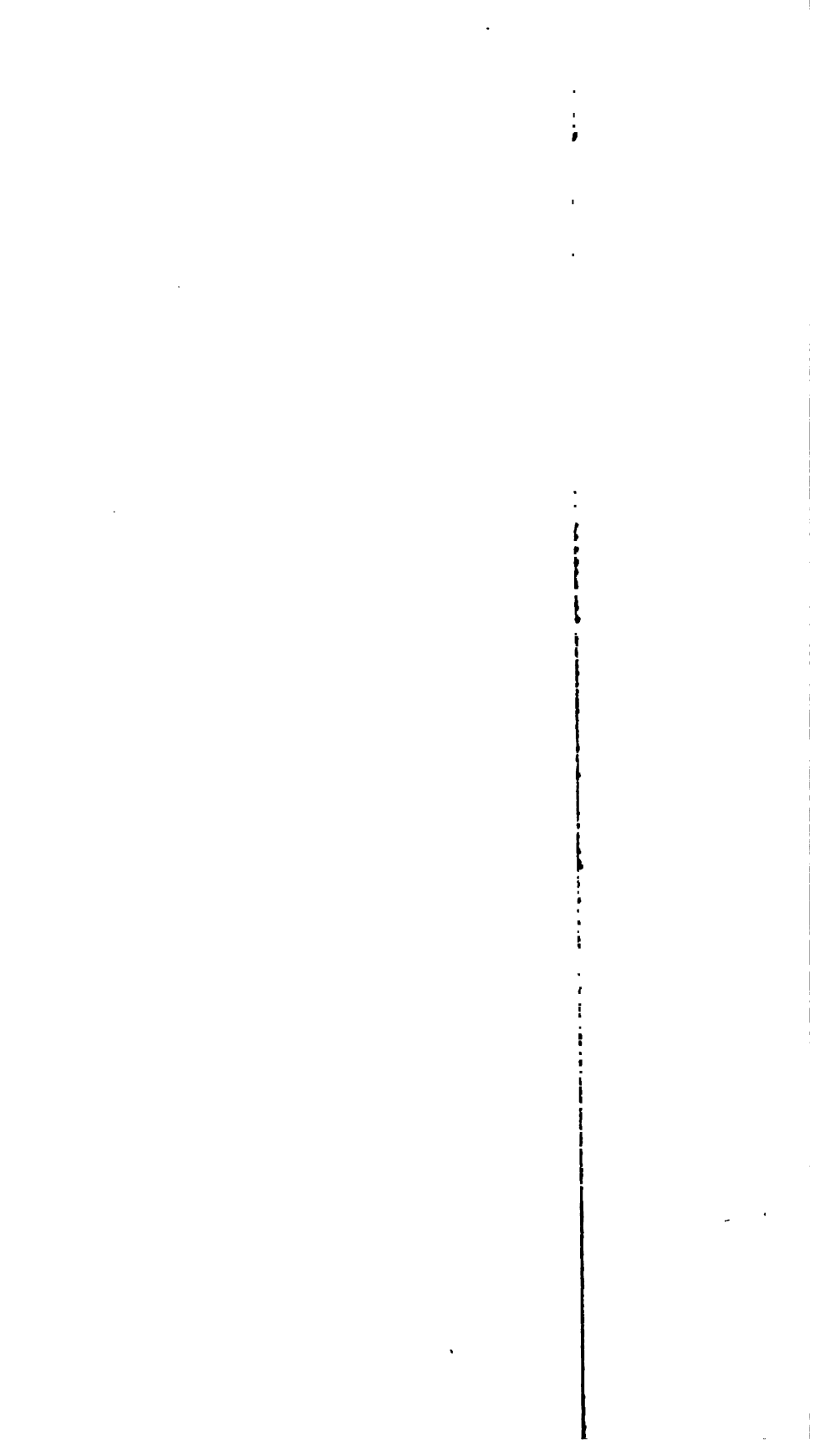
About 1 gallon of the mixture is taken from a considerable depth in the poacher, so as to obtain a representative sample. This is taken to the chemical laboratory and poured onto a clean muslin cloth, through which the water is allowed to drain. It is then

squeezed in a screw-press to remove as much water as possible, and is afterwards rubbed between the hands in the cloth to get it in as fine a condition as possible. It is then put into a steam oven at 43° C. and dried until it contains about 2 per cent of moisture. The drying usually takes from four to five hours. When the gun-cotton is sufficiently dried, it is weighed out into test-tubes, 20 grams to a tube, and the sides of the tubes are freed as much as possible from the particles of the gun-cotton by a roll of clean tissue-paper.

A strip of the standard potassium-iodide paper, 1 inch long by $\frac{3}{8}$ inch wide, is then hung on a holder, which consists of a glass tube running through a perforated cork, with a small piece of platinum wire fused in the end and bent up in the form of a hook. After hanging the paper on this hook, the ends nearest the wire are moistened with a drop of a glycerine solution (half pure glycerine and half distilled water), which wets it for about half its length. The holder is then inserted in the test-tube containing the gun-cotton, and the paper is drawn up close to the cork.

The bath used for the test is an ordinary copper water bath, 10 inches in diameter, with a cover containing holes for the test-tubes, and may be filled with glycerine or water, or a mixture of the two. This bath is heated by a two-burner oil stove to 65.5° C. (150° F.), and the flame is regulated until the temperature remains constant at that point. The test-tube containing a sample is then inserted in the cover of the bath, and the time is noted by a watch. If the gun-cotton contains the proper amount of moisture, a slight ring of this will shortly appear about $\frac{1}{2}$ inch above the level of the water in the bath. The test-tube is then lowered until the line of demarcation between the wet and dry portions of the paper is coincident with the lower edges of the ring of moisture. This moisture should be of the appearance of frost, and it should not be in large drops. If there is any subsequent change in the position of the ring of moisture, the test-paper should be moved accordingly. The paper is constantly watched; and when the first faint yellow color is noted at the line of demarcation between its wet and dry portions, the time is again noted, and the period between the time of inserting the tube in the bath and the time of the change in the paper is taken as the time of the stability test. This should be 40 minutes at 65.5° C. (150° F.) for military gun-cotton.





After passing the heat test the poacher is emptied into the "stuff" chest, and from there the cotton is drawn through the preliminary and then through the final press, and formed into the different shaped blocks required.

Forms of gun-cotton blocks.—The different forms in which gun-cotton is made depend upon the particular use for which it is intended. That for the countermines and for wrecking-outfits is made in the form of a block 2.9 by 2.9 by 2 inches, without central perforation (Fig. 1).

Gun-cotton which is used for filling war-heads is made in blocks $8\frac{1}{2}$ by $8\frac{1}{2}$ by 2 inches, without central perforation (Fig. 2).

The dry-primer blocks used in wrecking-outfits are of the same dimensions as the blocks used for the wet charges (Fig. 1). For automobile torpedoes the dry primers are made up of a number of cylinders 2 inches in height, $1\frac{1}{8}$ inches in diameter, with a central perforation of $\frac{1}{8}$ inch in diameter (Fig. 4). The dry primers for countermines are at present made in the form of a cylinder 2 inches in height and $3\frac{1}{2}$ inches in diameter, and have a central perforation of $\frac{3}{8}$ inch in diameter (Fig. 3).

Detonators, electric, for countermines and wrecking-outfits, are issued in boxes containing eight. If one detonator should be exploded accidentally, all the other detonators will explode. There is reasonable assurance that if one box of detonators explodes, another at a distance of 1 foot will not explode if it is protected from the flying fragments of the exploded detonator cases.

Detonators, electric, are cylindrical copper cases containing 35 grains of fulminate of mercury, primed on top with dry, pulverulent gun-cotton.

A plug is made of 1 part of ground glass and 2 parts of sulphur melted together, cast around the detonator legs—tinned copper wires, No. 20 A. W. G., 6 inches in length, insulated with a double layer of cotton thread soaked in paraffin, the outer layer colored red.

The inner legs of the detonator are bridged by a platinum-iridium wire, 90 per cent platinum, 10 per cent iridium, $\frac{3}{8}$ inch long and 2 mils in diameter, having a resistance of $.65 \pm .03$ ohm.

Detonators, electric, are painted red, and are for use with countermines, wrecking-outfits, etc. (Fig. 5).

Blocks for detonators, electric, are wooden cylinders with a cover which has a small circular motion. Each block holds eight detonators placed in holes around the circumference, the cover locking them in. The blocks are placed in a covered tin cylinder painted red and marked "Dangerous."

They are stowed in different parts of the ship, preferably in the tops, but never below the water-line or near any explosive (Fig. 6).

Detonators, percussion, are cylindrical copper cases containing 35 grains of fulminate of mercury, and are primed on top with dry, pulverulent gun-cotton. They are closed at the bottom and have in the top a fulminate cap connecting with the interior by means of a small channel. An anvil which rests on this cap detonates it when struck, and this in turn detonates the fulminate charge.

Detonators, percussion, are painted red, and are supplied for use with automobile torpedoes (Fig. 7).

Boxes for detonators, percussion, are made of cork forms which fit tightly in tin boxes and have holes for the detonators. The lid of the box is lined with cork and closes tightly on the heads of the detonators, thus preventing any motion (Fig. 8). They are stowed in different parts of the ship, preferably in the tops, but never below the water-line or near any explosive.

War-heads.—Hereafter wet gun-cotton shall contain 25 per cent moisture; that is, to dry gun-cotton must be added 25 per cent its weight in pure distilled water to make wet gun-cotton. War-heads filled with gun-cotton containing 20 per cent moisture will remain so until refilled or reloaded, when enough of the charge will be removed to compensate for the increased weight of water to be added, so that the buoyancy of the torpedo will remain unaltered.

The *charge* is the wet gun-cotton. The *weight of the charge* is the actual weight wet. The *primer* is the dry gun-cotton used to detonate the charge. The *weight of the primer* is the actual weight dry; it is approximately 1 pound 6 ounces. The *detonator, percussion,* is the fulminate of mercury mixture used to detonate the primer.

Stamped on the bulkhead of the war-head is the gross weight of the shell and the inclosed charge.

The war-heads are stowed in the torpedo-head room, which is arranged for flooding similarly to other ammunition-rooms.

Dry primers for automobile torpedoes are packed in glass tubes inclosed in wooden boxes, strips of litmus-paper being placed between the disks. The glass tubes are closed at each end by wooden covers with rubber washers. They must be stowed above the water-line in a cool, dry, secure place as far as possible from the guns. When more than one box is supplied, the boxes should be stowed apart.

Wet primers for automobile torpedoes, when issued, are packed in brass tubes, inclosed in wooden boxes. Stamped on the cover of the tube is the gross weight of the tube and primer. They contain 25 per cent moisture and are stowed where most convenient, though never near the dry primers or detonators.

Packing and stowage of dry gun-cotton.—The glass jars for dry primers, filled with dry gun-cotton, are put in wooden cases, varnished to correspond with the interior wood-work of the ship.

When received on board ship, these cases are stowed in different parts of the ship, never below the water-line. They should be kept as near the upper deck as possible, so that they may be readily thrown overboard in case of fire, but should not be exposed to the direct rays of the sun, nor to the weather.

On account of insurance restrictions imposed on freight companies, it is often impracticable to ship gun-cotton in its dry state. When this is the case, gun-cotton primers may be issued wet in proper packages, from which, on receipt on board ship, they are to be removed and dried, and then stowed as laid down for dry primers.

Care of gun-cotton and detonators.—The gun-cotton magazine should never be allowed to attain a temperature as high as 100° F. for any great length of time. Avoid as much as possible exposing any box or case containing gun-cotton, either wet or dry, to the direct rays of the sun for any length of time, as the temperature inside the box can, in this way, be raised to a point considerably above that of the open air, and this temperature will be maintained for a considerable time after the exposure.

The diurnal changes of temperature will not affect gun-cotton, wet or dry, provided the cases or boxes containing it are not exposed to the sun.

The detonating-charges of dry gun-cotton are designated "*primers*," and the fulminate of mercury igniters "*detonators*."

The primers of dry gun-cotton supplied to ships are packed in glass jars with tight covers to exclude moisture. Strips of blue litmus-paper are placed between the blocks of dry gun-cotton.

The glass jars are to be kept in their wooden cases, and with the cases they form a part of the permanent outfit, and must be cared for and turned in as such.

In stowing the dry primers, care should be taken that the cases are not too near each other. The explosion of a single primer would probably not detonate other dry primers unless they were within 10 feet of the exploding primer. Dry primers must not be stowed in the vicinity of the galley or other fires, nor too near the guns of the battery.

In removing from their cases the glass jars holding the dry gun-cotton, never expose them to the rays of the sun, as the glass may act as a lens and cause ignition.

The separation of one box of dry gun-cotton primers from others by a distance of 10 feet will prevent in a great measure the danger of fire among the different boxes of the explosive in case one should break out. Under ordinary conditions, small quantities of dry gun-cotton will not be detonated by influence at distances greater than 3 or 4 feet.

Dry gun-cotton should be stowed above the water-line. This precaution is taken so that the explosive will not become damp by the absorption of water and be too wet to detonate when required for use, and also as a measure of safety to the ship.

Dry gun-cotton, when kept out of sunlight and not exposed to a temperature above 105° F., does not deteriorate if properly made. All gun-cotton issued to vessels is tested immediately before it is shipped from the torpedo station, and none whose test is low is allowed to be issued.

Dry gun-cotton, when brought into contact with a flame or any material heated above its ignition-temperature, burns rapidly with a yellow flame and is quickly consumed. Small quantities, such as are contained in dry gun-cotton primer-jars, will not detonate under these conditions. In order to produce a detonation, the gun-cotton would have to be confined and the entire mass brought to the ignition-temperature at once.

Inspection of gun-cotton.—For instructions regarding the inspection of gun-cotton, see U. S. Navy Regulations.

CHAPTER XV. PLATE I.

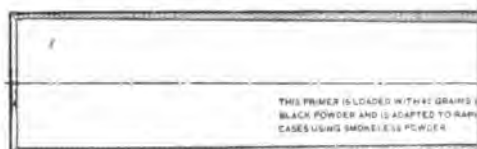


FIG. 1.—Percussion-Primer. (For 1-, 3-, and 4-inch field-gun cartridges)

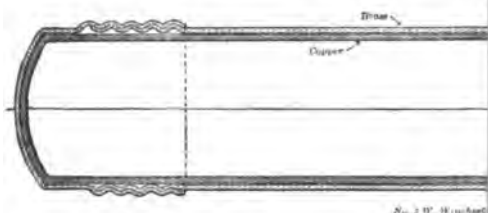


FIG. 2.—Detonator for Whitehead

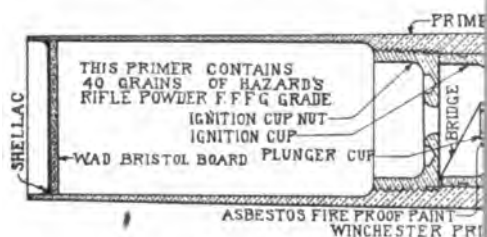


FIG. 3.—B. L. R. Combination

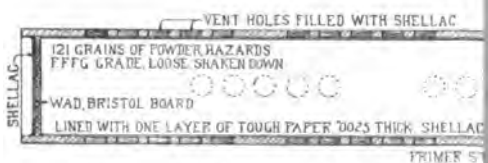


FIG. 4.—3-Inch Primer, Model 1890

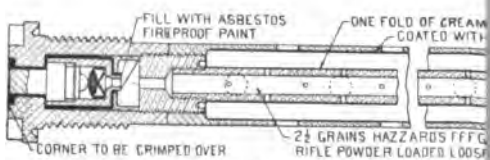


FIG. 5.—Extension-Magazine Screw Cap

VARIOUS FORMS OF P

CHAPTER XV.

AMMUNITION.

Definitions and Regulations.

"Ammunition" is the general term applied to all forms of powder charges, shells, cartridges, etc.

Fixed ammunition.—When the powder charge, either loose or in a bag, is enclosed in a metallic cartridge-case, which case also carries the shell, it is called *fixed ammunition*.

Separate ammunition.—When the powder charge is enclosed in a metallic case, but the shell is loaded separately, it is termed *separate ammunition*.

Service ammunition, which is supplied as a portion of the vessel's outfit for use only in battle, shall not be used for drill, instruction, or testing hoists, conveyors, etc. It shall be regarded a part of the vessel's outfit, shall be kept distinct from the ammunition issued for target-practice, and shall never be expended in target-practice without the authorization of the Bureau of Ordnance.

Ammunition supplied for target-practice shall be used for that specific purpose, and shall not be retained on board for long periods. It may, at the discretion of the commanding officer, be used for drill purposes.

Primers.

A **primer** is a specially constructed device, the flame from which, when exploded by the direct action of the firing-mechanism, ignites the powder charge in the chamber of the gun and causes the explosion.

In minor-caliber guns, the primer is screwed or driven into a recess in the base of the cartridge-case containing the powder. In the major-caliber guns, the primer is held in a firing-lock which is screwed on the end of the mushroom stem, and on explosion of the primer the flame travels down a hole in the center of the mushroom stem to the powder, igniting it.

Percussion-primers are those containing a sensitive explosive which is fired by the jar or friction resulting from the blow of the firing-pin or hammer. The explosive in commonest use is *fulminate of mercury*, which explodes by percussion, by friction, by the electric spark, by heating to about 300° F., or by contact with concentrated nitric or sulphuric acid. It is extremely sensitive, particularly when mixed with sand or ground glass, and is very sudden in its action, though its explosive force is, weight for weight, not much greater than that of gunpowder. It is the best known substance for detonating dry gun-cotton; equal weights of much more violent explosives will, when substituted for it, often fail to produce an explosion of the first order. For use in primers, the fulminate is usually mixed with niter, mealed powder or other substances, to moderate its explosive properties; and, to increase its sensitiveness, a small quantity of ground glass is incorporated.

Percussion drive primers for 1-pounders, 3-pounders, 6-pounders and 3-inch field-guns are shown in Plate I, Fig. 1.

The magazine contains 42 grains of powder and is closed by a paraffin-paper wad.

A combination-primer is in itself an electric primer and a percussion-primer, combining the functions of both in one case. As long as all the mechanism and attachments are intact, these primers are used electrically, and the percussion feature is regarded only as an alternative; the firing-mechanisms, as we have seen, are arranged to work in either manner.

It is to be kept in mind, however, that these primers contain fulminate, and the precautions needed in the use and handling of ordinary percussion-primers are called for, because of their sensitiveness to shock.

Combination-primers will in the future be supplied for all main-battery ammunition, and simple percussion-primers for all secondary-battery ammunition. Combination-primers will also be used in 3-inch ammunition until the present supply is exhausted, after which percussion-primers only will be used.

Single electric primers are issued for drill and for testing firing-circuits.

The B. L. R. combination-primer, shown on Plate I, Fig. 3, is the latest design of primer. The combination-type primer is the only type of B. L. R. primer now furnished the navy for service use. The latest type of B. L. R. combination-primer is designed so that it may be reloaded.

Extension-magazine drive percussion-primers.—The primer for the 3-inch 50-caliber cartridge-case is shown on Plate I, Fig. 4. The magazine of this primer contains 121 grains of fine-grain black powder, and no additional ignition-powder for the smokeless-powder charge is placed in the cartridge-case. This primer is reloadable. Many of these percussion drive extension-magazine primers have been reloaded and fired 20 times without deterioration. On reloading, the parts used are the primer stock and the primer-stock extension. The interval from the explosion of the primer-cap of the primer to the issue of the projectile from the 3-inch 50-caliber gun in service charges when this primer is used, as measured by chronograph, is .0205 second.

Extension-magazine screw combination-primer.—The combination electric and percussion extension-magazine reloadable screw-primer for the 4-inch and larger-caliber cartridge-cases—namely, 4-inch, 5-inch, 5-inch 51-caliber and 6-inch 40-caliber cartridge-cases—is shown on Plate I, Fig. 5.

The interval from the time the bridge of the electric element becomes incandescent to the issue of the projectile from the gun, when this primer is used, is from .0426 to .05226 second for the 6-inch 40-caliber and the 5-inch 51-caliber guns, requiring 17.5 and 23 pounds of smokeless-powder service charges respectively.

The extra length of the primer-stock extension in this primer requires a central ignition-tube extending into the extension-magazine about three-fourths of its length. The total weight of fine-grain black powder for this primer is approximately 270 grains. The extra ignition necessary for the smokeless-powder charge when the former type of short screw-primer was employed is obviated by the use of the extension-magazine primer; and the remarks as to reloadability, economy and efficiency noted under the 3-inch drive extension-magazine percussion-primer apply also to this primer.

The primer-cap.—The same primer-cap is used in both percussion-primers and combination-primers, and contains a sensitive mixture made up as follows: 35 parts of fulminate of mercury, 35 parts of chlorate of potash and 30 parts of sulphide of antimony, a small variance in these proportions being allowed manufacturers. These caps are known as "Winchester No. 2½ primer," and are vent-sealing.

Detonators are the devices which detonate the gun-cotton charges of torpedoes. For Whitehead torpedoes, they correspond, perhaps, more nearly to *fuses* than to primers. The Whitehead detonator is shown in Fig. 2, Plate I; it is carried in the war-nose and is fired by percussion. When the torpedo strikes, the firing-pin of the war-nose drives in the small striker, which is held in place ordinarily by a shearing-ring as shown. This striker explodes a cap, which in turn fires the 35 grains of fulminate in the attached copper magazine; the *dry* gun-cotton primer is detonated by the detonator, and in turn detonates the main charge of *wet* gun-cotton in the war-head.

Metallic Cartridge-Cases.

The powder charge for all rapid-fire guns is put up in brass cartridge-cases, which are hollow cylinders with flat heads, shaped to fit the bore, those for new guns being bottle-necked. The head has a rim for the extractor and a recess for the primer. They are made from solid disks and are drawn into shape in successive processes. The metal used is a brass composed of 70 parts Calumet and Hecla copper and 30 parts pure Bertha zinc. The metal produced by this mixture is very malleable and ductile, rolls well, and is of bright yellow color.

Inspection.—All cases are gauged by the workmen in charge during each process of manufacture. After a lot is reported ready, the inspector picks about 4 per cent of the lot and gauges them all and looks them over for flaws. There are nine sets of gauges (a maximum and a minimum) which check all surfaces and the mouth, extractor-rim, and primer-seat.

After inspection a small number are sent to Indian Head for proof, and must be fired and reloaded six times in a service

gun, without the use of a former, before the lot is accepted. The average life of a case is six firings, as after that the metal becomes fatigued and the case takes a permanent set. Empties are sent to some magazine, where they are reformed and reloaded in a press. Some cases have been fired between 30 and 40 times without destroying their usefulness.

Fit of shell in cartridge-case.—The base of the shell should fit tightly and be perfectly secure in the cartridge-case, in fixed ammunition. When the shell is loose, there is danger and delay in loading; and the space in the cartridge-case being increased, the ignition-charge may work away from the primer and cause hang-fires or misfires. The projectile is forced into the mouth of the cartridge-case until its rotating-band is at the end of the case.

Care and preservation of cartridge-cases.—To prevent the rapid deterioration of metallic cartridge-cases the following rules must be observed for their care and preservation:

(1) The cases at all times, whether before or after firing, should be kept free from salt, moisture, oil, or grease of any kind; and from time to time, as opportunity occurs, they should be examined, especially at the neck and mouth, for signs of corrosion.

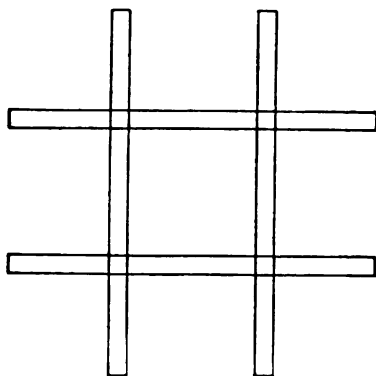
(2) The larger cases, when empty, should not be laid on their sides, except unavoidably, but should be stood up on end. The cases should not be replaced in their boxes until examined for powder gases, decapped and washed.

(3) As soon as possible after firing, the fired primers should be backed out, and the cases thoroughly cleaned with hot water and soap-suds. These primers should be thoroughly cleaned and dried, and should be turned in with empty cases for reloading.

(4) If the residuum is found difficult of removal, a little lye may be added to the water used in cleaning, but hot soap-suds will usually suffice, the soap not being used in lumps. After cleaning, the cases should be rinsed with clean water, drained, thoroughly dried, inside and out, and put away in their boxes.

(5) No oil or grease of any kind should ever be used on the cases, except in the operation of reforming, when they may be lubricated with soap-suds, or with a very light coat of white lead and tallow, in even quantities.

Distance-pieces for cartridge-cases.—The space between the powder and the base of the shell in 3-inch, 4-inch, 5-inch, and 6-inch cartridge-cases was sometimes filled with excelsior. This made smoke and was objectionable. To replace the excelsior, *distance-pieces*, made by crossing and locking four pieces of pasteboard, are used. The distance-piece can be cut to any length desired. For minor calibers, tubes of pasteboard are used in some

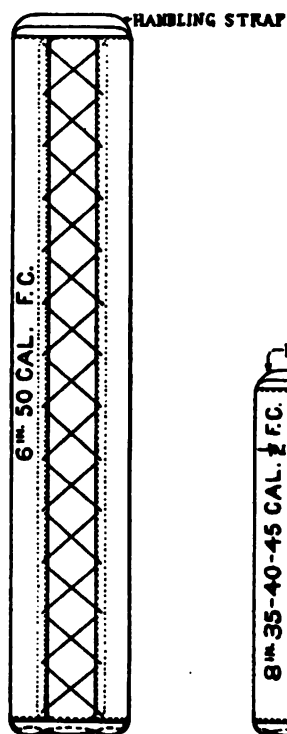


PASTEBOARD DISTANCE-PIECE.

cases. These tubes are much smaller in diameter than the cartridge and are held between two wads of pasteboard.

When the powder is confined in a bag, the distance-piece extends from the tie end of the bag to the base of the shell. When no bag is used, a wad is placed over the powder and the distance-piece extends from the wad to the base of the shell, or to the cover of the metallic cartridge-case when the ammunition is "separate," that is, with the powder charge in the metallic case but the shell separate.

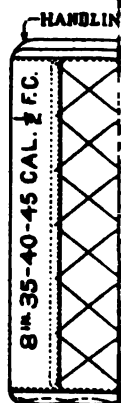
CHAPTER XV. PLATE II.



IGNITION POCKET
THIS END BYED
CARTRIDGE RED.



FIG. 1.



IGNITION
THIS END BYED
CARTRIDGE RED.



FIG. 2

CARTR

Cartridge-Bags.

Cartridge-bags (Plate II) for B. L. R. guns are manufactured from a special quality of silk cloth, sewn with silk, and laced with an approved quality of raw-silk cord.

The lacing-flaps are so spaced that the bags may be properly tightened by the lacing as the material stretches. There is as little material in the bags as possible.

The sides and front end are made of "cartridge-cloth, silk, heavy," and are entirely finished before going to the filling-house, with the exception of a small opening in the head for filling, after which operation it is closed by whip-stitching. A strong strap, made of the same material, is sewn to the front head, with short extensions running down the sides. Since charges are pulled out of the tanks and, in certain instances, are handled in loading, by the straps, the latter are strong and are very securely attached to the end and sides of the bag, sewn by hand when necessary. The strap is not sewn to the end of the bag at its middle point, and enough slack is left for inserting the fingers. A length of the silk cord for lacing is run along the edge of each flap, with the ends turned back and securely sewn, to keep the lacing from tearing through the flaps. The size, the number of the bag, and the index of the powder contained are stenciled on the side of each bag.

The ignition end of the bag is made of two thicknesses of "cartridge-cloth, silk, light," with the black cannon-powder ignition-charge in quilted divisions between the thicknesses. The *outside* portion of the ignition end is cut from cloth that has been dyed red.

Charges.

Charges are put up for the different guns, as follows:

(1) For the 3-inch, 4-inch, and 5-inch cartridges, the powder is put up in bags with an ignition-charge at the base, the whole charge being placed in a cartridge-case except in the case where an extension-primer is used.

(2) The 1-pounder, 3-pounder, 6-pounder, and 3-inch landing-gun and field-gun charges are simply placed in a cartridge-case, no bag being used, the ignition-charge being in the primer. A pasteboard wad is placed over the powder, and a pasteboard dis-

tance-piece between the base of the projectile and this wad, which holds the powder in place. The projectile is forced into the case in the same manner as in the larger fixed-ammunition cartridges.

(3) For the 14-inch, 13-inch, and 12-inch guns, the charges are in four sections, two sections being placed in each tank.

(4) For the 10-inch, 8-inch, and 7-inch guns, the charges are put up in two sections, one section in a tank, except the 8-inch 35-caliber, which has two sections in a tank.

(5) For the 6-inch and 5-inch guns, the charges are in one section enclosed in a tank.

Tagging charges.—To each bag containing a part of a charge a cloth tag is attached stating:

- (1) The caliber of the gun for which it is intended.
- (2) The proportion of the charge that the bag contains.
- (3) The weight of the charge.
- (4) The index of the smokeless powder contained therein.
- (5) The initial velocity given by the full charge.
- (6) The amount of ignition-powder contained in the section.
- (7) The initials of the inspector in charge of the magazine.
- (8) The name of the magazine at which the powder is put up, and the date it is put up.

The bag is stenciled to give the following data: (1) Caliber, (2) mark of gun, (3) charge (full, one-half, one-quarter, etc.), weight of charge, I. V. (initial velocity), initials of tag inspector, and number of grams on ignition end.

Attached to each tank is a tag giving the same information, except that the tag on the charge also has the psychrometer reading and the number of weigher and assembler.

Powder-Tanks.

Powder charges for B. L. Rs. are stowed in galvanized-steel or copped tanks. These tanks should be as strong and at the same time as light as possible for handling. They should be made to open quickly and must be perfectly air-tight, as the ballistic properties of smokeless powder change on being exposed to the air. As it has been found difficult to fulfill all these conditions, many types of tanks have resulted, and the latest are described below.

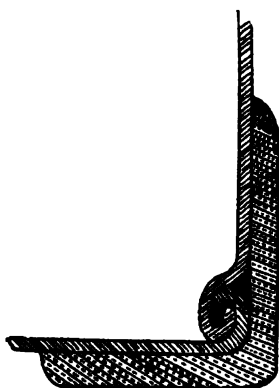


FIG. 1.—Bottom of Tank.

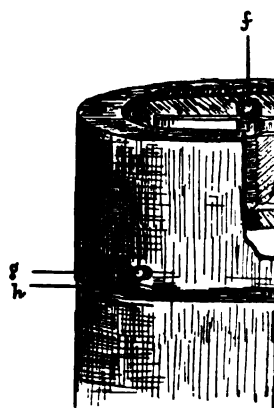


FIG. 2.—6-Inch Tank

POWDER-

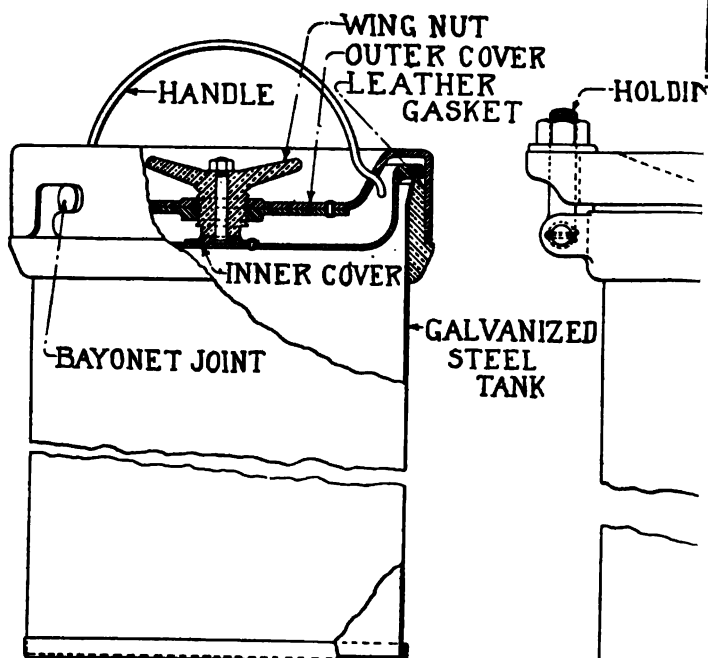


FIG. 4.



The general form is a cylindrical copper tank with edges crimped, and with a copper bottom bent on, forming a double-soldered joint, as shown in Plate III, Fig. 1. At top and bottom are brass strengthening-rings. The tanks are protected by vertical wooden battens held in place around the tank by three copper bands. Handles of brass are riveted to the sides of the tank for handling. All joints are soldered.

Some late designs of powder-tanks are shown in Plate III, Figs. 4 and 5. Sweated to the top of the tank is a bronze top-ring fitted with four studs to fit in slots in the cover to form a bayonet-joint. After the cover is locked to the tank by the bayonet-joint, turning the clamp presses the leather gasket in the air-tight cover against the rim of the top-ring, forming an air-tight joint which has to stand a water-pressure of 5 pounds per square inch. The top is fitted with a steel bail for lifting. The 12-inch, 13-inch, and 14-inch tanks have a cover which is held against the top-ring by four bolts. This tank is fitted with handles on the side and top.

Inspection.—Before use, powder-tanks should be carefully inspected for cleanliness and dryness. All dents should be hammered out, all holes should be soldered, and gaskets should be examined, to make sure that the tanks are *air-tight*. The designs now current depend upon leather gaskets soaked in cosmoline to seal the flanges of the covers; these should be renewed, if necessary, or re-treated with cosmoline or vaseline.

Any space in the length of tanks not occupied by the charges is filled with thoroughly dried "excelsior" (or other approved material) in bags of tough manila paper placed at the bottom of the tanks. Charges are placed in tanks with the front ends nearest the cover. It is to be borne in mind that the ignition ends of powder charges are the more dangerous portions, because of the great inflammability of black powder; this end should be handled carefully, and the charges should be so disposed in the tanks as to reduce the possibility of the cloth being cut or chafed through.

Marking powder-tanks.—Each tank containing all or a part of a *full charge* is marked on the lid with a circular band of white paint, two inches wide, with the index number of the powder stenciled on the white ground in black letters not less than $\frac{3}{4}$ inch high; also caliber and mark of gun when these are stenciled on the cartridge-bag.

Each tank containing all or a part of a *reduced charge* is marked with a circular white band, the index number and the letters "R. C." (not less than $\frac{3}{4}$ inch high) being stamped on the white ground.

Ammunition-Boxes.

Ammunition-boxes are made of poplar wood, with a becket at one end, the cartridge being held by corner wedges, and one side of the box being easily removed by cutting the three lashings which hold it in place.

All fixed ammunition is boxed except that for the 4-inch 50-caliber long-point, which is put in metal tanks, not painted, except at the ends. The boxes are painted lead color with a fire-proof paint, and contain various numbers of cartridges, as follows:

For the 4-inch and 5-inch cartridges.....	1 cartridge.
For the 3-inch 50-caliber gun.....	4 cartridges.
For the 3-inch landing-gun	6 cartridges.
For the 6-pounder gun	11 cartridges.
For the 3-pounder	16 cartridges.
For the 1-pounder	60 cartridges.

Marking ammunition-boxes.—The boxes are painted to indicate the character of the projectile and the type of the fuse. For the 5-inch, 4-inch, and 3-inch 50-caliber guns, for the 3-inch landing-gun and field-gun, and for the 6-pounder, 3-pounder, and 1-pounder, they are painted as follows:

Armor-piercing	All black.
Forged steel	All lead color.
Shrapnel	All white.
Blind shell	Red.

Saluting-charges.—Boxes containing saluting-charges are painted lead color, with top of box half red and half white, and are marked on top and front with black letters. Saluting-charges are made up of black, pea-shaped cannon powder.

Signal-charges.—Boxes containing signal-charges for signal-guns are painted light blue.

Drill-cartridges.—Boxes containing drill-cartridges are painted half black and half white, with white and black letters.

A tag giving the same information as that on the tanks is attached to the boxes, and the index number of the smokeless powder in the charge is stenciled on each end and on at least one side, as also the mark and the type of primer.

Boxes containing fixed ammunition loaded with explosive "D" have cover (edges and top) yellow.

Samples of tags for ammunition boxes.—The following forms illustrate tags for various ammunition-boxes:

- (1) 5-inch 40-cal. A. P. Shell. L. & F.
 Charge 15.8 lbs.
 Index No. S. P. 24.
 Ignition, 60 grammes fine-grain powder, or Pr. Ign.
 I. V. f. s.
Gunner, or Ch. Gunner.
 M. L. W. Inspector.
 Magazine, Iona Island, N. Y.
19... ..lbs.
- (2) 7-inch or 8-inch.....cal.
 ½ F. C.
 One-half charge.....lbs.
 Index No. S. P.....
 Ignition charge.....I. V.....f. s.
Gunner.
Inspector.
 U. S. Naval Magazine.....
19... ..lbs.
- (3) 12-inch B. L. R.
 One-fourth charge.....lbs.
 Index No. S. P.....
 Ignition charge.....I. V.....f. s.
Gunner in Charge.
Inspector.
 U. S. Naval Magazine.....
19... ..lbs.

NOTE.—L. & F. signifies.....Loaded and fused.
 S. P. signifies.....Smokeless powder.
 Pr. Ign. signifies.....Primer ignition.
 I. V. signifies.....Initial velocity.
 f. s. signifies.....Foot-seconds.
 F. C. signifies.....Full charge.

Drill-Cartridges.

Drill-cartridge for small R. F. Guns.—For exercise or for sub-caliber target-practice using small-arm ammunition, a drill-cartridge of the same general shape as the regular cartridge is made. It has a metallic base and point, and in the axis a short length of a rifle barrel, caliber .45, is inserted. The body of the drill-cartridge is a hard, close-grained wood.

Drill-cartridges for 4-inch and 5-inch R. F. guns are the same in shape and size as the regular complete cartridge, and are



DRILL-CARTRIDGE.

similar in design to those for the secondary battery, with the same provisions for sub-caliber practice with .45-caliber ammunition.

The drill-cartridge used with the 3-inch and 5-inch drill-guns consists of the regular case, with base cut off and a steel base screwed on. The object of this steel base is to prevent wearing out the rim from frequent extraction. The rest of the case is reinforced to take a cast-iron projectile, which slips out in the drill-gun or loading-machine.

The drill-charge for B. L. Rs. is composed of beans, and the bag is made of canvas. The whole is made as nearly as possible like the actual charge in weight and size.



CHAPTER XVI.

PROJECTILES.

Steel for armor-piercing projectiles is made by the crucible process, or open-hearth process, or in an electric furnace.

The performances required of projectiles are:

(1) If armor-piercing, to pierce armor and still be in a condition for effective bursting, the high explosive being detonated by the fuse, which has a delayed action.

(2) If "high-capacity" or "common," to fragment satisfactorily on detonation, to penetrate thin plates, and to throw fragments in all directions at high velocities.

Classes of projectiles.—Projectiles used in the U. S. Navy are classed as *armor-piercing*, *high-capacity*, *common*, *shrapnel*, and *target*.

Shrapnel (Figs. 3, 7, and 8) is for use primarily with landing-guns and field-guns, it having been found, up to the present time, impracticable to develop a time-fuse shrapnel for the larger-calibered high-power guns, and no satisfactory mechanical fuse having as yet been developed. These forms of shrapnel are high-explosive, the matrix or rosin or sulphur of the common shrapnel being replaced by a matrix of molten high explosive, such as picric acid or trinitro-toluol.

Common projectiles (Fig. 2) are loaded with fine black powder or explosive "D." If loaded with the former, they are exploded by a simple ignition-fuse; if loaded with the latter, a delayed-action high-explosive fuse is used.

Target projectiles, or blind projectiles (Fig. 6), as a rule, are assembled for issue for target-practice, although a certain small percentage of service ammunition taken at random from ship's magazines is fired every year.

The high-capacity shells have thin walls and carry a large charge of high explosive—up to 10 per cent. In this country explosive "D" is used. These shells do not perform the same function as armor-piercing projectiles, but are very valuable against upper works.

All armor-piercing projectiles (Fig. 1) are capped with caps of soft steel fitting over the head; these are rigidly secured in place to insure their not becoming loose in the rough handling incurred in service.

Form of projectiles.—Modern projectiles are of the same general shape, a cylindrical body with ogival head. The ogival head is found by experiment to be the most advantageous, as it offers little resistance to the air and at the same time provides enough metal at the point of the projectile to give the requisite strength to perform the work of penetration.

The ogival is struck from a center on a line perpendicular to the axis of the projectile, and with a radius usually expressed in calibers. The radius of the ogival varies in different projectiles.

The lower part of the ogive is turned off to make a cylindrical bearing surface for the front part of the projectile. This surface is called the *bourrelet*.

Manufacture of armor-piercing projectiles.—Ingots of the necessary size and containing the required extra metal are formed in projectile molds. The charge is made up of from 50 per cent to 75 per cent of pig iron or wrought iron (pig iron in open-hearth process, wrought iron in crucible process), metallic nickel, ferro-chromium, ferro-manganese, ferro-silicon, and projectile scrap, *i. e.*, discard taken from the base ends of projectiles. Carbon may also be added, if necessary.

After casting, ingots are reheated and forged to a desired form under a hammer, forging-dies being used. The blanks are then annealed to take out stresses, after which they are sent to the machine shop.

From the machine shop the shells go to the treating-house, where they are specially hardened and where their bases are annealed.

The treatment of projectiles differs, and the details of any operations carried on at the works of the manufacturers are considered confidential in so far as the contractor may desire. The government inspector, however, has free access at all times to all parts of the works in which any work is being carried on in connection with material being furnished, and the projectiles are subject to government inspection during all the processes of manufacture.

After final treatment the shells are subject to the immersion test in hot and cold water. Chemical and physical tests are made for the purpose of insuring uniformity in each lot, and while not specifying the amount of carbon, nickel, or chromium, or other hardening element, a specimen from each heat is analyzed and the percentage determined, which is not permitted to vary more than a certain specified amount from the mean percentage of carbon, chromium, and nickel of the entire lot.

The armor-piercing projectiles manufactured by the Hadfield's Steel Foundry Co. (Ltd.), Sheffield, England, whose processes the army has acquired, are cast and treated by special secret processes. While these projectiles are of good quality, it has not yet been demonstrated that they are as satisfactory as those forged in this country.

Practically all projectiles above 7 inches in caliber are either armor-piercing or high-capacity, the armor-piercing having thick walls and being loaded with explosive "D," detonated by a delayed-action high-explosive exterior fuse called the *Semple tracer detonator*. The weight of the explosive, which is sufficient to fragment the shell, is from 2 to 3 per cent of the gross weight.

The function of the cap is to give the projectile better armor-piercing qualities and a better trajectory in the air by reducing the air-resistance, and thereby increasing the danger-space. The capped projectile has a higher striking-velocity for equal ranges than the uncapped shell.

The long-pointed cap.—This cap is a combination of a blunt-pointed cap and a *wind-shield*, the latter being a thimble secured to the end of the cap proper.

Theory of the cap.—It has been established beyond doubt, by exhaustive experiments, that under certain conditions capped shell may even pierce armor that has the balance of power, armor for which uncapped shells are no match under the same conditions. Although forms for caps which increase the efficiency of armor-piercing projectiles have been worked out in all nations in an empirical manner, there is no unity to-day regarding theories as to the manner in which the caps attain their results.

When an uncapped projectile strikes the extremely hard face of a modern armor-plate, the whole energy of the projectile is applied

to the point, and the high resistance of the face of the plate puts upon the very small area at the point of the projectile a stress greater than the metal can resist, however highly tempered it may be. The point is therefore broken or crushed, and the head of the projectile is flattened. The flattening of the head brings loss of penetrative power, and the energy of the projectile is expended largely in shattering the projectile itself. The head of the projectile adheres to the plate and is practically welded to it. The effect on a plate of thickness equal to the caliber of the projectile may be the partial or complete punching out of a cylindrical piece. But even if the plate is completely perforated, the projectile does not get through as a whole, and behind the plate are found only fragments of the projectile and of the metal forced from the plate.

When a projectile provided with a cap strikes a hard-faced plate, the pressure due to the resistance of the plate is not confined simply to the point of the projectile, but is distributed uniformly over a comparatively large cross-section. In addition, the point of the projectile is firmly supported on all sides by the metal of the cap. As a consequence, the point is not deformed, and, passing easily through the cap, it finds the hard face of the plate dished and severely strained and more or less crumbled by the impact of the cap. The unexpended energy of the projectile forces the point through the weakened face and the softer metal of the back. The face of the plate is crumbled, and a conical hole is made through the softer metal, through which the projectile passes practically intact and in condition for effective bursting.

New theory of the cap—The radial-inertia theory of cap-action.—The action of a cap and its power of increasing the penetration of an armor-piercing shell have been the subject of many theories and much speculation. The following theory of the cap is advanced by Major Clarke, late R. A., of Messrs. Hadfield's (Ltd.).

It has been suggested that the actual failure of an armor-piercing shell, when such failure occurs, originates in the extreme point becoming detached and forming a wedge, which splits open the metal round the point, and that by successive or cumulative actions of a similar nature the entire head of the shell becomes disintegrated. Major Clarke has not found this to be the case in practice.

When no perforation occurs in a round fired against armor, the forward part of the head is usually found adhering to the damaged face of the plate, and is often detached by the shock of a succeeding round. In these cases the point is almost invariably found to be flattened, and the following is suggested as the probable explanation: An uncapped shell which is overmatched by a plate fails, in the first instance, by the point being crushed in; and for this to occur, the front of the shell must be deformed outwards. The nature of the stresses are compressive, while the lateral stresses, both radial and circumferential, are tensile. To illustrate the action of the impact of the point, we may imagine the shell composed of a number of longitudinal rods, tapered and curved to follow the outline of the shell and cemented together by an elastic substance. If such a body be struck on the point, the longitudinal members will be arched outwards; and if the elastic medium which binds them together is not sufficiently strong, it will be ruptured, and the longitudinal members will be bent and broken.

This outward distortion takes an appreciable time to travel down the head of the shell, each portion being subjected to the wave of disturbance as it passes; and the most vulnerable part is the point, which has to bear the brunt of the impact with less material to resist it. If the front end of the bundle of rods is bound more strongly or held together by an inward radial pressure, it will obviously be in a far better condition to withstand the shock. *To supply the radial pressure is the function of the cap.*

For this purpose, no great reliance can be placed upon the hoop tensions of the cap itself, as the force available from this source is comparatively small, the more so as the metal must become more or less plastic under the force of the impact. It will be seen, from what follows, that the radial inertia of the cap metal is a far greater factor in the case, and supplies a pressure of an order much more in keeping with the observed effect produced by the addition of a cap.

The plate itself is made up of a tough back, to which it owes its general resisting power and girder strength, and a hard, rigid face, whose function is, to distribute the blow delivered by the point of the shell over as large an area of tough metal as possible, it being for this purpose assisted by the intermediate layer by which the hard face graduates into the tough back.

Penetration can only be effected by driving a portion of this hard face into the comparatively yielding material behind, and success in this direction can in turn only follow the concentration of the blow over the smallest possible area. It is thus of supreme importance for the point of the shell to remain intact. When a capped shell strikes such a plate, the front portion of the cap first flattens itself on the plate, arresting its forward motion and causing the interior portions of the cap to be in a state of considerable pressure and in intimate contact with the head of the shell. As the forward motion of the cap is checked, the head of the shell progressing through the mass of metal displaces it radially, and thus changes its direction of motion. This change of direction can only be accomplished by a definite force in a radial direction, the force representing the pressure existing between the surface of the shell head and the metal of the cap. Major Clarke introduces mathematics to prove his theory.

The critical moment when support from the cap is needed is when the point of the shell meets the face of the plate, and the maximum advantage from the inertia of the cap metal exists when the point of the shell is commencing to move through the mass of cap metal and displace it radially. In order to obtain the maximum support at the critical moment, the point of the shell must meet the face of the plate when the shell is commencing to move through the cap; or in other words, the thickness of metal in front of the point must be small.

Nearly every nation has now adopted, or is adopting, a long ogival cap of large radius of curvature, on account of the greatly increased range thereby obtained. Such a cap, if made solid, must have a considerable thickness of metal in front of the point; and it is easy to understand that by the time the point of the shell meets the plate, the greater part of the cap metal will have been displaced outwards, and its inertia resistance will have been dissipated. It is also clear that the most effective portions of the cap are those that surround the point, and that therefore the greatest mass should be situated there, too much metal in front of the point being not only wasted but actually harmful.

The only way of combining these features with the long point necessary for good ranging, is to have the front portion of the

cap hollow. This theoretical reasoning is strikingly confirmed by the great increase of efficiency displayed by the hollow cap as compared with the solid pattern.

A typical hollow cap is shown in Plate I, Fig. 1, which embodies the essential features of massing the metal round the point of the head and thus keeping it from in front of the point.

The main objects attained by the cap are as follows:

(1) The cap receives the strongest shock of the impact of the projectile, distributes the effect of the recoil over a large area, and thus lessens the compressive strain in the sectional unit of the projectile.

(2) It lengthens the time during which the pressure increases up to its highest point.

(3) While the head of the projectile is pressing through the cap, it presents an ever-increasing section of itself to a smaller section of the cavity in the cap. Therefore the cap exerts a radial pressure directed inward upon the point of the projectile, which opposes the destruction of that portion of the shell in a manner analogous to the hoop of a built-up gun.

The action of the cap is not satisfactory unless it is rigidly secured to the projectile, and therefore it is of the greatest importance that projectiles be inspected before firing, to see that the caps are not loose.

Angle of impact.—Projectiles striking armor at an angle of more than 10° from normal are subjected to severe cross-breaking stresses, and it is not expected that penetration will be effected under such conditions unless the projectile considerably over-matches the armor.

Position of axis.—There is conclusive evidence that the projectile travels with its axis in the trajectory, and that modern armor can be penetrated at battle ranges. This has been determined as a result of exhaustive tests.

Figure of merit.—Projectiles are said to have a certain *figure of merit*, this being based on penetration derived from the De Marre formula for homogeneous nickel steel, certain percentages being added to give the velocity desired for test.

Rotating-bands.—Projectiles manufactured by some governments have two bands, the forward being at the bourrelet. The

single rotating-band used by the U. S. Navy is about one-fourth the caliber of the projectile in length, and is designed in such a way as to insure accuracy in flight and not to be in any way detrimental to the life of the gun. (See Fig. 4.)

The bands are made of pure copper or cupro-nickel ($2\frac{1}{2}$ per cent nickel), and are secured to the projectile in accordance with the bureau's approved design.

Base-plugs.—Nearly all projectiles, with the exception of common projectiles of 6-inch and lower calibers, are fitted with *base-plugs*, but some major-caliber projectiles of old types were made with solid bases.

Fuses.—The *point-fuse* is used at present only in shrapnel fitted with combination time- and percussion-fuses. All other service projectiles are fitted with *base-fuses*. There are in store a number of obsolete common projectiles fitted with obsolete point-fuses.

Gas-checks.—The base-plugs of recently designed projectiles, and those of older types modified, are fitted with the *internal fuse*; that is, the fuse is fitted in the interior surface of the base-plug before the base-plug is screwed home in the projectile, making it unnecessary to cover the whole rear surface of the projectile base with a base-cover. In order to make the base-plugs of these projectiles gas-tight, an undercut score, half in the base-plug and half in the projectile, is made in the projectile. This score is filled with a copper gasket, the interior of which is filled with lead wire. This is caulked into the score flush with the base. In the old types that require a base-cover, the spanner holes of the base-plug are filled with lead; next a lead disk is placed over the base, covering the plug and the fuse. A copper disk is then placed over the lead and caulked into the base-score, the caulking-score being filled with a lead wire outside the turned-down edges of the copper disk.

The function of the gas-checks described above is to prevent the gas of the powder propelling-charge from entering the interior of the projectile and causing a premature explosion.

Bursting-charges.—All armor-piercing projectiles of every caliber are loaded with a bursting-charge, consisting of explosive "D" for all guns of 6-inch caliber and above.

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The following table shows the weight of the bursting-charge for projectiles of the various calibers:

Gun.	A. P. Projectile.	Com. Projectile.	Charge.
14".....	31.5 lbs.....	.....	Explosive "D"
13".....	13.6 lbs.....	.....	" " "
12".....	22.5 lbs.....	.....	Black powder
10".....	24.0 to 24.7 lbs.....	.....	Explosive "D"
8".....	13.25 lbs.....	.....	" " "
7".....	6 to 6.2 lbs.....	.....	" " "
6".....	4.4 to 4.5 lbs.....	5.50 lbs.....	" " "
5".....	2.4 lbs.....	.....	" " "
4".....	1.8 lbs.....	4.00 lbs.....	" " "
3".....	.....	1.70 lbs.....	Black powder
3" L. G. & Fld....	.....	1.10 lbs.....	" " "
3" High Explos..	.....	.50 lbs.....	" " "
6-pdr.....	.....	.35 lbs.....	" " "
3-pdr.....	.....	.33 lbs.....	Explosive "D"
1-pdr.....	.....	1300 gr.....	Black powder
	.....	900 gr.....	" " "
	.....	180 gr.....	" " "

Weight of projectiles.—All projectiles of the same caliber are now of the same weight, the common shell having been brought up to the weight of the capped, armor-piercing projectiles. Following are the weights loaded and fused:

Caliber.	Weight.	Tolerance.
	<i>lbs.</i>	<i>lbs.</i>
14".....	1400	4
13".....	1130	3
12".....	870	2½
10".....	510	2
8".....	260	1
7".....	165	¾
6".....	105	½
5" 51-cal.....	60	½
5" 50-cal.....	60	½
5" 40-cal.....	50	½
4".....	33	½
3".....	13	¼
3" field.....	13	¼
	<i>gm.</i>	
6-pdr.....	2735	..
3-pdr.....	1525	..
1-pdr.....	477	..

Marking projectiles.—(1) The major-caliber projectiles are marked as follows: On the base, with the name of the manufacturer, lot number and date of specification, and weight; on the rotating-band, with the initials and stamp of the inspector of ordnance, caliber, kind (A. P., F. S.), mark and modification.

(2) The minor-caliber projectiles are stamped on the base with the name of the maker, and the lot and year of their specification; and on the band, with the inspector's initials.

(3) The exterior of projectiles (except the rotating-band, base, and bourrelet, fuse, and the ogival from one caliber's distance from the nose to the bourrelet) is coated with a thin, hard, smooth paint of the following colors, respectively:

Armor-piercing	Black.
Common	Lead color.
Shrapnel	White.
Blind	Red.

(4) Target-projectiles are painted red on the ogival only; the rest of the projectile is vaselined.

(5) Projectiles for fixed ammunition are not painted in rear of the rotating-band, but are given a thin coat of vaseline or heavy grease.

(6) The bursting-charge of all projectiles is indicated by painting the ogival a distinctive color for one caliber's distance from the nose toward the bourrelet.

(7) Projectiles loaded with black powder have the nose painted lead color.

(8) Projectiles loaded with explosive "D" have the nose painted yellow.

(9) Projectiles blind-loaded have the nose painted red.

(10) Projectiles fitted with night tracers and tracer-fuses, have a white band one inch wide painted around the ogival just below the color indicating the bursting-charge.

Projectiles for different classes of guns.—(1) For the 14-inch, 13-inch, 12-inch, 10-inch, 8-inch, and 7-inch guns, common and armor-piercing projectiles only are provided. Common shells are not now manufactured for any gun larger than the 5-inch.

(2) For the 3-inch 50-caliber, 4-inch, 5-inch, and 6-inch guns, armor-piercing and common projectiles and shrapnel are in service. Shrapnel is not now being manufactured for any gun of more than 4 inches in caliber.

(3) For the 3-inch landing-gun and field-gun, shrapnel and high-explosive shell are issued.

(4) For the 6-pounder, 3-pounder, and 1-pounder guns, steel shells only are issued.

All of these projectiles and forms of shrapnel are issued loaded and fused, except such projectiles as are issued for target-practice only, which do not contain any bursting-charge, but are brought to weight with any convenient material.

Care of service outfit.—Projectiles comprising the service outfit of ammunition shall not be altered or disassembled on board ship in any of their parts, without explicit instructions from the department. Fuses shall not be removed from loaded shell except under explicit instructions from the bureau. Projectiles shall be kept free from rust, and the paint or lacquer shall be renewed when necessary. The old paint shall be removed before painting, in order that the dimensions may not be increased thereby. Projectiles for separately loaded 5-inch and 6-inch guns shall be stowed in their rope slings. Care shall be observed in handling all shells not to score or indent the rotating-bands.



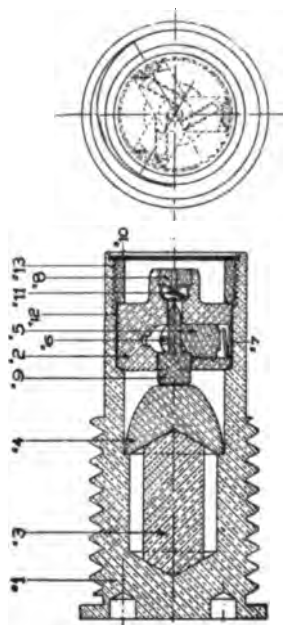
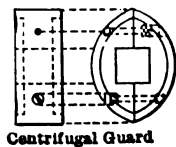
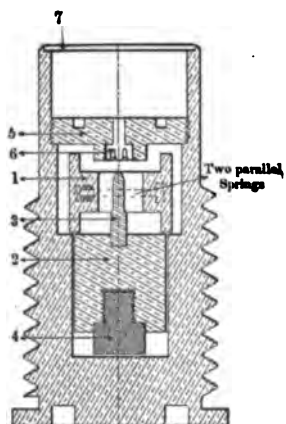


FIG. 1.—Merriam Fuse.



FIG. 2



Centrifugal Guard

FIG. 3.—Wilson-Chase Fuse. (Major caliber.)

CHAPTER XVII.

FUSES.

A fuse is a device which, when exploded by the action of its mechanism, ignites the bursting-charge of a projectile. Three classes of fuses are used at present in the naval service, as follows: *detonating-fuses*, *ignition-fuses*, and *time-fuses*.

Detonating-fuses for use in armor-piercing projectiles loaded with high explosive may contain a delayed-action element, so as to permit the projectile to pierce and detonate in rear of the heaviest armor. The details of these fuses cannot be published. It is known, however, that projectiles loaded with high explosive and fitted with detonating-fuses are entirely safe for handling and stowage in the naval service, and the fuse cannot act until the projectile has been propelled from the gun.

Ignition-fuses are used for all projectiles which are loaded with black powder and contain only black powder in addition to their primer-caps. The stocks of these fuses are sized and threaded in two sizes, one for projectiles of 4-inch and larger caliber, and the other for projectiles of 3-inch and smaller caliber. According to these sizes, they are designated as major-caliber and minor-caliber fuses respectively. These fuses act practically instantaneously on impact.

The following fuses are being manufactured for issue to the service:

6-inch and above. . . . Tracer detonator-fuses.

4-inch and 5-inch. . . . Semple medium-caliber tracer-fuses.

3-inch and below. . . . Semple minor-caliber tracer-fuses.

Shrapnel. 15-sec. F. A. C., and 21-sec. F. A. C.

A number of Merriam (Plate I, Fig. 1), Wilson-Lynch (Plate I, Fig. 2), Wilson-Chase (Plate I, Fig. 3), Watson (Plate I, Fig. 4), and Semple (Plate I, Fig. 5) base-percussion fuses are still in use where shells are loaded with black powder.

The tracer-fuses now being made have comparatively heavy plungers and sensitive primer-caps. These fuses act very sensitively on impact, and in addition have the tracer element. The old base-percussion fuses have as a rule light plungers and ordinary primer-caps, and are not very sensitive when used in heavy projectiles.

The stocks of ignition-fuses are made of brass or bronze and are fitted with left-handed threads to prevent unscrewing in flight. The fuse-holes of blind projectiles are fitted with a brass or bronze fuse-hole plug, the head and threads of which are of the same size as those of the fuse.

Time-fuses.—A time-fuse is one which explodes by its own internal action after a definite time of flight, which fixes the distance from the gun at which the projectile will burst; this interval may be varied within large limits by the operation of "cutting" or "setting" the fuse.

The time-fuse depends upon the burning-interval of its train of compressed slow-burning powder; this composition is made as uniform as possible, and, if accuracy is to be attained, equal lengths of it should be consumed in equal intervals of time. When the fire reaches the end of the time-train, it ignites the quick powder of the fuse-magazine and bursting-charge, and the projectile explodes instantly. The time of burning of a particular size or variety of fuse depends upon the distance the train is lighted from its end.

The first fuses used for bursting projectiles were time-fuses which depended upon the slow-burning powder train; since that time the only progress, as far as principles are concerned, lies in the method of igniting the time-train. These old-fashioned fuses, formerly used with common projectiles, were ignited by the flame of the gun's powder-charge, which came into contact with the exposed time-train—if it had been "cut." Their bodies were sometimes made of wood, and the time of burning was varied by sawing off a few inches of the end. This method of ignition answered very well for low-power guns, but for modern guns the high powder-pressure would crush one of such construction, or at least derange it so as to interfere with its working. The modern method of ignition is the self-contained. The methods used vary with the different types, but in general the time-train is ignited by

a primer struck by a plunger that is released by the shock of explosion of the gun-charge.

Time-fuses are used in the navy for shrapnel only, and are invariably carried in the point or nose of the projectile.

There is fitted a percussion element also to the common time-fuse, so as to explode the projectile on impact. These fuses are known as combination time- and percussion-fuses.

Ignition-Fuses.

Merriam base-percussion fuse.—The Merriam base-percussion fuse, of which a number have been issued to the service, is shown in Plate I, Fig. 1.

The *striker* (9), the *primer* (11) and *anvil* (8) are carried in a *block* (2) held in the forward part of the fuse-cavity by a *screw-sleeve* (13). The flame from the primer communicates with a small powder-chamber, the powder being confined by a thin *copper disk* (10).

The point of the striker is held back from the primer in the block by three *radial keys* (5) which are pressed against the striker by spiral springs, as shown in the plate. When the shell leaves the gun, the centrifugal force due to the rotation of the shell causes the keys to fly back against the springs and unlock the striker, which is then free to move forward against the primer.

The *plunger*, which gives force to the striker, is in two distinct parts (3 and 4). The rear plunger (3) is designed to cause the fuse to act upon oblique or side impact. Being of smaller diameter than the fuse-cavity, and its ends being conical where it bears against the cavity and against the forward plunger (4), it is evident that a side impact would cause the plunger to move sidewise and impart a forward movement to the forward plunger (4), driving the latter against the striker (9).

The action upon direct impact will be evident from the plate. The centrifugal locking- or safety-arrangement and the device for side impact are the distinguishing features of this fuse.

Wilson-Lynch base-percussion fuse.—This fuse is shown in Plate I, Fig. 2. It consists of the following parts: the *stock; sleeve* (2); *magazine* (3); *plunger* (4)—plunger consists of two parts, (a) male and (b) female, held together by the *spring-screw* (8) and *spring* (9)—annealed *copper disk* (5); *primer-cap* (6),

which is a Winchester No. 2 of copper; *steel ball* (7); *firing-point* (10); and *starting-pins* (11).

The powder-chamber in the magazine (3) is filled with 60 grains of black powder, the copper disk is expanded into place and sealed with shellac. When the plunger is closed, a small shoulder on the magazine holds the plunger central; the point is then out of line with the cap.

The action of this fuse is as follows: When the gun is fired and the shell starts its rotation, the plunger tends to lag behind, but the starting-pins (11) bring up in the recesses in the base of the stock-cavity and start the opening of the plunger. The sleeve (2) prevents the plunger from sticking to the wall of the fuse, as the commencement of the rotation would tend to throw the plunger violently to the side. As soon as the projectile obtains a rotation of about 3000 revolutions a minute, the plunger opens out and the steel ball, which has rested in the recess in the plunger, now flies out, along the groove of decreasing depth, and holds the plunger open. Upon impact the plunger flies forward, and the point, now being in a central position, strikes the primer-cap, exploding it.

The design of this fuse as submitted by the U. S. Ordnance Co., the owners of the patents, provided for side-impact weights behind the plunger; but the side-impact explosion not being considered necessary, this feature is omitted in the fuses being made for the service. The fuse shown in Plate I is improvised so as to use up a number of old Frankford Arsenal ring-resistance fuse-stocks. The standard fuse has a stock and closing-plug similar to the Wilson-Chase, and a heavier plunger.

Wilson-Chase base-percussion fuse (major-caliber).—This fuse is shown in Plate I, Fig. 3. It consists of the following parts: the *stock*, the *centrifugal guard* (1), *plunger* (2), *point* (3), *lead base* (4), *closing-plug* (5), *primer-cap* (6)—Winchester No. 2½, brass cap—and *copper disk* (7).

The plunger is held to the rear by the centrifugal guard (1), which is in two parts held together by two springs and screws, which are parallel (shown in the section). The lead base (4) is to prevent the plunger from being driven forward by any heavy blow on the base of the fuse.

The action on being fired is as follows: When the projectile is in flight, the guard opens out, due to the high rotation, and the plunger, which has been held to the rear by the guard-ring, can now fly forward sufficiently to drive the point into the primer-cap on impact.

The Watson base-percussion fuse.—This fuse is shown in Plate I, Fig. 4. It consists of the following parts: the *stock* (1); *plunger* (2); *pawls, springs, and hinge-pin* (3); *primer-plug* (4); *point* (5), which is of bronze and is part of the plunger; *plunger-spring* (6); and *copper disk* (8). There are two longitudinal slots in the plunger diametrically opposite, and a starting-pin in the stock travels in one of them. The parts are made of bronze of about 50,000 pounds tensile strength.

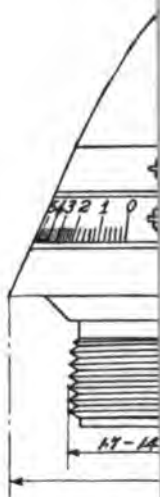
The action of the fuse is as follows: The shock of discharge causes the plunger to set back against the spring (6) at its rear, which releases the lugs of the safety-jaws (3) from engagement with the inner side of the primer-hub, which engagement had locked the plunger in the safety position. The acceleration of the shell through the bore of the gun and for a short distance beyond holds the plunger to the rear. This action is aided by the rotation-pin, which engages the longitudinal slot in the side of the plunger, giving to it a positive rotation which is in turn imparted to the jaws (3), the whole being actuated by the projectile. This rotation by centrifugal action throws the jaws to the periphery of the plunger; and once the shell is in flight, the spring at the rear forces the plunger forward until the jaws are on the outside of the primer-hub, when they are locked open to allow the plunger to move forward and explode the primer-cap (a brass Winchester No. 2½) on impact. The fuse is therefore locked in both safety and armed positions.

Simple base-percussion fuse (minor-caliber).—This fuse is shown in Plate I, Fig. 5. It consists of the following parts: *outer plunger* (1), *inner plunger* (2), *magazine* (3), *knife* (4), *knife-pin* (5), *shear-wire* (6), and *primer-cap* (7).

In the safety position, as shown, the outer plunger rides forward on the inner plunger, and is held there by a copper shear-wire. The knife (4) is carried in a slot in the outer plunger, and in the safety position is folded inside. The front part of the fuse is shaped to form the magazine (3), and holds a small charge of powder and the primer-cap.

The action of the fuse is as follows: The shock of firing shears the wire, and the outer plunger flies back, due to inertia, sliding over the inner plunger. The slot in the inner plunger forces out the knife, and upon impact both plungers fly forward and explode the cap. The fuses are now made long-threaded, as are all minor-caliber fuses.

Test and inspection of centrifugal fuses.—The following applies to those manufactured at the Gun Factory, and the tests of other fuses are similar. Out of every 1000 fuses the inspector carefully gauges about 30. There is a gauge (maximum) in which the fuse must be screwed home, a minimum, which it must just not enter, and a ring-gauge which must fit over the nose. These 30 are then spun in a clutch driven by a motor, and each fuse must arm at 3000 revolutions. Two of these fuses are then picked out for drop-testing. The fuse to be drop-tested is screwed in the base of a 4-inch projectile and is dropped from a height of 32 feet, point first, base first, and on its side, on a 4-inch steel plate. The fuse must not arm on any of these drops, and after being drop-tested must be armed at 3000 revolutions on the spinner. Eight fuses that have been spun are picked out and sent to the proving-ground for test, and must explode when fired from a 5-inch 40-caliber gun at 1000 f. s. m. v., through a $\frac{3}{8}$ -inch plate at a range of about 300 feet.



FIG

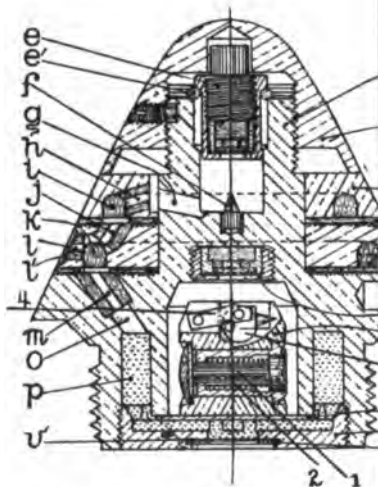


FIG. 2.—Before Arming.

FRANKFORD ARSENAL 2

Time-Fuses.

Frankford Arsenal 21-second combination-fuse.—This fuse, which is the standard fuse, is shown in Plate II. Most of the parts are made of bronze. There are two time-train rings, *c* and *d*, and an annular horseshoe-shaped groove is milled in the lower face of each ring. Meal powder is compressed into these grooves under a pressure of 70,000 pounds per square inch, forming a time-train, the total length of which is 7 inches.

The *time element* of this fuse is composed principally of the following parts: the *time-plunger e*, the *split-ring spring e'*, the *firing-pin f*, the *vent g* leading to the *upper time-train i*, the compressed *powder-pellet h*, the *lower time-train k*, the *compressed powder-pellet m*, in the *vent o*, leading to the *powder-magazine p*.

The upper ring *c* is prevented from rotating by the *pins x*.

The vent *g* is drilled through the walls of the time-plunger chamber, and is exactly opposite a hole in the inner surface of the upper time-train leading to the end of the train from which the direction of burning is anti-clockwise. The hole *j* is drilled through the upper face of the lower time-train ring *d*, to the end of the lower time-train groove from which the direction of burning is clockwise.

The lower time-train ring is movable, and is graduated on its outer edge in a clockwise direction from 0 to 21, each full division corresponding to one second of time of burning in flight; these divisions are subdivided into five equal parts, each corresponding to one-fifth second. A radial hole is provided in the lower ring for a pin to be used in setting the fuse. An arrow on the lower flange of the fuse-stock is the datum-line for settings.

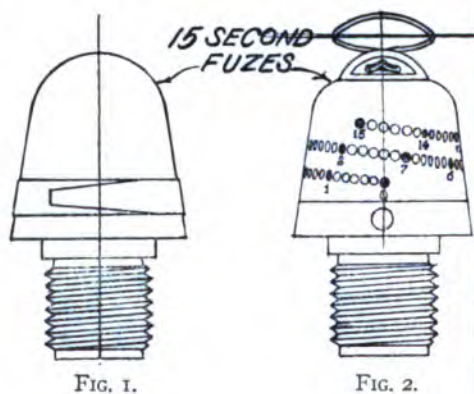
The vent *o* is drilled through the flange of the fuse-stock to the powder-magazine *p*, and leads to the same end of the lower time-train as the vent *j*—that end from which the direction of burning is clockwise when the fuse is at its "zero" setting.

The *action of the fuse as a time-fuse* is as follows: Assume first the "zero" setting as shown in the figure. The time-plunger, a ring-resistance plunger, arms on the stock of firing. The flame from the primer passes out through the vent *g*, igniting the pellet *h*, to the end of the upper time-train *i*; and down through the vent *j*, to the end of the lower time-train *k*; and thence through the vent *o*, to the magazine *p*.

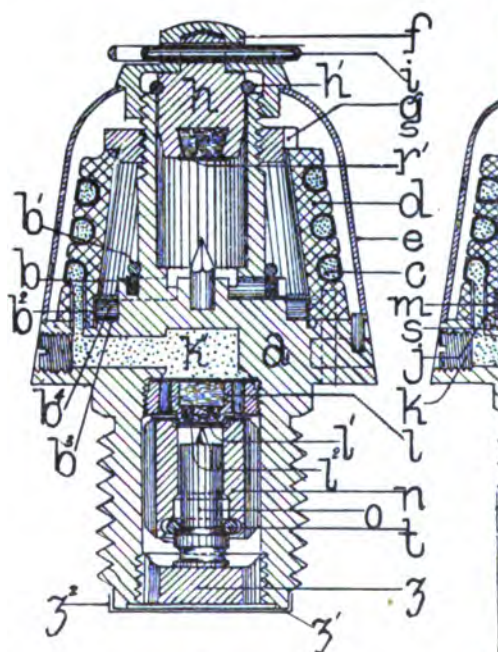
It will be seen that for the "zero" setting of the fuse the origins of both upper and lower train are in juxtaposition. Assume any other setting, say 12 seconds. The vent *j* has now changed its position with respect to the vent *h*, leading to the beginning of the upper time-train, and the vent *o*, leading to the powder-magazine *p*, both of which points are fixed by the angle subtended between the "zero" and the 12-second settings. The flame now passes out through the vent *g* and burns along the upper time-train in an anti-clockwise direction until the vent *j* is reached, when it passes down to the beginning of the lower train and burns back in a clockwise direction to the position of the vent *o*, whence it is transmitted by the pellet *m* to the magazine *p*.

For the 21-second setting the flame burns the length of both trains. As the trains do not extend all around the fuse, the solid part between the ends of the trains is utilized to obtain a safety-setting. When this point, marked *S*, is brought opposite the arrow on the lower flange of the fuse, the vent *j* is covered by the solid metal between the ends of the upper train, and the vent *o* is covered in a similar manner by the lower or movable ring.

The percussion element consists of the primer *r* and the new centrifugal plunger *q*. The plunger is in two parts held together by the bolt (1), and spring (2). When the fuse attains 2500 revolutions, the plunger opens out and the cross-pin (4) pulls the point (3) to an upright position, so that upon impact the plunger will fly forward and the point will strike and explode the primer.



FRANKFORD ARSENAL COMBINATIO



FRANKFORD ARSENAL 15-SECOND

Frankford Arsenal 15-second combination-fuse.—This fuse is shown in Plate III. The action of the fuse is as follows:

(1) *As a time-fuse.*—A hole is punched through the *cover e*, the *time-train c*, and the *lead cone d* at the point in the cover corresponding to the number of seconds desired. Just before loading, the *safety-pin i* is removed. This allows the *time-plunger h* to rest on the fuse-body, where it is held by the *split-ring spring h'*. By shock of discharge, the split-ring spring is expanded and the plunger is forced to the rear, the *primer r* in the plunger striking the *point m* and exploding. The flame from the primer passes through four *radial holes s* and ignites the ring of compressed powder *b*. The only vent for these gases is the punched hole, and they ignite the time-train *c* at that point. The latter burns and ignites the powder in the *tube j* and the *magazine k*. The flame from the magazine-charge passes through the percussion *primer-plug l* and percussion-plunger, and ignites the bursting-charge in the shrapnel.

(2) *As a percussion-fuse.*—By shock of firing, the *sleeve n* is carried to the rear. The *split-ring t* opens out and is forced back into the groove around the rear end of the *plunger o*, where it springs into place. The plunger *o* and sleeve *n* are now locked together, and the point is exposed. On impact, both fly forward and explode the *primer-cap v*.

The percussion part of this fuse is similar to that of the old Frankford Arsenal base-percussion fuse, which was discarded by the navy, as it would not stand the drop-test.

The time-fuses described above were developed for use in low-power guns. When these fuses are employed in high-power naval guns, that is, with velocities of 2700 f. s. and over, with 16 and 17 tons chamber pressure, the time of bursting is considerably accelerated over the times marked on the time-train. The Frankford Arsenal 21-second combination-fuse is the most reliable combination-fuse used at present in the naval service.

Frankford Arsenal primer-caps.—These caps, which are considered to be safer than the fulminate caps, consist of the following ingredients in the proportions named:

Chlorate of potash	50.54
Sulphide of antimony	26.31
Sulphur	8.76
Ground glass	12.39
Shellac	2.00

The thoroughly pulverized ingredients are mixed dry, and alcohol is added to dissolve the shellac. The percussion-pellets are formed by pressing the mixture while in a plastic state into the percussion-primer recess. Upon the evaporation of the alcohol, the shellac causes the pellet to adhere strongly to the metal of the recess.

This primer-cap is thought to be much safer for handling than the fulminate caps.

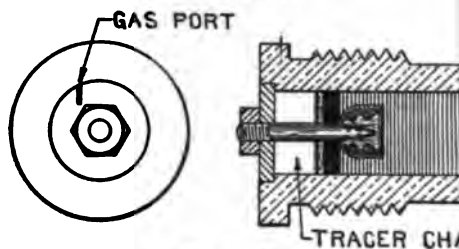


FIG. 1.—Target-Tracer for Minor-6

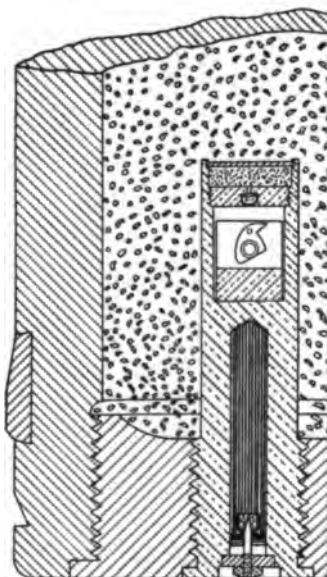


FIG. 2.—Tracer-Fuse for Minor-6

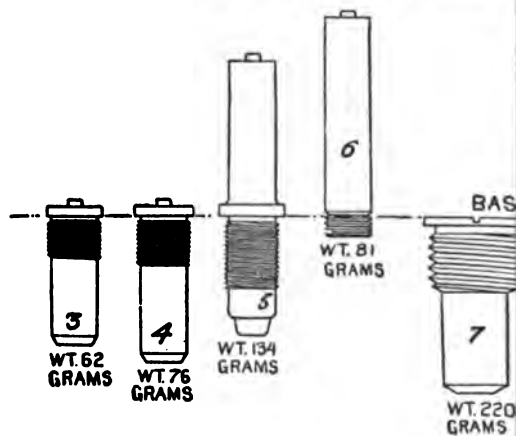


FIG. 3.—Tracers (3, 4, 6, 7, 9 and 10) and
TRACERS AND TRACE

Tracers and Tracer-Fuses.

The tracer (Plate IV, Fig. 1) is used in order to make it possible to spot at night by following the projectile in flight. This is accomplished by means of a highly compressed slow-burning composition ignited by means of a friction element on gun-fire. There is a small air-chamber at the mouth of the tracer covered by a metal disk, in which is cut a gas-port, the size of which depends on the caliber of the gun in which the tracer is used. The cover is connected to the friction element by means of a rod.

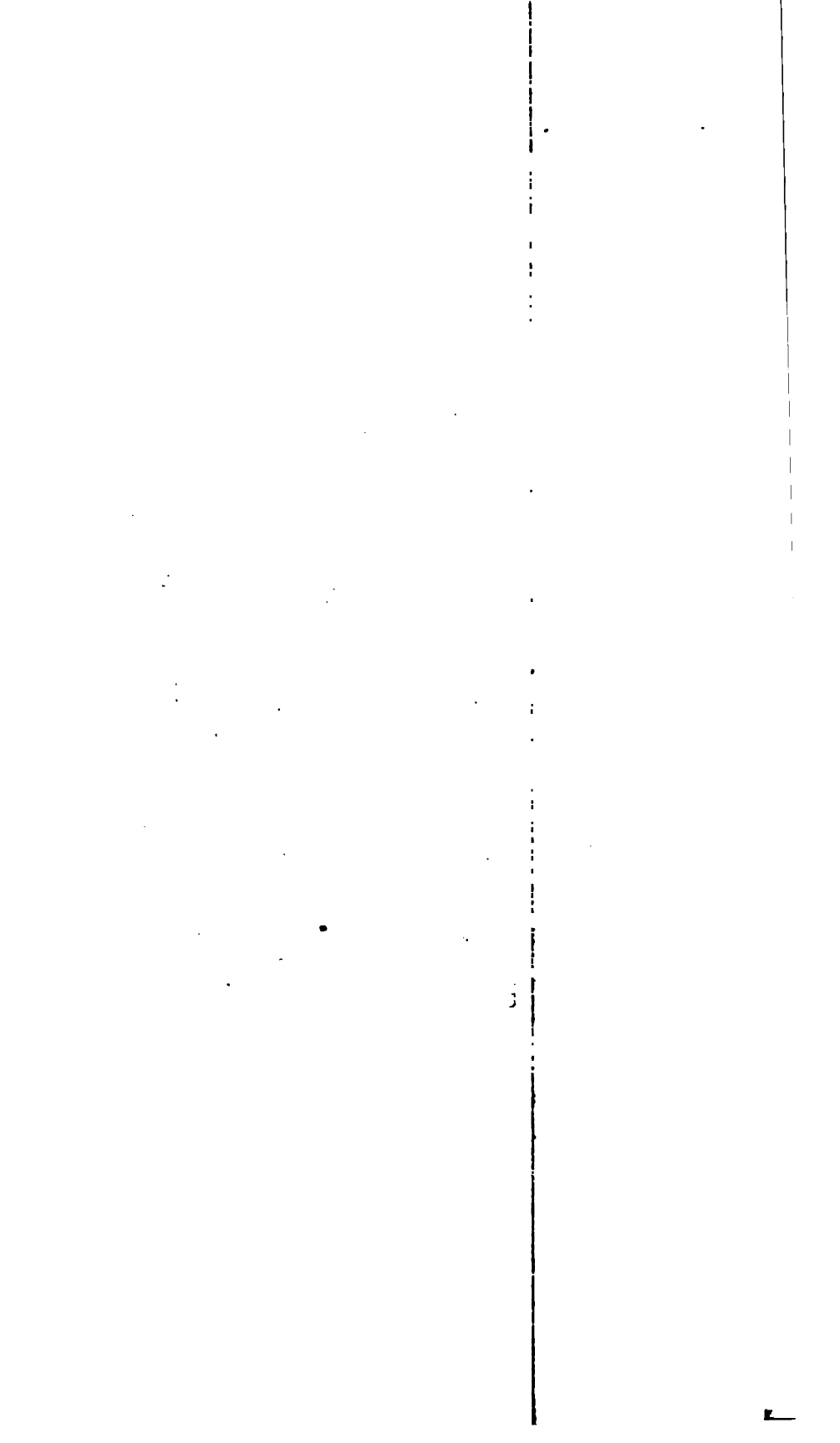
The action of the tracer is as follows: On explosion of the smokeless-powder charge of the gun, the gas of the charge enters the tracer-chamber through the gas-port; and, while the projectile remains in the bore of the gun, the gas in the tracer-chamber is under high pressure. After the projectile leaves the gun, the pressure on the tracer-port being released, the cover of the tracer is forced to the rear by means of the expansion of the gas in the chamber. The forcing of the cover to the rear draws the central rod to the rear and ignites the friction element, which, in turn, ignites the slow-burning composition of the tracer. This composition burns from 12 to 15 seconds, depending upon the design of the tracer.

Tracers for use in target-practice ammunition are not fitted with a fuse element.

The *tracer-fuse* (Plate IV, Fig. 3—cuts 3, 4, 6, 7, 9 and 10), is a combination of the Semple ignition-fuse and the tracer, and is used in minor-caliber and medium-caliber service ammunition. The fuse element is armed by means of the acceleration of the projectile in the bore of the gun, and acts on impact in the same manner as a simple ignition-percussion fuse. The Semple fuse element is quite efficient, because all the moving parts are locked together when the fuse is armed, giving it the maximum weight of plunger.

Tracers for major-caliber projectiles are composed of the Semple tracer element, and are introduced into cylindrical unthreaded holes bored in the rear side walls of the projectile. Two of these *side-wall tracers* (Plate IV, Fig. 3—cuts 9 and 10) are used in each projectile, and are placed in holes drilled 180° apart.

The holes for receiving the side-wall tracers are made with enough clearance to allow the tracers to be slipped in by hand. The metal of the projectile is upset slightly over the ends of the tracers, so that the side-wall tracers will not fall out during transportation or during the flight of the projectile.



CHAPTER XVIII.

STOWAGE AND SUPPLY OF AMMUNITION.

Ammunition Stowage.

Ammunition-rooms, magazines.—With the exception of the detonators and dry gun-cotton primers for torpedoes, all ammunition, of whatever character, is stowed in specially constructed rooms set apart for that purpose alone; a few projectiles are often stowed in racks around the gun-emplacements or below decks, where they can be expeditiously supplied to all guns in emergencies; and in turrets and below the turret floors.

The ammunition-rooms are commonly distinguished in name by the kind of ammunition they contain, as well as by their regular numbers; for example, compartment A-37-M is one of the forward 12-inch magazines; compartment D-33-M is the small-arm magazine.

Flooding and draining.—All ammunition-rooms are watertight compartments. Arrangements are made for admitting seawater to each room. Those situated above the water-line have pipes leading from the fire-main; those situated below the water-line have pipes leading from a sea-valve. The *flood-pipe* in shell-rooms is a simple pipe with one opening. The pipe in powder-magazines has many small holes on the underneath side, and is called a *sprinkler*. Sprinklers are also fitted over gun-loading positions in turrets, and over powder-loading positions in handling-rooms. In every case the pipe, both flood-pipe and sprinkler, must be of sufficient size to fill the magazine in 20 minutes. This requirement necessarily varies the number of holes in the sprinkler pipes, depending upon the size of the magazine.

On the pre-dreadnought types of ships the flood-pipe leads from the outer skin of the ship (sea-valve), below the water-line, directly to a *flood-valve* which is worked either in the magazine itself or from the berth-deck. A spindle leads from the pipe to a plate on the berth-deck, and ends in a square section on which is shipped a large key turning the valve. This key or wrench is

kept near at hand in a locked rack, the key of which is kept with the magazine keys. In some cases the socket in the deck, in which is the head of the spindle, is locked by a padlock, the key of which is kept with the magazine keys. Magazine keys are kept in the captain's cabin.

The deck-plate is stamped with the name and the compartment number of the room it floods, and an arrow-head indicates the direction in which the valve opens. In addition, a specially shaped plate, with a red ground, secured to the beam above, gives the same information. For example, see Fig. 1.

The air escapes from the magazine through the exhaust *ventilating-duct*; if none is fitted, a special *escape-pipe* is provided to allow the room to fill. Those compartments flooded from the fire-main have *relief-valves* to prevent the accumulation of a pressure that would make the bulkheads collapse.



FIG. 1.

Ammunition-rooms in the hold drain into *bilge-wells*, from which suction-pipes lead to drain-manifolds. Upper compartments sometimes have individual drain-pipes to drain wells or lower compartments. In most cases they can be freed of water, that happens to find its way into them, only by portable pumps. No recent ships have any means of draining magazines and shell-rooms other than portable pumps.

Later ships.—In the later ships, instead of each magazine and shell-room being flooded separately, they are divided into groups, and flooded by groups, by turning one valve. Each compartment is fitted with a cut-out valve, so that the whole group or any certain compartments in a group may be flooded. The cut-out valves can be operated only from the magazines.

Method of testing.—It is only necessary for testing-purposes to determine if, when the valve is opened, water will enter the pipe in the magazine. Therefore these pipes are fitted with a cap which is *secured* to the end of the pipe when testing. The valve is then opened, either from the berth-deck or from the magazine, and a

magazine bucket is held under the drain-cock fitted on the pipe near the cap. The drain-cock is then opened, and if water comes out through the cock the flooding system is in good order.

Testing sprinklers.—There is no way by which the sprinkler can be tested without letting the water into the magazines. The valve on the sprinkler pipes which controls the water can however be tested.

Ventilation.—*The adoption of a smokeless powder which, in the process of manufacture, is colloided with a very volatile liquid, makes the subject of ventilation a very important one; the ether fumes are inflammable and must be carried off and, in addition, the powder must be kept cool. To this end, every ammunition-room is fitted to receive, directly from the ship's artificial ventilating system, a supply sufficient to renew the air once in about eight minutes. A natural exhaust-pipe of greater area than the supply-duct is placed in each room as far away from the supply as possible; the upper end is carried up at least above the berth-deck and terminates in a goose-neck covered with wire mesh. When ammunition-hoists open directly into the magazine, the trunk of the hoist itself is used for natural exhaust ventilation; a goose-neck outlet, covered with wire mesh, is fitted at a height above the berth-deck. Piping in ammunition-rooms is generally of brass.*

The question of ventilation is not fully settled at this time. In ships that are not fitted with magazine refrigeration-plants the ventilation system is as outlined above. Where refrigeration has been installed, however, various arrangements have been made, from no ventilation at all (as in the case of those ships using ethyl-chloride refrigerating-machines) to the ordinary amount of ventilation provided by a blower operated on either the closed or the open system—that is, the blowers drawing the supply of air either from the magazine or from the open air.

Refrigeration.—The question of magazine-refrigeration first occupied attention about 1899, on the advent of smokeless powder. At this time an experimental system was installed in the *Illinois*. This consisted of dense-air machines having brine-pipes in the magazines. The magazines were not insulated, and the installation was not a success. From 1899 to 1908 the question was not actively considered, but in 1908 a magazine-refrigeration system

similar to that being installed in British ships was experimented with in the *Iowa*. This consisted in installing a cooling-box outside the magazine, with the cold air to the magazine-room on a closed circuit. This was considered generally satisfactory, and was followed in 1909 by a similar installation on the *Ohio*. The ice-machine was an electrically driven CO₂ machine. Both in the *Iowa* and in the *Ohio* the magazines were insulated.

The *North Dakota* and *Delaware* were the next ships to have magazine-refrigeration. On these ships dense-air steam-driven machines were installed. The dense air circulated through cooling-boxes located outside the magazines, and the air to the magazines was circulated over the coils in the cooling-boxes. The ventilation-blower could draw the supply either from the magazines or from the open air. This installation was not entirely satisfactory, and an entirely new system was experimented with on the midship magazines of these vessels.

This new system consists of an ethyl-chloride ice-machine in which the cold brine is circulated directly to the magazines, no ventilation being provided. The magazines are fitted with coils, drip-pans, etc., and the system has proved satisfactory.

The following table shows the types of installations that have been made:

Machine.	Motive power.	Cooling box.	Brine in magazine.
CO ₂	Electric	Yes	No
CO ₂	Electric	No	Yes
C ₂ H ₅ O	Electric	No	Yes
Air	Steam	Yes	No

The air-machines have not been satisfactory except where thick insulation has been used.

The original requirements as regards temperature were that the magazines should be kept not above 70° F., and as near 70° F. as possible. Experience has proved that a temperature of 80° F. is satisfactory, and all present installations are based on this temperature.

In the installation of magazine refrigeration-plants the following requirements when well met add to the efficiency of the plant:

- (1) Decks and bulkheads to be well insulated by cork.
- (2) Beams and stiffeners to be insulated by cork.
- (3) All piping to be efficiently lagged.

(4) Number of supply-ducts to be left at a minimum, and with outlets 3 feet from the deck.

(5) Exhaust-ducts also to be left at a minimum, and to take from upper part of magazine.

(6) No cold-air piping must pass through heated compartments, such as machine-shop, evaporator-room, etc.

Lighting.—Each magazine and shell-room is lighted by one or more *light-boxes*, of standard navy pattern, which throw light in three directions through round ports covered with double glass plates. The boxes are water-tight, and are separate compartments opening *only* from the deck above or from some passage or compartment outside the magazine. The light-boxes each contain *incandescent lamps* and are arranged to burn *candles* if the lamps fail; in the latter case, enough water to cover the bottom should be poured into the light-box.

The above holds for ships of the pre-dreadnought type. In all ships built since the *South Carolina* and *Michigan* the magazines and shell-rooms are lighted by bunker lights, either set into the bulkhead in a recess or attached to the bulkhead on the magazine side. They contain the incandescent lamp, and have no facilities for using a candle.

All magazines and shell-rooms are lighted from the magazine lighting-circuit.

The wing-passages or ammunition-passages in these ships are also very useful in transporting ammunition from one 12-inch handling-room to the other, in case of emergency—such as when one turret is disabled, while the other turret is running out of ammunition.

Recent designs.—In the recent designs of all big-gun ships, the location of ammunition-rooms is more complicated. Plate I shows the arrangement of magazines and shell-rooms, and ammunition-passages, on the upper and lower platform decks of a dreadnought.

Taking the *Delaware* for example, all the turret handling-rooms are on the upper platform deck, with magazines and shell-rooms adjacent, and with ammunition-passages to adjacent turrets. On this deck the handling-rooms for the No. 1 and No. 2 turrets, and also for No. 4 and No. 5, are communicating. Magazine-rooms

are also below the handling-rooms, on the lower platform deck, except for the No. 3 turret.

On the lower platform deck, an ammunition-passage runs from the magazine under the forward turret on both sides, to the 5-inch magazines and shell-rooms under the No. 3 turret. These ammunition-passages connect both forward and aft by athwartship passageways. At the ends of these ammunition-passages are situated the 5-inch magazines and shell-rooms.

The ammunition for the 5-inch guns is passed from the ammunition-rooms to conveyors in the ammunition-passages, which take it to the proper chain-hoist. These hoists are scattered along the length of the ammunition-passages, inboard, and supply the broadside guns.

The 5-inch magazines and shell-rooms for the forward and after guns are also situated on the lower platform deck forward and aft of the ends of the ammunition-passages, and the chain-hoists for the ammunition are situated in a small space outside the ammunition-rooms called the 5-inch handling-room.

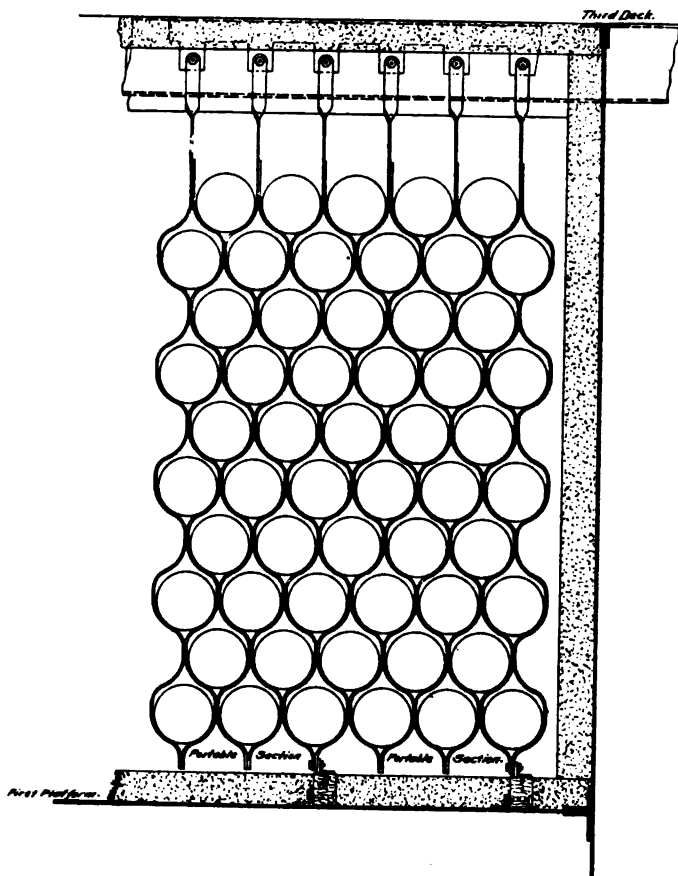
Rooms for naval defence mines, saluting-powder, and small-arm ammunition are situated on the lower platform deck. The torpedo war-head room is in the hold.

The present practice in the new 14-inch-gun ships is to do away with turret handling-rooms proper. All shells for the turret-guns are stowed (base up) in the turret and barbette. There is a powder handling-room adjacent to the powder passing-platforms. The magazine opens into the powder handling-rooms.

Plate II shows the method of stowing 12-inch and 14-inch shells. Note the magazine insulation.



CHAPTER XVIII. PLATE III.



5-INCH POW

Powder-tank stowage.—Powder-tanks are stowed in bins, usually on their sides. They should be stowed so that their contents can be removed without disturbing them. It is usual to arrange them, particularly those for the turret-guns, with their heads to the passage. The bins are built up from stationary vertical channels and rolling-boards, which are removed to get at the tanks. Bins are arranged in the different magazines with a view to accessibility in supplying powder to the hoist, and, where necessary, alleys are run between them. While the ship is rolling, projectiles, powder-tanks, and charges are more secure if stowed parallel with the keel, but the tanks and charges should be perpendicular to the passages. It has been found that when the tanks are stowed on end, the powder settles and stretches its bags; this has been so troublesome that the charge could be gotten into the gun only with great difficulty.

The new interlocking powder-tanks will not only save room by allowing the tanks to be stowed closer together, but will also be more accessible and save some weight.

Plate III shows the latest method of stowing 5-inch powder-tanks. Note the magazine insulation.

The ammunition-rooms of small ships are simply arranged in two groups in the hold, forward and aft. The regular type of hoists are used to convey ammunition to the main battery, while whips are generally used to hoist the boxes of secondary-battery ammunition through the hatches.

Ammunition Supply.

For the efficient use of a ship's battery in action, the supply of ammunition is next in importance to the correct use of the guns. The excellence of the gun-pointers and crews will avail nothing unless they can receive the ammunition in exactly the proper way.

Save for a few projectiles, it is unsafe to stow any ammunition near the guns; in fact, it is imperative to stow it *below* the water-line in certain places, which may be a long distance from some of the guns. The problem, then, which varies in its intricacy in each class of ships, is to maintain a supply of ammunition to each gun—firing several rounds per minute—as fast as it is needed, without allowing it to accumulate on deck, as, for instance, when the gun to which a particular chain of supply leads is silenced. All prac-

licable precautions against powder-explosions from the enemy's fire must be enforced.

Obviously, the simplest and surest solution of the problem is to install a magazine and shell-room directly beneath each gun, with hoists leading upward to it. This would involve placing a line of magazines along each side of the ship, extending the whole length of the machinery-spaces, which cannot be done, because many rooms would be too near sources of heat, and the space is not available. These restrictions, which complicate the problem on board ship, do not affect the question of gun-installation on shore, where space and weight are unlimited.

This ideal arrangement of individual magazines and hoists is, in general, attained only for turret-guns, which, as it happens, are mounted over spaces available for magazines; the tendency, however, is to provide a hoist for each main-battery gun and a sufficient number for the smaller pieces. The hoists cannot lead very obliquely, and in some cases ammunition must be transported by hand over considerable distances, both below and on the battery decks; however, it is the best that can be done, and the difficulty exists in all navies.

Ammunition stowage and supply is a problem to which the designer devotes much thought; but when he has exhausted his ingenuity in the finished ship, the question of *efficient supply* is only partially solved, because the more important part is concerned with the *personnel* rather than with *matériel*. It remains for the "powder-division" (which contains many good men, and many not suitable for work at the guns) to manipulate the machinery of supply to the best advantage. The best thought of the officers in direct command is needed at this point, and complete success will come only when all the details have been minutely and patiently worked out. Care in stationing every man according to his fitness will often give good results from a manifestly imperfect system.

Ammunition-hoists for turret-guns were described in a previous chapter. Fig. 2 shows a 5-inch chain-hoist. The ammunition is brought from the magazines to the base of the hoist by an ammunition-conveyor. In some cases the chain-hoist is in the magazine.

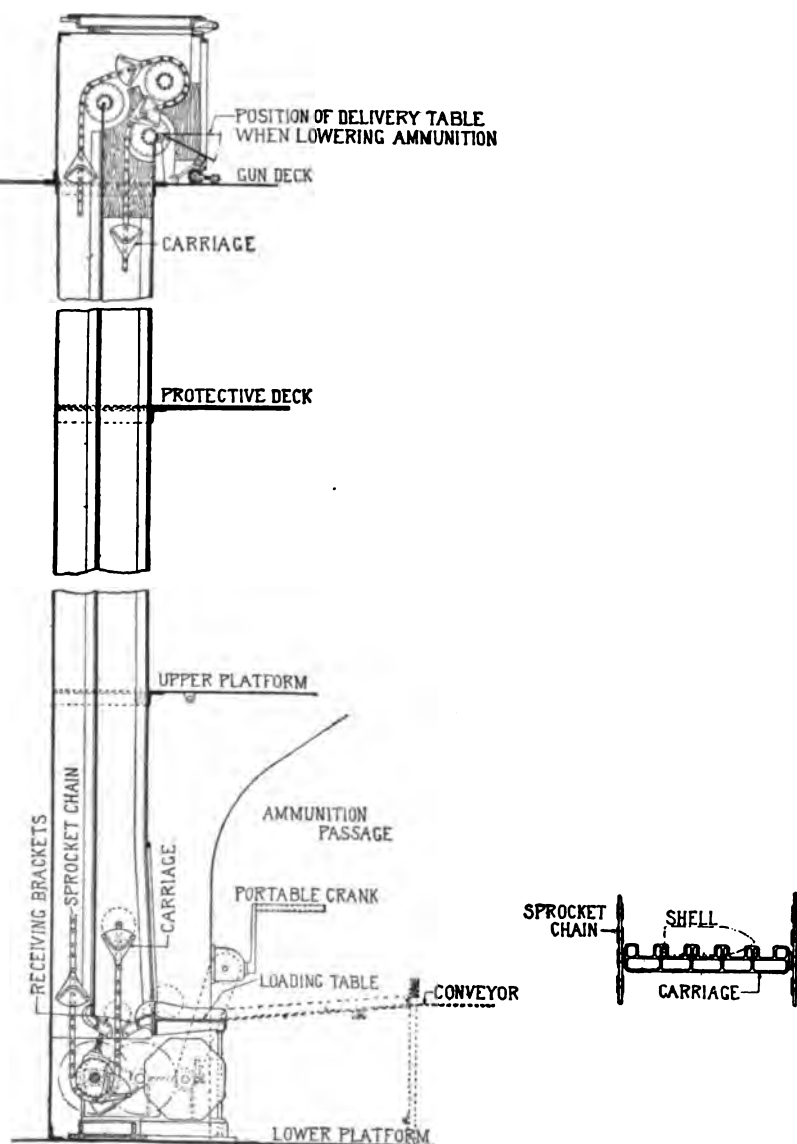
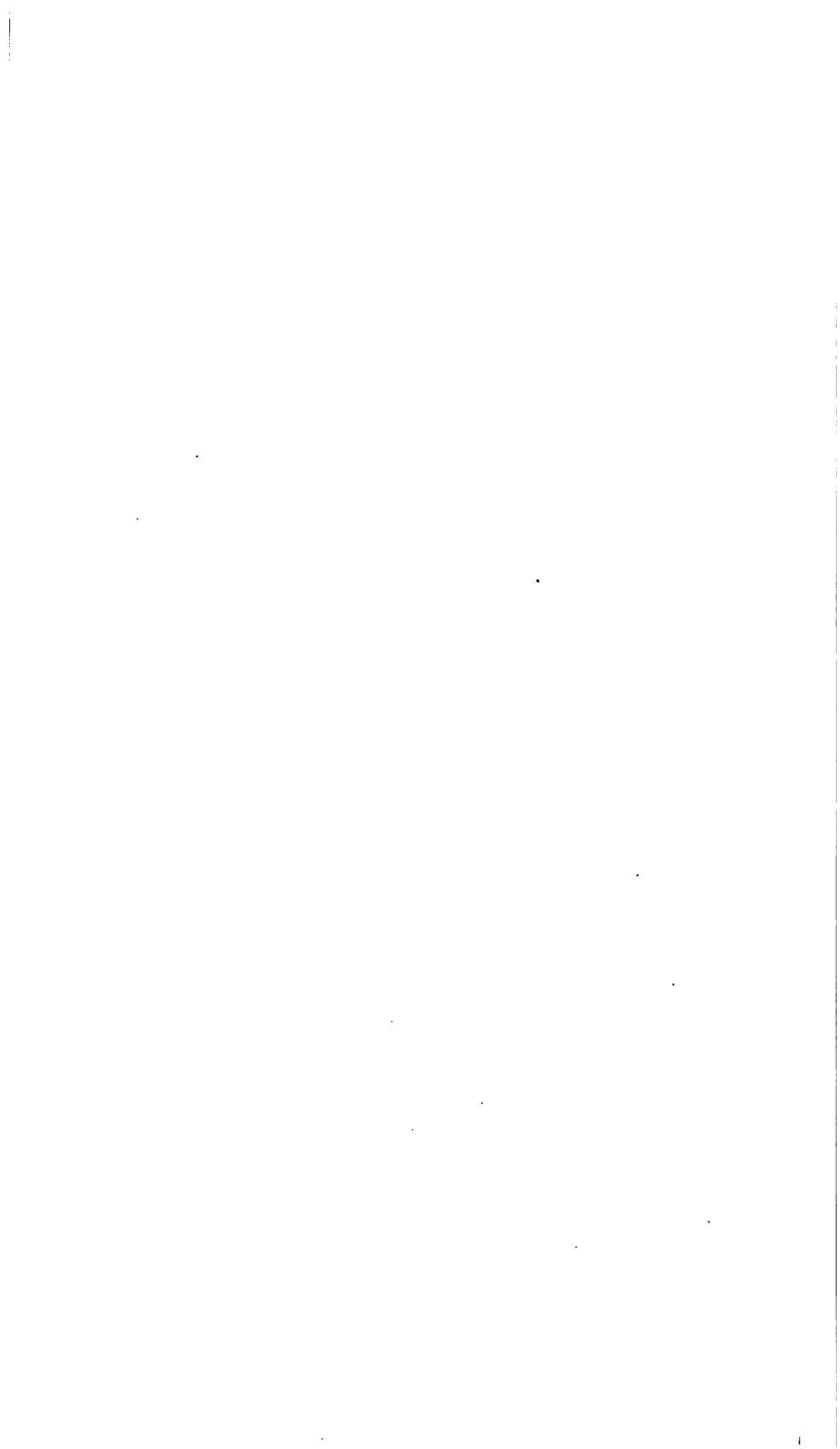


FIG. 2.—5-INCH CHAIN AMMUNITION-HOIST.



CHAPTER XIX.

ARMOR.

Historical.

In so far as it is of record, John Stevens, of Hoboken, New Jersey, was the first to propose the use of armor for the protection of vessels of war. In 1812, he designed a vessel whose battery was protected by inclined armor. This plan, however, like nearly all innovations, was not seriously considered. The Stevens family then began a series of investigations and experiments with armor that extended over many years, and in 1842, Robert L. Stevens submitted a report to a committee of Congress containing the results of these experiments, being deductions concerning the laws of the resistance of armor and the penetration of projectiles. These results were of great value to naval architects, and the principles therein set forth are to this day, many of them, applied in naval construction.

In 1854, Congress appropriated money for an ironclad on the Stevens design, and construction was begun, but the vessel was never finished. The development of the gun, however, in energy, range, and accuracy, and the introduction of explosive shell, rendered the use of armor imperative; and thus we see the construction in 1855, immediately after the laying of the keel of the *Stevens Battery*, first by France and then by England, of armored batteries and ironclad vessels. This marks the adoption, generally, of wrought-iron armor. The United States quickly followed, and produced on the one hand, by the Confederates, the so-called ironclad, such as the *Merrimac*, and on the other the novel type of turret vessel, the *Monitor*.

Further improvements in ordnance, especially the adoption of the rifled gun, made it apparent that wrought-iron armor applied to vessels of war was of little avail against improved projectiles fired from rifled guns, so that strenuous efforts were made to increase the resisting power of armor, with the result that com-

pound armor was developed in England, and *all-steel armor*, in France, early in the eighties. The efficiency of these two types was about equal. The former had greater resisting power, but the tendency of the steel face to flake off over considerable areas made it unsatisfactory. However, the two about held their own until 1889, when the introduction of nickel into steel materially increased its toughness and power of resistance, so that homogeneous nickel-steel plates showed marked superiority over the compound type. Almost immediately thereafter, in 1890, the *Harvey process* was developed in the United States. The success of this process marked the greatest advance in the history of armor, and it was soon adopted by all the naval powers. The *Krupp process*, which followed in 1895, effected an improvement over the Harvey, though the principle remained the same.

Experiments.—During all this time, numerous experiments were made in the effort to produce novel types that would effect a saving in weight and cost of armor. Target structures of almost every conceivable description were made and subjected to ballistic test. There were homogeneous cast-iron and wrought-iron plates, and built-up targets of every description, including sheets of metal bolted together and presented flat or edgewise, alternating layers of metal and wood, of metal and rubber disposed in various ways, and of springs behind solid plates and between the laminations of built-up plates. The targets were fired at vertically, and inclined at various angles.

These experiments demonstrated the following general principles:

(1) That, to be efficient, armor must be homogeneous as to mass, so as to concentrate the resistance.

(2) That armor should be rigidly attached to the structure, and that devices such as springs or rubber cushions do not add to its resisting qualities, but are in reality a source of weakness.

(3) That inclined armor, designed to deflect the projectile upon impact, is, for purposes of protection, about equal to vertical armor of equal weight, when the angle of inclination is greater than the biting angle of the projectile; but when the angle of inclination is not greater than the biting angle, vertical armor of equal weight is more efficient. *The introduction of the cap has not altered this principle.*

Resistance of Face-Hardened Armor.

Modern hard-faced supercarbonized armor is the logical development of the principles of compound armor. With the advent of the armor-piercing projectile, it was recognized that to be defeated the projectile must be made to expend its energy upon itself. In other words, the resistance must be so concentrated as to greatly reduce the velocity of the projectile in a short space. The ideal armor-plate, therefore, would be composed of metal homogeneously hardened so as to make it as hard as, if not harder than, the projectile itself, and at the same time so tough as not to be shattered upon impact of the projectile.

Compound armor.—But this was then, as it is now, metallurgically impossible of attainment, in the state of the art. The nearest approach to this principle was found in *compound armor*, which consisted essentially of a high-carbon steel face and a wrought-iron back, the idea being for the hard-steel face to break up the projectile, and the tough back to hold the plate together. It was manufactured by casting the steel upon wrought iron, the latter being heated and otherwise prepared to make as intimate a union as possible. This was a distinct advance upon the homogeneous wrought-iron armor, and compound armor was immediately adopted by nearly all the leading powers. The limitations of manufacture, however, made it practically impossible to obtain an intimate union between the two metals and so prevent flaking off of the steel plates, and caused the compound type to be superseded by homogeneous steel and homogeneous nickel-steel plates in the latter part of the eighties. Advance in the art of manufacture of steel enabled the manufacturers to produce steel of what was then considered a very superior quality.

Harvey armor.—The application by Mr. Harvey of the well-known process of *cementation* to homogeneous steel plates quickly followed, and the result was the perfection of the compound-armor principle, producing *an integral plate supercarbonized to a considerable depth, giving an extremely hard, elastic face, bound together and supported by a tough back, having a minimum tendency to crack.*

The theory of resistance is as follows: When the point of the projectile strikes the face of the plate, the hard inextensible sur-

face does not immediately give way, but there occurs an elastic or diaphragmatic dishing, in diameter equal to about three times the caliber of the projectile. The stress of impact is thus distributed over a considerable area, and the concentrated resistance works to suddenly stop the projectile and cause it to break up through its own inertia.

Krupp armor.—Krupp armor has exactly the same ballistic characteristics as that produced by the Harvey process. Its superiority is due to its composition, which makes it susceptible to treatment that improves the ballistic qualities. For example, Krupp armor has a greater affinity for carbon than the manganese nickel steel used in the Harvey process, so that although the cementation may be accomplished in exactly the same way, carbon will be absorbed to a greater depth in Krupp plates than in Harvey plates, giving a greater depth of hard face in the former and thus increasing its resisting powers accordingly. Another point of superiority in Krupp plates is a less tendency to crack.

In both the Krupp and Harvey processes it is impossible either to regulate the depth to which carbon is introduced or to increase that depth beyond a certain point. The reason of this is that the carbon is absorbed decrementally—that is, it begins to shade away from the surface, the carbon in each successive layer being absorbed from that immediately preceding it, and being less in proportion, so that, the limit in the surface layer being fixed to retain the characteristics of steel, the depth to which carbon is introduced is determined by that limit.

Future development of armor.—It is, of course, impossible to predict with any certainty the course of development of armor. It is probable, however, that it will be along the lines of improvement in the quality of steel and methods of manufacture, following the face-hardened principle, rather than any radical change in type of mechanical construction. Recent improvements in the quality of projectiles, assisted by the cap, are such that the hard face of armor, as now manufactured, is not equal to the task of stopping the projectile: so that improvement in the quality of the metal of the hard face, as well as greater depth, would seem to be demanded.

Arrangement and Distribution of Armor.

The prime function of armor.—Armor serves two purposes: first, *protection for the personnel*, which involves that of the gun-positions and armament; and, second, *protection for the flotability and interior mechanism of the vessel*. The latter includes protection of the hull and machinery.

This protection is afforded to as great an extent as possible by the armor-belt, extending the whole length of the ship, the side-armor and casemate-armor, the protective deck, turrets, barbettes, gun-shields, and armored conning-towers. A certain amount of protection is afforded also by coffer-dams filled with cellulose, and by coal-bunkers.

The arrangement and distribution of armor on ships of various classes is described in works on naval construction, to which the reader is referred for details.

MANUFACTURE OF ARMOR.

The manufacture of modern face-hardened armor comprises a series of operations which require the greatest care and attention to details to produce the best results, and these operations are so elaborate that a period of nine months is allowed in the manufacture of service armor from the time of the receipt of the original drawings until the completion and delivery of the plates.

Requisite Qualities.

The qualities sought in armor are: (1) Resistance to penetration, (2) minimum tendency to cracking.

To be efficient, armor must be homogeneous as to mass, so as to concentrate resistance, and must be securely attached to the structure. Its efficiency is determined by its resisting quality when subjected to ballistic tests.

The penetration of face-hardened armor, as shown in the range tables, is based upon the De Marre formula for homogeneous nickel steel, giving it a certain *figure of merit* based thereon. Thus, Class A armor is always referred to as having a certain figure of merit, based upon the penetration of homogeneous nickel steel. This figure of merit is about 1.5; i. e., 6 inches of face-hardened

armor is equivalent to 9 inches of homogeneous nickel steel. "*Penetration*," as shown in the range table, means the thickness of armor which the point of the shell will just penetrate at normal impact.

Classes of Armor.

The armor used on ships of the U. S. Navy is face-hardened, excepting the thin plates for turret and conning-tower tops, which are of special-treatment steel. Face-hardened armor is designated as *Class A*, and the special-treatment steel plates as *Class B*.

Class A armor may be *cemented* or *non-cemented*. In both cases the steel ingot is made by the open-hearth process.

The composition is predetermined, being low-carbon steel, containing inseparable ingredients of phosphorus and sulphur, the percentage of which it is endeavored to keep at a minimum, and nickel, chrome, silicon, and manganese. (Other alloys, such as those of molybdenum and vanadium, have been tried, but without any absolutely satisfactory results.) For non-cemented armor the carbon content is somewhat greater than for cemented armor.

Cemented armor.—The initial carbon is low. The plate is supercarbonized to a considerable depth, giving an especially hard, elastic face, bound together and supported by a tough back, having a minimum tendency to crack. The cementation depends upon the fact that iron or steel heated in contact with carbon absorbs that element. The carbon is absorbed decrementally, the limit of absorption being about $1\frac{1}{2}$ inches from the face. This armor has stood the test of years, being practically universally used.

Non-cemented armor.—In this armor the initial carbon is somewhat higher, and the composition of the finished armor is homogeneous. It also has a greater depth of chill. It is more homogeneous, as in this case the structure of the metal does not have to be restored, as it does after cementation. It has its hard face water-hardened and back-fibred in the same general manner as obtains in cemented armor.

Special-treatment steel.—Class B armor, for turret and conning-tower tops, is made of *special-treatment steel*. This is an alloyed steel made by the basic open-hearth process. These plates are from 1 to 5 inches in thickness, and plates of similar material are used for protective-deck plating. The great efficiency

of these plates is due to the presence of vanadium alloy, in addition to nickel and chrome. This content of vanadium, coupled with a new method of heat treatment, produces a fibrous structure within a certain physical range. The surface is not as hard as in Class A armor, but is extraordinarily tough and shows remarkable results when subjected to oblique impact, withstanding striking-energies that easily shatter plates of similar thickness manufactured by other methods.

Plates of this material are subject to ballistic tests of acceptance at certain prescribed angles of impact, which are given in the specifications; and on such tests the plate must not be pierced nor develop "through" cracks. These tests are based on the probable maximum angle of attack, which includes the angle of fall at an assumed battle range, the probable extreme roll at which engagement would take place, due to the state of the sea, and the fixed angle of inclination of turret tops.

Special-treatment steel is more satisfactory for turret tops than face-hardened armor, as it can be machined and therefore secured to top of turret without annealing, as would be necessary with face-hardened armor; furthermore, the energy of impact is localized and there is less danger of carrying away the securing-bolts and taps.

Manufacture of Cemented Armor-Plates.

All cemented armor-plate is manufactured by what is known as the *Krupp cemented process*.

Outline schedule.—Steel: (1) This is of nickel-chrome steel produced by the *Seimens-Martin process*.

Ingot: (1) Cast in sand or metal mold.

(2) Allowed to cool.

(3) Heated to forging heat, forged and scaled at same time.

(4) Upper end discarded.

Plate: (1) Treated, heat treatment.

(2) Scaled, cleaned, charged in furnace for carbonizing.

(3) Carbonized.

(4) Cooled and cleaned by scaling.

(5) Heated to re forging heat, 1,020° C., and re forged.

(6) Treated.

(7) Specimens cut out for chemical analysis and to determine treatment.

(8) Specimens cut out for tests for elastic limit, ultimate strength, elongation, and contraction of area for record.

(9) Straightened or formed.

(10) Rough-machined. Coupons are left on each end of Krupp plates, for determining chill, etc.

(11) Formed or curved in accordance with official drawings.

(12) Heated to tempering heat, tempered, and hardened.

(13) Rectified. Coupons broken off, if any.

(14) Finish-machining and grinding according to official drawings.

(15) Erected on surface plate. Length, width, curvature, and bolt-holes verified.

Structure: (1) Erected as on ship's side, according to assembled drawings. Inspected for length, width, curvature, and joints.

(2) Individual plates weighed and compared with estimated weights, and stamped for shipment.

Detail schedule.—Steel: (1) The metal is nickel-chrome steel, produced by the Seimens-Martin process, which consists in general of a reverberatory gas-fired furnace having a dolomite bottom, with construction such as is in general use for structural steel and is popularly called the "open-hearth" process.

(2) A sample charge for an average ingot would consist of about

49,000 pounds of pig iron, melted or cold.

54,460 pounds of steel scrap.

32,600 pounds of nickel scrap.

4,300 pounds of metallic nickel.

100 pounds of ferro-manganese.

800 pounds of A. M. S. metal, compound of Al, Mn, and Si, remainder Fe.

4,260 pounds of chrome.

45 pounds of coal.

1,800 pounds of cinder.

200 pounds of calcium.

2,800 pounds of limestone.

This produces about 135,000 pounds of basic steel, with 3800 pounds of pit scrap, with a loss of 6550 pounds. The cinder is

not always used, but ore is generally a part of the charge. The pig is generally supplied in molten condition, although it can be, and is at times, charged cold. The hot metal makes a saving of about two hours, or a little more, in the time of heating the charge. The other parts of the mixture are charged from time to time as the heat progresses.

Schedule for Harvey plates.—For Harvey plates, plain nickel steel is used, having about 3.25 per cent nickel, and other elements, such as carbon, .17 per cent; phosphorus, .02 per cent; manganese, .58 per cent; sulphur, .024 per cent; silicon, .03 per cent.

Samples for a ladle chemical analysis are taken before pouring. These are analyzed by the "rapid" or volumetric method.

Ingot: (1) If a sand mold is used, the metal is tapped from the furnace and usually allowed to flow into a ladle, then into a metal sand-lined mold with a bottom (cast), the main part of the ingot being at the bottom and a sink-head at the top.

For a large ingot, this mold is made in sections and joined by clamps. These sections are of cast iron, and are arranged to have sand lining attached where assembled. The ingot is to be so proportioned that its weight shall not be less than double the finished plate for which it is intended, and it is generally more in practice.

(2) Allowed to cool. This requires about 48 hours before it can be handled, depending upon the size of the ingot; but it is generally 1000° C. before the mold is stripped. It is then taken to the press-shop.

(3) Surface cleaned by scaling, the surface defects being removed. These consist, generally, of small projections and test coupons for analysis, if required. The scaling is done by hand labor.

(4) Heated to forging heat, which requires from 30 to 75 hours, the time depending upon the size of the ingot. The temperature is about 1100° C. It is then forged under a hydraulic press. This press must be of sufficient size to take in a plate of maximum dimensions, and should be of 10,000 to 12,000 tons capacity. The furnace for this forging heat is gas-fired, and is placed near the press, so that little loss of time and heat occurs while handling the ingot. Temperatures are taken by water pyrometer or millivolt meter. An ingot for a 6-inch plate is about 18 inches thick and is forged to 6½ inches the first forging, while the ingot for a

10-inch plate is 38 inches thick and is forged to $11\frac{1}{2}$ inches the first forging.

(5) The upper end or sink-head is now discarded, or cut off, since it consists of the poorer metal. Thirty per cent by weight must be discarded from the upper end to insure against including any part of the segregated portion of the ingot in the finished plate. The ratio between the cross-section of the ingot and that of the finished plate must not be less than 2, and is generally more in practice.

Plate: (1) The forged plate is now heat-treated, the length of time depending upon the size of the plate and the treatment required. The temperature is from 1000° C. to 1025° C.

(2) Cleaned by scaling.

(3) Charged in furnace for carbonizing. There are two processes in use: (a) By gas, (b) by direct application of carbon.

(a) In the first process, two or more plates may be carbonized at the same time. The surfaces to be treated face each other. An air-tight compartment is built up with the plates as top and bottom. gas is admitted, and the face surfaces of the plates are brought up to the required percentage by carbon deposited and absorbed when the plates are at the proper temperature. There are several ports in the compartment for the admission of the gas, also one exhaust-port.

(b) In the second process, the carbon is placed directly to the faces of the plates at the proper temperature. For large plates, a bed is made up as follows: Bottom layer of sand, middle layer of old carbon, and top layer of new carbon. The plate is laid on this bed, care being taken to see that the carbon is in contact with the plate at all points. The sides of the compartment are bricked up, and the soft back is covered with sand. The furnace is then brought up to proper heat. The temperature of the furnace is maintained until the proper percentage has been absorbed.

When two plates are to be carbonized by this method at the same time, a layer of carbon is placed between them, and a compartment is formed as in the first instance; the whole is then charged in a furnace, which is brought up to proper temperature and then maintained as before.

The time of treatment varies with the thickness of the plate, the depth of carbonization, etc. For example, take a 10-inch plate.

If charging has begun at 10 a. m., then firing would begin at 4.30 p. m. the same day, or 6 hours and 30 minutes later. The furnace would be up to heat at 5 p. m., 11 days later, or in about 264 or 265 hours. This heat would continue for 216 hours, making a total time of firing of about 480 hours. The furnace temperature, up to heat, is about 1040° C. The plates are then allowed to cool, and in about three days the furnace is broken open; then, in about 12 hours the opening is made larger, and in about 12 hours more the table or car can be run out and the plates can be stripped. The total time of charge will be about 630 hours. The plates are allowed to cool and are cleaned by scaling, and drillings are taken of the top and bottom of the plate for determining the carbonization at different depths; first, at $\frac{1}{16}$ inch, which should be about 1 to 1.30 per cent; second, at $\frac{1}{2}$ inch, which should be .75 to 1.10 per cent; third, at 1 inch, which is about normal and up to .60 per cent.

(4) Heating to reforging heat, which is about 980° C. In heating this plate it is necessary to cover the top of the plate and the carbonized surface with a layer of old carbon about 1 inch to $1\frac{1}{2}$ inches thick. This prevents the heat from taking all the carbon out of the plate.

(5) Plate now reforged, which brings it down to the proper thickness. For example, the ingot thickness for a 6-inch plate is about 18 inches. The first forging reduces it to $6\frac{3}{4}$ inches. It is now reforged to $6\frac{1}{2}$ inches, the extra $\frac{1}{4}$ inch being allowed for scaling. For a 10-inch plate the ingot thickness is about 38 inches. The first forging reduces it to $11\frac{1}{2}$ inches. It is now reforged to $10\frac{3}{8}$ inches, the extra $\frac{3}{8}$ inch being allowed for scaling. Test specimens are now cut or drilled from the plate and pulled to determine what treatment is required to place the steel in the best condition. Chemical analysis is now made, if not made before.

(6) Hardening treatment at 875° C. Two annealing treatments at 700° C.; the time of heating, 7 hours for a 10-inch plate.

(7) Test specimens are again cut or drilled from the plate and pulled for record, and as to the ballistic qualities of the plate. A good Krupp plate should give approximately the following: Elastic limit 60,000 to 70,000 pounds to the square inch; tensile strength 100,000 to 130,000 pounds per square inch; elongation 15 per cent to 25 per cent; contraction of area, 35 per cent to 50 per cent.

(8) Heated to proper temperature, about the same or a little less than second-heat treatment, and straightened under hydraulic press.

(9) Allowed to cool, and placed on machine and rough machined to dimensions, due allowance being made for shrinkage or expansion of plates in subsequent treatments. The plates have coupons left on top and bottom for determining the chill, crystallization, and fiber after water-hardening. The machines in general use for this work are saws, planers, and milling-machines.

(10) Heated to proper temperature, about 700°C ., and formed to template.

(11) Charged in tempering-furnace, heated to proper temperature, which, for a 10-inch plate, would be for the top 895°C and for the bottom 510°C . The time required for heating is about 25 minutes per inch of thickness, for a cemented plate. The plates are bedded in sand, so as to keep the bottom of the plate from becoming too hot, and from getting too hard.

(12) Plates withdrawn and tempered or hardened by the application of water to the carbonized or top surface for about 2 hours and 30 minutes. The water is turned on the bottom surface for about 15 or 20 minutes; this prevents warping of the plate in the wrong direction, as the soft side can be stretched, but the hard side cannot be when the plate is rectified; therefore the top, or hardened surface, should be convex.

(13) Heated to proper temperature, which is about 100°C ., and the curvature rectified. Coupons on plates are now broken off to show the chill, etc. This is generally about $1\frac{1}{2}$ inches deep, but ranges from 1 inch to 2 inches deep from the top surface. The coarser crystallization is generally next, and ranges from zero to 1 inch. The back is fibrous and composes the balance of the plate. Records are kept of these fractures, as they are very important in determining the qualities of the plates. Most plates have a light skin with a hard surface directly under it. In some cases soft strips are left on portions of the plate to facilitate drilling the holes for attachment to the ship. This is done by protecting the carbonized surface in the furnace, and when the water is turned on the plate, by means of asbestos strips. These prevent the plate from becoming too hot, and also prevent the water from chilling the surface under them.

(14) Finish-machining in accordance with official drawings. The plate now being hard on the face, but having a soft back, only a part of the edge can be cut by machines such as planers, millers, etc.; and the hard part must, therefore, be ground off with suitable emery wheels and, as usual, finished to dimensions by small hand emery wheels. Bolt-holes are now drilled and tapped in the back of the plate for securing to the ship's side and for lifting. Bolt-holes are drilled and tapped in the upper edge to facilitate handling in the shop and when assembling on the ship.

(15) Placed on surface plate; bolt-holes checked; length, width, and curvature taken to see that the plate is in accordance with drawings and specifications. The present specifications require that plates shall not exceed plus or minus $\frac{1}{2}$ inch in length, plus or minus $\frac{1}{8}$ inch in width, and, for thickness, plus or minus $\frac{1}{8}$ inch. The tolerance must be such as not to exceed a variation of $\frac{3}{4}$ inch plus or minus for every 10 feet of length or width of the plate, and $\frac{1}{2}$ inch every 36 inches in length or breadth, or part thereof. In every case, however, a variation of length or width must be corrected by variation in other plates, so as to insure a full bearing of all butts and joints.

Structure: (1) After individual plates have been inspected, all are erected as they are to be on the ship. This structure is inspected for length, width, and joints, and checked up with official drawings.

(2) Structure disassembled and individual plates calipered, weighed, compared with the estimated weights, and, if within tolerance, shipped.

(3) Sketches of the plates showing dimensions, curvature, and variations, with any surface cracks, checks, or pits that there may be, are to be made of each plate; also a sketch of the assembled plates with dimensions, etc., as required.

Ballistic test.—For the purpose of testing and payment, plates are divided into groups of about 500 tons each, one plate from each group being tested ballistically at the proving-ground at Indian Head. Ballistic plates are recommended and selected by the inspector, subject to the approval of the Bureau of Ordnance. The chemical analysis of each plate, together with the coupon fractures and depth of carbonization, which are considered with the surface of each plate, go to determine which plate shall be

selected as a ballistic. These data are obtained, and are on file for this selection. The plate whose record is the poorest, all things considered, is selected. If this passes the test, the chances are that the plates with better records would pass also.

The ballistic test is the chief one, and the object of all other tests is to insure, as far as possible, that the remaining plates of the group are capable of standing as severe a test as the test-plate has been subjected to; and the uniformity of plates of the group will be only such as may be necessary for this purpose. Three rounds are fired at each ballistic plate. The points of proposed impact must not be closer to the edges of the plate or previous impact than $3\frac{1}{2}$ calibers of the gun used in the test.

Tests for acceptance are made as strict as practicable in accordance with the table contained in the specifications based on the De Marre formula for homogeneous nickel steel, which is as follows:

$$V = (3.00945) \frac{d^{0.75} e^{0.7}}{p^{0.5}}$$

V = the striking-velocity in foot-seconds.

d = the caliber of the gun in inches.

e = the thickness of the plate in inches.

p = the weight of the projectile in pounds.

To the velocity thus found is added a certain per cent for guns and plates of various calibers and thickness, the final striking-velocity used being determined from actual practical results.

If a group represented by the successful plate has shown a close uniformity in quality and treatment, it is accepted as far as the ballistic test is concerned. The success of test-plates defines the status of the group in a ballistic sense, but does not secure the individual plates from rejection on account of dimensions, cracks, etc., which seriously impair their resistance.

Spalling.—Spalling of an armor-plate always is the result of stresses in the hardened face releasing themselves by rupture of the material. These stresses are originally introduced during the operation of face-hardening. Every armor-plate, without exception, contains these stresses after face-hardening. They chiefly manifest themselves by distortion of the form of the plate; but if the hardening be carried out to the extreme edge of the plate, there

is likely to be an actual throwing off of slivers of metal during the sudden cooling, due to inequalities in the rate of cooling, the extraction of heat at such edges being more rapid than farther in. The same thing occurs with a plate whose surface presents many cracks, which may arise from a variety of causes during the earlier steps of manufacture. The sharp edges of these cracks present lines along which such spalling may occur. It almost invariably occurs at the works of the manufacturer, and is rarely pernicious, being usually quite negligible.

When, as is usually the case, the distortion of the plate on final hardening causes it to exceed the tolerances in shape which render it acceptable for installation on shipboard, it is necessary to reshape it, which must be done hot if the distortions exceed fairly well recognized limits, but may be done cold if within these limits. Even if the plate be first reheated for rectification and then be rehardened, it almost invariably has to be brought cold to its final shape. For the purpose of such cold rectification of its shape, the armor-plate is laid face downward upon a die beneath a hydraulic press, and pressure is applied through a small block of metal, called a *pad*, interposed between the top die of the press and the face of the plate in order that the pressure may be applied at the exact spot desired. Such a spot, being a center of maximum pressure, is evidently a center of maximum distortion, and it is around such spots that spontaneous pernicious spalling occurs. On a belt or casemate-plate, whose general shape is flat, the pads can be placed on any part of the surface, and spalling, consequently, may occur anywhere.

Spontaneous pernicious spalling is usually of considerable size, generally measuring one or more feet along each axis when detached. Separation of the metal appears to occur first at the maximum depth, and to spread to the edges. Such a spall rings hollow even when there is no visible indication of its existence.

If the question be approached from the point of view of the annealing, a different condition of affairs is at once evident. Every piece of hardened steel has its surface in a state of stress; the mere fact of its hardness is the evidence of the existence of such stress, because when the stress is removed by annealing the hardness vanishes; conversely, when the hardness vanishes, stresses cease.

If it is desired by the shipbuilders, following the designs of the department, to produce on the hardened surface of armor-plate the soft zone for any width required to secure fittings, etc., it is necessary to blowpipe a greater width than that absolutely required to be soft. This blowpiping must be done very carefully and in accordance with a general order to all inspectors and shipbuilders. It should be done under the supervision of the inspector of ordnance at the shipbuilding plant, and in such a manner as to insure the extension of the softened area over the restricted area desired.

Unless great care is taken regarding the application of heat and to prevent the plate from being heated to too high a temperature the injurious effects will extend beyond the restricted area and may result in the hardened surface detaching itself and spalling off. It is therefore necessary to cool the plate off very slowly after the application of heat.

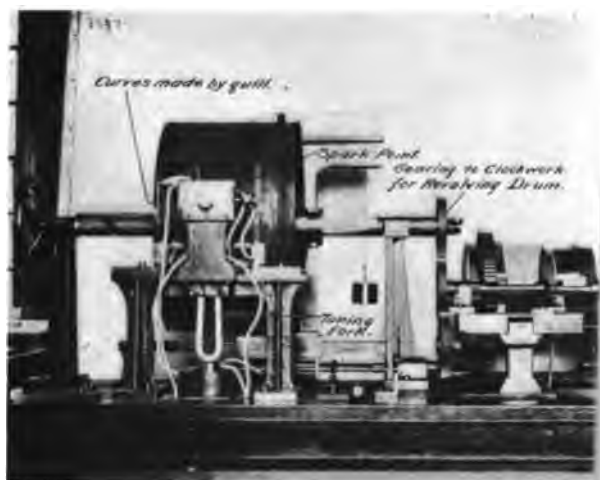
Spalling is more liable to occur on non-cemented armor than on that which has been cemented. Frequently plates of cemented armor, however, have spalling-cracks on the edges, due to the plates being hardened to the extreme edges, and this necessitates the grinding of the edge in final machining. These spalling-cracks will not develop, however, if a protection-strip of suitable size is used.

Armor-bolts.—The following table shows the size of bolt for each thickness of armor:

Size of bolt.	Thickness of armor.
1.5 inches.....	To and including 5 inches.
2.0 inches.....	From 5 inches to 9 inches.
2.4 inches.....	From 9 inches to 13 inches.

Armor-bolts are so spaced as to provide one bolt for every 5 square feet of surface, so far as the framing behind armor will permit, except in the case of 3-inch armor, for which one bolt is used for about 6 square feet of surface.

The bolts are made of nickel steel of such remarkable toughness that the plate will remain in place even if severely cracked.



CHRONOSCOPE.



INSTRUMENTS USED

CHAPTER XX.

THE PROVING-GROUND.

All guns, gun-carriages, ammunition, armor and new devices in naval ordnance are tested at the proving-ground before being accepted for the service.

The U. S. Naval Proving-Ground is situated at Indian Head, Md., and comprises a tract of land of nearly 1000 acres on the left bank of the Potomac River, about 25 miles below Washington. There is a clear range over the water $6\frac{1}{2}$ miles long.

Proof of guns.—After a gun is completed, it is sent to the proving-ground. With the exception of special cases, the gun is fired five times with pressures ranging up to one and one-quarter times the service pressure it is designed to withstand. The proof velocities must also be comparatively high, in order that the chase and muzzle may be tested for their ability to withstand high pressures. The fourth round is usually the proof-pressure round. In guns that prove at 20 tons, the first round is usually above 12 tons, and the pressure is run up gradually until proof pressure is reached. If there is any doubt about the proof round, an extra round is fired. Pressure and velocity curves for all types and calibers of guns are kept for ready reference. In weighing out charges to give the approximate pressure desired, these curves are referred to, and the weight of charge is obtained from them (referring to the web thickness and characteristics of the powder).

Before firing, the gun, including the breech-mechanism and firing-mechanism and mounts, is inspected. The temperature of the powder is noted, the weight of charge and of ignition-charge is carefully checked, and the shell and band are measured with micrometers.

At least three pressure-gauges are used for proof work. For pressures above nine tons, copper disks already submitted to a nine-ton pressure are used; and for pressures below nine tons, uncompressed disks are used. All abnormal readings are thrown out. In cases where great accuracy is desired, six or nine pressure-disks are used.

A pair of screens, 50 meters apart, the nearer one about 80 feet from the gun's muzzle, are adjusted so that the shell will pass through the wires of both screens. These screens are connected electrically to chronographs (to be described later), by means of which the velocity is obtained.

Points on the pressure and velocity curves, with the weight of charge as the abscissa, are plotted after each round. The critical point of the curve thus formed is watched for very carefully. In small-chambered guns these points exist at high density of loading, and at these points pressures will jump excessively.

After firing each round, a thorough inspection is made of the gun and mount for any defects that may have developed. The following points are noticed in particular: (1) Cracks in screw-box liner, (2) cracks in plug, (3) cracks at muzzle, (4) crawling of tube or liner at breech, and muzzle, (5) diameter of bore at muzzle, (6) recoil and counter-recoil, (7) blow-backs, (8) primer and (9) gas-check pad, and (10) any signs of failure of mount.

The velocity of recoil is taken by means of the chronoscope in special cases.

Various guns are given special proof, as follows:

(1) Six rounds constitute the proof of 14-inch 45 caliber guns. The fourth and fifth rounds are fired at proof pressure, and the sixth round at service pressure.

(2) Relined guns are proved in four rounds. The first round is fired at about 50 per cent of the service pressure. This is done in order to "set" the liner in place before putting a heavier pressure on it. The second round is fired at service pressure, the third round at proof pressure and the fourth round at service pressure.

(3) 1-pounders are proved with three light and two heavy rounds.

(4) 3-inch 50-caliber S. A. guns are proved with four rounds, and 10 rounds are fired for test of the S. A. mechanism.

After proving an ex-caliber gun, 50 rounds are fired to get its dispersion.

After proof, the gun is returned to the Naval Gun Factory at Washington, where it is stamped with the letter P, and the initials of the officer in charge of the proving-ground.

Every gun manufactured for the naval service is submitted to proof before being sent aboard ship.

For economy's sake, and also to reduce the range, solid cylindrical square-nose cast-iron shell, termed "*slugs*," are used both in proving guns and in proving powders.

Proof of gas-check pads.—New types of gas-check pads are proved by a running test extending over a year or so, until the proof-officer feels he can either recommend for acceptance or otherwise.

Proof of mounts.—Gun-mounts are generally proved at the same time the gun is being proved. In case the gun has been proved, the pressure is run up to within one ton of the proof pressure of the gun. The Tabor indicator and the velocimeter are used to obtain the recoil data.

Proof of powder.—An "*index*" of powder is, generally speaking, the largest lot of a single kind of powder that the capacity of the manufacturing plant is capable of blending. Blending-houses are usually large enough to mix 100,000 pounds, and this number therefore represents the maximum weight of one index. The weights of the indices of the various sizes of powder are given in the Bureau of Ordnance Specifications for the Manufacture of Powder.

After the manufacturer's lot is boxed and ready for shipment, a sample of prescribed weight is sent to the proving-ground for proof.

In proving a powder an attempt to develop a curve is made, starting at about 150 or 200 f. s. below service velocity and running up to about 100 f. s. above service velocity, unless it is seen that an excessive pressure will be obtained. Thus, by consulting the velocity-curve of a powder already fired, a sufficient charge is weighed out to give a velocity of 150 to 200 f. s. below service velocity on first round. Four rounds or more are usually fired. Service velocity is tried for on the second and fourth rounds.

A powder is chosen (if possible, from the same factory, with a web near the size of the one to be fired) that has already been fired, and pressure- and velocity-curves of this powder are used as a guide. Having fired one shot from the powder for proof, the remainder of the curve will be parallel to that of the guide powder,

if they are of the same web, by the same factory, and proved from the same gun.

All shell are brought carefully to weight.

The powder is always fired at a uniform temperature of 90° F. (32° C.) and made up exactly as it is issued to the service.

During the firing of the proof powders, a sample is taken out and sent to the laboratory for analysis, in order to ascertain whether the stability, percentage of nitrogen, residual volatiles and solubility are in accordance with the specifications.

Powder for current use is blended from time to time and stored in the proving-ground magazines.

Guns of all calibers and known indices of powder are kept on the station at all times for use in the proof work.

After fixing the charge, a report of the ballistic and chemical qualities is forwarded to the Bureau of Ordnance, upon which the powder is either accepted or rejected. If accepted, an index number is assigned, the charge and manufacturer's lot number are stenciled on the boxes, and the index is shipped to a magazine.

Proof of shell.—Three kinds of shell are at present purchased for the navy: *Armor-piercing shell*, *common shell*, and *target-shell*.

Armor-piercing shell, which include the 6-inch and all calibers above, are capped. Proof of shell is made in accordance with specifications under which the contract was let. The contractor is always present at the test. The inspector selects four shells from every lot manufactured, banded and capped, and these are shipped to the proving-ground. One of these shells is fired with a striking-velocity (fixed by the Bureau of Ordnance) against a face-hardened plate, similar to the service armor-plate used for protection of ships, which is set up at a distance of about 100 yards from the gun. This plate, the thickness of which is given in the Bureau of Ordnance Specifications, is set up in the same manner as described under "Proof of Armor." A chalk mark is put on the plate, and the gun is bore-sighted on the mark. A pocket or large horizontal steel tube is laid in front of the plate, in order to catch all fragments.

Formerly, to insure getting correct velocities at the shell test, one shot was fired over range previous to firing the proof shell, in order to fix the charge. This is no longer done, except in cases

where the action of the powder is unknown. There are on hand sufficient curves of powders in current use, from which to pick the charge for any given velocity. A margin of safety is always allowed on the contractor's side.

A pasteboard screen is placed in the line of fire in front of the plate, in order to ascertain if the shell flights correctly, *i. e.*, with its axis tangent to the line of fire.

After the impact, the thickness of the point of impact is checked, and the dimensions and position of the impact are noted. A search is made, to see if any shell fragments are in front of the plate; and if so, these fragments are weighed.

The shell is afterwards recovered, inspected and photographed; and in case of doubt as to the effective condition of the shell, it is given the water test (hydrant pressure) to discover leaks.

Four armor-piercing shells are also selected from the first lot of each contract. One of these is given the fragmentation test and three are ranged.

Common shell include all calibers below the 6-inch, and they are now fired at face-hardened plates of a thickness equal to about half the caliber of the shell. The projectile must pass through the plate unbroken and be recovered in a condition for effective bursting.

Common shell are also fragmented, and fired down the range according to the specifications. One shell is loaded with fine black powder, fused and exploded in an *explosion-chamber*. To be satisfactory, all parts must break up well. The three shells fired down the range must not break up, upset, or strip their bands, and the dispersion must not be greater than that given by standard shell.

Target-shell are fired for flight only. These shell, 3-inch and above, are identical in design with armor-piercing shell, but are of cast iron and are used as a matter of economy in the place of armor-piercing shell. Two target-shells are fired down the range at service velocity, and must give smooth flight and not strip their bands nor show erratic dispersion.

Ranging-shell.—Unless work is urgent, projectiles are not flighted until several of one caliber are on hand. Then they are flighted in the highest-powered gun available, along with one

target-projectile of an accepted lot. This target-shell must be of standard characteristics, and is used as a standard of comparison.

All conditions must be as uniform as possible when getting ranging and flight data. The powder charge is carefully ascertained a short time before the ranging is to be conducted, in order to eliminate any changes in velocity that may have occurred since the last proof of the powder. The same weight of charge is used. The position of the center of gravity of the shell is taken of all shell for flight.

The line of fire is established with a theodolite, and the gun is trained and set at the 8° elevation, using a Vickers clinometer. Observers with theodolites are stationed at three points down the range, to get the horizontal angles of the fall of shot. They are so stationed that a good "cut" can be obtained in plotting. These observations are plotted on a large plotting-board, and the exact position of the splash is thus obtained.

In case of three-gun salvos, triangulation cameras are used instead of the theodolites. These cameras are similar to the ones used aboard ship for plotting the fall of shot on target-practice. By having long, steady base-lines and three different cuts, the fall of shot can be accurately plotted.

From the data obtained in ranging a shell, its coefficient of form is computed, from which the range table is worked out. Thus the range table is obtained from actual firings, and not theoretically.

Proof of cartridge-cases.—One hundred cartridge-cases constitute a lot. One case out of every lot for guns above 3-inch 50 caliber is fired six times at service pressure for proof. One case from each lot of 3-inch 50-caliber cases and below is fired once. These cases must stand proof pressure without becoming unserviceable or developing any cracks.

All cases are tried in the gun before loading and priming, and no force except by hand is used in loading cases.

Proof of primers.—All primers are now manufactured by the Washington Navy Yard and Trepco Station, and are proved under instructions issued from time to time by the Bureau of Ordnance.

Chronoscope times are taken to check some new design of primer, or when the test is especially ordered.

Primers are tested during current work at as high a pressure as practicable. Five B. L. R. primers are selected from each lot of 1000. In the proof of B. L. R. combination-primers, three are fired by electricity and two by percussion. With extension-magazine primers, two are fired by electricity and three by percussion. One primer of each lot is fired at a chamber pressure of at least 15 tons.

In case of failure, the primers are returned with the report to the Bureau of Ordnance. This report includes the approximate pressures, caliber of gun fired in, functioning of primers, and any damage to the primer or stocks, such as cracks, breaks, or other defects.

Proof of fuses.—Fuses are tested according to the specifications under which the contract was made.

Detonating-fuses and other experimental fuses are tested in accordance with instructions received from the Bureau of Ordnance. All detonating-fuses with high-explosive shell are fired into a covered butt.

Minor-caliber tracer-fuses are given five tests: (1) One must withstand a drop of 30 feet when inserted into a blind shell, without arming the fuse or igniting the tracer element. (2) Two are fired at a $\frac{1}{8}$ -inch plate with a striking-velocity not greater than service and not less than 1000 f. s., and the fuses must act in both cases. (3) One is fired in a loaded shell. This must fragment the shell but not blow out of projectile. (4) One is fired in a common projectile, and must not burst in flight in air. (5) Three are fired at night. Two of these three tracers must function so as to be followed not less than 12 seconds.

Major-caliber tracer-fuses are also given five tests: (1) Two fuses are given the drop test of 40 feet. (2) One fuse is given the safety test. (3) One fuse is fitted in a projectile loaded with "D," and is exploded for fragmentation. (4) Three fuses are fired against any plate ranging from $\frac{1}{8}$ inch to one caliber in thickness, and must explode in all cases. (5) One fuse is fired down the range. The fuse must not act in flight in this case. As a safety precaution, to prevent damage to the property near by, all but three threads are cut from the plug, and the booster-charge is replaced with black powder. If the fuse should act, the fuse would be blown out and the shell would not be fragmented.

Proof of armor.—Armor is proved ballistically under specifications published yearly.

The remarks regarding the fixing of velocity for shell tests apply also to the proof of armor. The velocity of impact and the caliber of shell are fixed with reference to the state of the art of armor-manufacture, and the plate must be able to resist a given number of blows without developing through-cracks or permitting any shot to penetrate through the skin-plates. Armor-plates are usually attacked with guns of caliber the same as the thickness of the plate. For plates of varying thickness, guns of two calibers are used.

Pasteboard screens are interposed normally in the flight of the projectile, to ascertain the character of flight.

The plate is set up on a heavy timber structure in front of the sand butt, backed with 6 inches of oak backing secured to two $\frac{1}{8}$ -inch skin-plates by armor-bolts spaced at normal intervals. If the plate is one which is to be attacked at an angle to normal, this angle is carefully checked.

Suitable pockets of plates or conning-towers are placed in front of and around the place being attacked, to prevent fragments from scattering about the station.

Plates are never attacked by shell manufactured by the same company. The inspector of ordnance at the steel-works selects a plate from a group which, in his opinion, will give the poorest results. A representative of the manufacturer is always present to witness the test.

Photographs are always taken of all plates after test, and have stenciled on them the striking-velocity for each impact.

Armor-plates are now divided into five classes, as follows:

Class A-1 consists of armor-plates having a thickness of 4 inches or greater, to be face-hardened, and to be manufactured by a process satisfactory to the Bureau of Ordnance.

Class A-2 (turret) consists of port, side, and rear plates of turrets and conning-tower tubes of 4 inches thickness and greater, to be face-hardened and manufactured by a process satisfactory to the Bureau of Ordnance.

Class B consists of thin plates, such as turret and conning-tower tops, to be of special-treatment steel.

Class C consists of armor-bolts and nuts.

Protective-deck plates are of nickel steel, and are set up so that the projectile strikes them at an angle of from 7° to 15° from the tangent to their surface. The plate must not fracture under the single blow delivered.

Instruments Used at the Proving-Ground.

Boulengé chronographs.—For velocity work, three Boulengé chronographs are used. A separate circuit and screen are provided for each instrument. The Boulengé chronograph is operated, briefly, in the following manner: Two electro-magnets are provided with separate circuits, which are cut in turn by the passage of the projectile. The wires that are cut are placed 30 meters apart. When the first circuit is broken, a metal rod is dropped from the first magnet; and when the second is broken, a weight drops from the other magnet, which releases a knife that springs out laterally and cuts a nick in the first rod, which is still in the act of falling. Before firing, a datum point is secured by breaking both circuits at the same time with a suitable key; the distance between the datum point and the second nick furnishes a measure of the elapsed time between cutting the first and second circuits. From this time the mean velocity of the shot is calculated, and for all practical purposes represents the remaining velocity at the middle point between screens. A correction which reduces this velocity to the muzzle of the gun is readily taken from the ballistic tables.

In order to insure the cutting of the circuits, each wire is arranged in the form of a screen, the mesh being continuous and parallel at a distance apart depending on the caliber of the shot. The triple screens are placed a few inches apart, the first of a set being exactly 30 meters from the first of the second set. The use of three chronographs permits the selection of the most probable result in case the results vary.

Schultz chronoscope.—Besides the three Boulengé chronographs, a Schultz chronoscope is used for time measurements where more exact results must be obtained, such as velocities of recoil and counter-recoil, or in any case where several consecutive intervals must be measured.

This instrument consists, essentially, of a nickel-plated cylinder revolving by means of a falling weight, and the rotation of which

is controlled with more or less constancy by means of a fan which is in gear with the mechanism. A stylus is fastened to one prong of a tuning-fork, and the tuning-fork is kept in vibration by means of small electro-magnets, in much the same manner as electric trembler bells are arranged. The breaking of an electric circuit is the means employed to mark successive intervals of the measurement, the break causing a spark to leap across from a point near the stylus on the tuning-fork to the metal cylinder, the latter having been coated lightly with lamp-black just before the measurement is to be made. As the cylinder revolves and the tuning-fork vibrates, a wavy line is traced on the surface and each spark is marked on the line by a small bright dot whenever the current is broken.

The speed of vibration of the tuning-fork is nearly constant, and is equal to about 250 per second. The distance between two sparks in terms of the vibrations would then measure .004 second. By means of a magnifying-glass and micrometer the wavelength may be divided quite accurately into 100 parts, thus permitting the determination of time intervals of $\frac{1}{25000}$ of a second.

The **velocimeter** measures the velocity of recoil of a gun, and is used in connection with a chronoscope. Its principal part is a drum rotated by a string made fast to the gun. Each two inches of recoil, by turning the drum composed of insulated segments, makes and breaks an electric circuit to the chronoscope. A strong spiral spring takes in the slack on the counter-recoil and keeps a good tension on the line, so that the drum moves according to the recoil of the gun at all times. On the rotating smoked drum of the chronoscope in the laboratory, each two inches of recoil, then, is marked by a spark formed by an interruption in the electric circuit as the segments of the drum are passed over. The number of vibrations of the tuning-fork on the chronoscope per second being known, by counting these vibrations between the successive sparks on the drum the velocity for every two inches of recoil is known.

Guns do not recoil as rapidly as might be imagined. Twenty feet per second, or 12 knots per hour, is a good maximum value. Counter-recoil velocities are about one-eighth of the value of recoil velocities. By studying the curve of recoil velocities in connection with recoil-cylinder indicator-cards, abnormal stresses in the mount may be detected and avoided in design.

The gunner's quadrant consists of a flat base with a pivoted arm carrying a spirit level. The arm is set at the reading corresponding to the desired elevation, the quadrant is put on the gun, and the gun is elevated until the bubble centers. It is then at the desired elevation.

The Vickers gun-clinometer is a more accurate instrument. The level arm is adjusted to the degree next below the elevation desired. By turning a screw handle, a needle arm on a large arc graduated to minutes is worked so that the setting of the instrument to degrees and minutes of elevation is done more quickly and more accurately than with the simple type of gunner's quadrant.

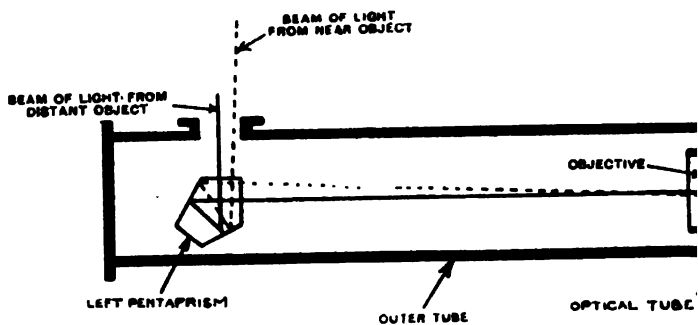
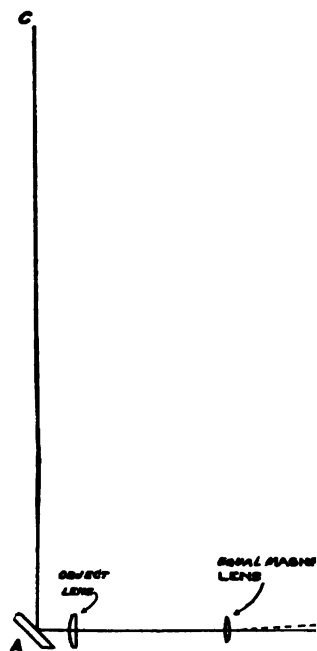
Droop may be expressed as the angle that the final tangent of the curved bore makes with the axis of the gun at the breech. To measure the inclination of the muzzle, a muzzle-rest with two cylindrical disks or bearing surfaces is fitted snugly into the muzzle of the gun. On the central shaft of this device is placed a striding clinometer, lying parallel to the center line of the gun, which is leveled crosswise and also fore and aft with reference to the gun, by set-screws. In using this clinometer it is read, then reversed, end for end, and read again. Were the instrument perfect, the readings should agree. This is not generally the case, so the average of the two readings is taken to eliminate error. At the same time (the gun being approximately level) the elevation at the breech is taken with the Vickers clinometer (read both ways and averaged for the same reason). The difference between the elevation at the muzzle and at the breech is the *droop*. This should be only a few minutes of arc, even in the largest guns.

The Tabor indicator is similar in all respects to those used on a steam-engine, except that the piston area is $\frac{1}{8}$ square inch instead of $\frac{1}{2}$ square inch. This is used to get pressures of the liquid in the recoil cylinder. It is screwed in a threaded plug-hole in the recoil cylinder, and the string is attached to the gun or to the yoke. When the gun is fired, a card is made showing the pressure corresponding to any amount of recoil. These pressures run from 2000 to 3000 pounds for modern guns, and the general appearance of the curve—the presence of “peaks,” etc.—shows whether or not the recoil system is behaving normally.



CHAPTER XXI. PLATE I.

THE
VINTAGE
ALPHABET



CHAPTER XXI.

SHORT-BASE, SINGLE-OBSERVER RANGE-FINDERS.

There are two types of range-finders used in the navy: (1) The Barr and Stroud, (2) the Bausch and Lomb. The first of these types is made in England, the second in the United States. They vary in length from 1 meter to 25 feet, 4 inches.

As the name implies, a single-observer range-finder is one in which a single observation alone is required for the determination of the range of an object; and in this respect it differs essentially from a range-finder of the double-observer type, in which two observations from the ends of the base are necessary.

In both types of instrument, the range is obtained virtually by the measurement of the parallax of the object—that is, of the angle subtended by the base of the instrument at the object. This base, in the case of single-observer instruments, is comparatively short, and, other things being equal, the accuracy obtainable is directly proportional to the base-length and also to the magnifying power of the range-finder.

Advantages.—The more important advantages of the single-observer type of instrument are as follows:

- (1) Only one observer is required.
- (2) The ranges of moving objects can be observed continuously.
- (3) The accuracy of the determination is independent of the azimuth-bearing of the object.
- (4) In case of the smaller types, the range-finder can be set in any position—horizontal, inclined, or vertical—to suit the nature of the object.
- (5) In general, there are also the further advantages of greater convenience, simplicity, and rapidity of operation.

Accuracy.—The accuracy of any range-finding operation in actual practice must depend largely upon the nature of the object under observation and upon the atmospheric and other conditions of working; but assuming that the object to be observed, such as a

mast or pole, is clearly defined, and that the atmospheric conditions are favorable, the limit of accuracy attainable will depend upon the base-length, which determines the angle of parallax, and, further, upon the smallness of the angle the instrument is capable of detecting.

Resolving power and magnification.—The unaided human eye is incapable of appreciating so small an angle as one-half second. From the results of many years of practical experience with range-finders of the coincidence type, it would appear that under favorable conditions the unaided eye can resolve angles of about 12 to 15 seconds. Although the range-finder may be able to measure an angle of one-half second, the eye can therefore only appreciate such an angle when it is sufficiently magnified. It would be necessary, accordingly, in the above instance, to use a telescopic system having a magnifying power of about 30 diameters. If the magnification of the telescopic system were 15 diameters, an angle of not less than one second, measured by the range-finder, could be appreciated by the eye; whereas, if the magnification were 30 diameters, an angle of one-half second could be appreciated.

The accuracy of the range measurement under similar natural conditions is determined, therefore, not only by the length of the base employed, but also by the magnification of the telescopic systems.

General Description.

The principle of the range-finder is based upon the solution—by observation—of one side of a horizontal right triangle, given a side and two adjacent angles. The given side, called the *base-line*, is the distance between the centers of the two reflectors at each end of the instrument. The angle on the left (when looking through the range-finder) is constant, and equal to 90° . This angle, CAB , is automatically made 90° by keeping the observed object in the center of the range-finder field. The one on the right side varies with the distance of the observed object.

Referring to Plate I, Fig. 1, A and B are the reflectors at either end of the instrument set at an angle of 45° with the base-line. If CA and $C'B$ are parallel rays of light from an object at an infinite distance, they will meet at the center D . If the object is at a finite distance, CA and $C''B$ may represent them. Then CA will

be reflected to D as before, but $C''B$ will be reflected to D' . The angle $D'BD$ is equal to the angle $C'BC''$, and varies with the distance of the observed object. The ray BD' could be made to take the direction of BD by revolving the reflector B ; but the amount of this revolution is so small for moderate changes in range, and so difficult of accurate measurement, that the same result is obtained by the use of a prism, P , the refracting angle of which is very small. By moving this prism P along the line DB , a position will be found, varying with the distance of the observed object, where the refracted ray will pass through the point D , thus meeting the ray CAD . Two coincident images of the same object will then be formed at the point D . To render these images visible to the observer, prisms are so placed at the point D that they reflect the light from both ends of the range-finder into the eye-lens F ; and the images are actually formed at some point in front of the eye-lens, the position of the images depending upon the type of instrument. By means of various optical arrangements the upper part of an object is seen through one end of the instrument and the lower part through the other end, as shown in Fig. 4, Plate I. Since there is a certain position of the prism P which will bring the two halves of any object into coincidence, as shown in Fig. 3, Plate I, a suitably graduated scale attached to the prism and moving with it will record the distance of the object corresponding to that position of the prism.

In the actual range-finder, various prism and lens combinations are employed in place of the simple parts shown in the diagram, in order to obtain the desired erect or inverted appearance of the partial images in the field of view.

As the outer tube of a range-finder is liable to be distorted as a result of the effects of temperature changes or of handling during the working of the instrument, it was necessary to adopt a type of end reflector that would not alter the direction of the beams of light entering the range-finder, even though its position was varied by small amounts. In all except the earlier range-finders, use is made of the type of prism known as the *pentagonal* or *Prandl prism* (as shown in Fig. 8, Plate I). A prism of this type, designed to bend a beam of light through an angle of 90° , consists of a block of glass having two reflecting-faces placed at an angle of 45° to one another. It is necessary that these two

reflecting-faces should be silvered, as the angle of incidence is within the critical angle of glass.

Any rotation of such a prism about an axis perpendicular to the common normal plane of the two reflecting-surfaces does not affect the direction of the doubly reflected beam of light, as the effect of the rotation of one reflecting-surface is exactly balanced by the equal rotation of the second reflecting-surface.

From a study of the instrument, it is found to be partly the equivalent of two telescopes, as the light passes through separate lenses and prisms until it reaches either the *coincidence-prism* or the *dividing-lens*. On the right side it traverses an *objective-lens*, a *deflecting-prism*, and the *coincidence-prism*; on the left an *objective-lens*, an *equal-magnification lens* (omitted in most of the Bausch & Lomb instruments), and the *coincidence-prism*.

The images formed by both objectives lie in the same plane. These images are erected by prism reflections or by lenses, or a combination of both prisms and lenses.

During the construction of the range-finder, the objectives are very carefully focused, so that their images in the field of view are in simultaneous focus with one another, and also with the separating-line, all of which, therefore, appear to be equally well defined in the field of view.

If the images are not correctly set for focus, there will be apparent in the field of view a *parallax error* of the images above and below the separating-line, and this parallax error will cause a resulting inaccuracy of the range observation. It is therefore important that the positions of the objectives should not be altered, or, if any alteration is necessary, that they should be readjusted with considerable care. The existence of this parallax error may be determined by moving the eye from side to side at the eyepiece and observing whether the partial images move with reference to each other.

In all these range-finders the following method is adopted for bringing the partial images into coincidence and obtaining the range:

As already described, a *deflecting-prism* (sometimes called *measuring-wedge*) is placed in the path of the ray from one of the end reflectors, and is moved longitudinally in the tube by means of the range working-head. The action of this prism in producing coin-

cidence is illustrated in Fig. 8, Plate I. The position marked *A* may be considered to be that of the deflecting-prism for an object at a very great distance. As the object approaches, the deflecting-prism must be moved toward the position *B* to maintain coincidence.

If a piece of glass having parallel faces were used instead of a prism, it is evident that the longitudinal motion of such a piece of glass along the path of the beam would have no deflecting effect on the image; and therefore by making the angle of the prism small enough, as large a longitudinal motion as may be desired can be made to correspond to a given motion of the image in the field of view—that is, to a given change of range.

It is evident from the above remarks that the position the deflecting-prism occupies when alignment of the partial images has been attained, constitutes an indication or measure of the range; and therefore a scale connected to the deflecting-prism, and moving with it, can be so graduated as to indicate the range directly in yards, meters, or other units. The deflecting-prism is moved longitudinally in the tube by means of a screw and nut in some cases, and by a rack-and-pinion mechanism in others; but imperfection or slackness in the mechanism will not produce errors in the indications of the instrument. The alignment, or want of alignment, of the partial images depends only upon the position of the deflecting-prism—that is, assuming the end reflectors and other parts of the instrument remain undisturbed; and as the scale is connected to and moves with the deflecting-prism, it always indicates the same range for any given position of the prism. Therefore, even if the mechanism were so untrue that for a continuous motion in one direction it moved the prism first outward and then inward, both the images and the scale would be moved accordingly, and hence no errors would be introduced, such as would result if the rotation of the screw itself were made to measure or to indicate the range, as in the case of micrometer devices.

Finder.—A finder of simple construction is usually provided to overcome the difficulty of finding, in the first instance, the object whose range is required—a difficulty greatly increased by the motions incidental to a ship at sea. The type of finder employed is modified to suit the various instruments.

Separation of the images.—An important feature is the separation of the partial images in the field of view by means of a fine *separating-line*, upon which the success of the coincidence method largely depends.

By means of the eyepiece prisms, referred to in the next section, the two beams of light from the ends of the instrument are caused to approach the separator in directions inclined to one another at an angle of a few degrees. As the separator is placed symmetrically with reference to the two beams, each beam makes different angles with the two faces of the biprism, and these angles are so arranged that the portion of the beam falling upon one face is refracted out through the eyepiece toward the observer's eye, while the portion of the same beam falling upon the other face is refracted at such an angle that it does not pass through the eyepiece. The partial image in the upper field is thus formed only by light from one end of the instrument, and the partial image in the lower field by light from the other end. In this way a perfectly clear separation is obtained.

Erection of the images.—This is accomplished in the various types of range-finders by means of the system of prisms placed at or near the center of the instrument. The construction of these prisms, which also serve to turn the beams of light outward to the eye of the observer, necessarily varies in different types of instruments. They are known as the *eyepiece prisms*, or *coincidence-prisms*, and they consist of several pieces of glass cemented together or otherwise rigidly held in the correct relative positions to each other and to the other optical parts. The arrangement is such that the images formed by the objectives of the telescopes are turned upside down or right for left, or in both ways, as the case may be, so that when viewed through the eyepiece they appear to the observer magnified, but otherwise as they would appear if viewed by the unassisted eye.

Use of the Range-Finder.

Choice of objects.—Experience will soon enable the observer to choose the most suitable parts of the object whose range is required, and to make the best use of those that are available. An object or part of an object exhibiting a straight vertical line should be chosen in preference to one showing only inclined lines; but

if there is no choice and the latter type of object is alone available, the halving-adjustment of the range-finder should be specially examined, as will be described later, to insure that there is no error which, on an inclined object, would affect the value of the coincidence setting.

Under certain conditions of lighting, the difficulty of making accurate observations is greatly increased, but it is generally possible to find a portion of the object that is suitable. For example, when the sun shines upon a round flag-pole or mast, the side which is in the sunlight may appear to merge into the sky and be indistinct, while the other side, which is in the shadow, may appear sharply defined. Under these circumstances, ranges obtained by bringing the indistinct edge into coincidence would be less accurate than those obtained by observing on the well-defined edge.

Objects of indefinite outline, such as clouds of smoke, can generally be ranged most satisfactorily when astigmatized as described later. The object then appears as a collection of dark and light vertical streaks, corresponding portions of which in the two fields can readily be recognized and brought into alignment. Good observations can sometimes be obtained on very small objects by moving the halving-adjustment head so as to make the object appear slightly *duplicated*, as explained later. (Fig. 6, Plate I.) The range may then be determined by making the separating-line pass between the two images and by bringing the upper image into alignment over the lower. When using this method, the duplication should be kept as small as will suffice.

Focusing.—The observing-eyepiece should be so adjusted that the halving-line is sharp and distinct; when this is the case, the instrument will be in focus on distant objects.

In using range-finders having two eyepieces, the left one for observing the scale, especial care should be taken that the left eyepiece is focused on the scale while the right eye is observing a distant object. If the left eyepiece is not so focused, the left eye will, of course, accommodate itself to the scale, but in so doing it will affect the right eye so that the halving-line and the observed objects will not appear to be in the best focus.

To effect coincidence.—Upon the exactitude of the coincidence setting depends the accuracy of the range-determination; but provided the conditions are favorable and that some attention is given

to the directions in this and the preceding section, no difficulty should be experienced on the part of the learner in obtaining good results after a little practice, or even at the first attempts, though in range finding, as in anything else, accuracy increases with practice.

It has been found that different observers have what might be called personal errors which diminish as their experience increases. Range-finder observers should therefore be given every opportunity for practice at measuring ranges, and also at testing the coincidence- and halving-adjustments.

The following instructions may appear somewhat complicated at first, but their full significance will be realized by an observer after he has had a little practice, and they will then appear quite simple.

Ranges of stationary or slowly moving objects can be most accurately obtained, as described below, when the atmospheric conditions are good, by what may be termed the *above-and-below method* of observation. First move the working-head until the upper image is not in exact alignment but is, say, just perceptibly to the right of the lower, and note the indication of the scale. Then move the working-head until the upper image appears by an equal amount to the left and note the scale indication. The arithmetical mean of the two scale indications obtained will be the range of the object.

After some practice it will be found possible and serviceable to move the working-head backward and forward between the two positions that give equal want of alignment in the two directions, and then to bring it midway between these positions. The necessity of noting the above-and-below scale indications and taking their mean value is thus avoided; and when the working-head is put in the intermediate position, the true range is indicated upon the scale.

The great accuracy obtainable in this way may be explained as follows:

Suppose that the range of the object is exactly 3,000 yards and that a change of 8 yards up or down in the setting of the range-finder cannot be readily detected as a want of coincidence. When working with special care, the operator may then get indications of range varying from 2992 to 3008 yards. On the other hand,

a change of setting corresponding to, say, 12 yards, may be distinctly visible. If, then, the observer sets the scale to read 2988, he will see the images perceptibly out of alignment in one direction; and if he sets the scale to read 3014, they will appear out by about the same amount in the other direction. The arithmetical mean of these readings, namely, 3001 yards, gives the distance of the object to within 1 yard of the true range.

If the scale had been set to read 2988 and then 3024, the images at the latter range would have appeared to be twice as far out of coincidence, and the difference would have been very distinctly visible. Even then, however, the mean would only be 3006, and as the observer will readily see the difference between a want of coincidence that is just perceptible and one that is double the amount, great accuracy of observation is obtainable by the use of this method.

When the range is changing too rapidly to use this method, the images of the object under observation must be brought directly into coincidence and the scale be then read; but as there is frequently a tendency on the part of the observer to be prematurely satisfied with the alignment, it is advisable to move the working-head still farther, but not so far as to affect the apparent alignment of the images. When this method is used, the observer should always approach the object from the same side, *i. e.*, move the coincidence-prism until the scale reads more than the range, and then make the coincidence by moving the prism so that the scale readings decrease (this is the preferable method, as the range of the target or the enemy would usually be decreasing), or make the coincidence by moving the prism so that the scale readings increase. When both edges of the object are equally well defined, the observer should always make his coincidence on the same edge, the right or the left. The individual observer will obtain better results by so doing than if he used the right edge sometimes and the left edge at other times.

When the object observed upon is a mast, it may be found convenient to balance the coincidence setting of the two sides of the object, the edges of which may be clearly defined against the sky. If the mast is tapered, and if the halving-adjustment is slightly imperfect and is, say, giving "duplication," it will be found that the width of the part immediately above the separating-line is greater

than that of the part below the line. The true range will then be obtained, not by bringing either edge into alignment, but by balancing the setting so that the want of alignment at the sides appears equal.

Under certain conditions of lighting, when one edge of the object appears dark against the sky, while the other appears light and poorly defined, it will be found difficult to balance the coincidence with the desired accuracy; and under such circumstances the well-defined edge only should be worked upon, care being taken to have the halving correct.

Whichever method of obtaining the alignment is adopted, it is advisable, when time permits, to obtain the range by taking the mean of several consecutive readings, provided the range does not change appreciably during the operation.

Astigmatizer.—In Fig. 3, Plate I, the object viewed is the mast of a ship, which is regular and usually clearly defined. When a single point (such as a star or a distant light) or an irregular object (such as a cloud of smoke) is being observed, it is evident that it cannot be readily divided by the separating-line, and therefore its range cannot be determined by the alignment of two partial images. This difficulty is simply and effectually overcome by placing in each of the two beams of light from the ends of the instrument a small cylindrical lens, having the axis of the cylinder horizontal and transverse to the direction of the beam. The effect of such a lens (or *astigmatizer*) is practically to put the light or object greatly out of focus vertically while not altering its focus horizontally. A point of light is thus drawn out into a vertical streak in each partial field, and the alignment can then be effected exactly as when working upon an object such as a mast, and the distance be determined. The astigmatizer is also used for taking observations on the stars, for checking the coincidence-adjustment.

Using the range-finder at night.—Connect up the battery to the contact switch and see that the scale lamp is in efficient working order. If it is light enough to make out clearly the vertical edges of the object whose range is desired, work in the same way as during the daytime, but use the lamp to illuminate the scale when the reading is to be taken. If the range of a light is required, set the astigmatizer to the "in" position. It will be noticed that a

small bright light is a better object to work upon than a large very brilliant light, and care must be taken, when several lights are visible in the right-eye field, that alignment is made between the upper and lower astigmatized image of the same light. The best way to identify the light is to remove the astigmatizer for a moment and then replace it in the field; or the astigmatizer may be moved half-way into the field, leaving the right-hand portion of the field clear and the left-hand portion astigmatized; then, by a slight movement of the range-finder in azimuth, the object can be seen astigmatized or not at will.

Adjustments.

It has been assumed in the preceding sections that when the partial images of an object are brought into alignment in the field of view, they appear to form a complete image, and that the range indicated by the scale represents the true distance; but the range-finder may be out of adjustment in one or both of these respects, and it should be tested frequently for such errors.

The arrangements provided for correcting the range-finder in these two respects are described in detail below under separate headings.

The adjusting operations are not difficult, and take only a few minutes to perform. The coincidence-adjustment should, however, be undertaken very deliberately and carefully, and, as far as possible, only when all the circumstances are favorable.

Halving-adjustment.—An object viewed through the range-finder may appear partly *duplicated*, as shown in Fig. 6, Plate I; or, on the other hand, it may appear *deficient*, that is, a portion of the object may be absent, as illustrated in Fig. 7, Plate I.

Halving-errors are produced by a movement of the images in a vertical direction, that is, at right angles to the separating-line, and they may result from the irregular bending of the tube in the vertical plane, or from a displacement of one of the end reflectors.

The halving-adjustment is not affected by errors in the coincidence-adjustment, but errors in halving affect the coincidence except when observing vertical lines. The halving-adjustment should therefore be made first. In the Barr & Stroud range-finders the halving-adjustment is never absolutely accurate except

for the range at which adjustment was made. In the Bausch & Lomb instruments the halving-adjustment is good for all ranges. In any case it is better to measure ranges on vertical lines rather than on inclined lines. It is advisable, however, on all occasions to test halving before commencing to make range observations, and to facilitate the operation the halving-adjustment head is placed in an accessible position.

A rotation of the halving-adjustment head affects only one of the images in the field of view.

To test the *halving-adjustment* of instruments, the following method is recommended:

Direct the range-finder in altitude so that the object is seen only in the lower half of the field of view, and then gently and steadily alter the elevation in such a way that the image rises in the field

HALVING ADJUSTER

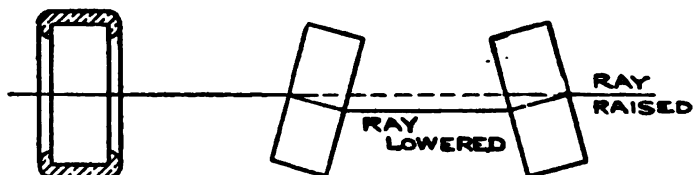


FIG. 1.—ILLUSTRATING THE PRINCIPLE OF THE HALVING-ADJUSTMENT.

up to the separating-line. If halving is correct, the top of the object will appear in the upper half of the field of view the instant it disappears from the lower. If it appears too soon, there is an error of *duplication*; if too late, of *deficiency*.

It is important to note that halving can be tested and adjusted upon any object that can be brought into alignment, and it is not necessary that the range of the object should be known.

The principle of the halving-adjustment is illustrated in Fig. 1. The *adjuster* is a thick piece of plane glass which raises or lowers the axis of one objective, according as it is rotated to the left or to the right.

Coincidence-adjustment.—When observing upon the moon or a star, or upon a terrestrial object at a known range, the indication of the scale obtained when the partial images are brought into true alignment may differ from the known range, owing to the instrument being out of adjustment for coincidence.

The range-finder is so designed that every cause capable of affecting the coincidence-adjustment has been eliminated as far as possible; but although it is unlikely that in ordinary service the adjustment when once set will vary to any serious extent, the setting should be tested whenever favorable opportunities present themselves.

Any alteration of the coincidence-adjustment should only be undertaken very deliberately and carefully, and, as far as possible, when the weather conditions are favorable.

It is also important that halving should be tested, and, if necessary, adjusted with special care before proceeding to adjust coincidence, as a slight error in halving may cause an error in coincidence.

The method of adjusting for coincidence varies in different range-finders. In all the Bausch & Lomb range-finders, the coincidence of the object is perfected, and the scale or the scale index (usually the scale) is then moved to the known reading, if an object at known range is being used; or to infinity if the moon or a star, the self-contained adjuster, or the adjusting-bar is being used.

In some of the Barr & Stroud range-finders, the method is the same as in the Bausch & Lomb instruments. In others the scale is set to the known distance, and the coincidence is obtained by angling a parallel-sided glass plate in the path of the rays from one of the images; or the scale is thrown out of gear, and the coincidence is obtained by the movement of the measuring-wedge in the usual way, the scale being again thrown into gear when the coincidence is obtained, or by rotating one of the windows, which is made slightly wedge-shaped for this purpose. Which method is used can be readily ascertained by reading the detailed description and examining the plates of the various marks of range-finders. The Bausch & Lomb method is the best, both mechanically and optically.

An alteration in the coincidence setting is due to some alteration in the horizontal plane of the beams of light forming the images in the field of view, and the correction is effected by adjusting the relative positions of the scale and the measuring-wedge.

To adjust for coincidence, the object should be brought into accurate alignment, and the scale be moved to indicate the true known range of the object, or the scale should be set to indicate

the correct range, and then the two halves of the image be brought into alignment, according to the type of instrument. Readings should then be taken on the object to check the setting.

To effect the adjustment, it is necessary to observe upon a natural object of known range or upon some equivalent artificial device; and the adjustment can be made in a variety of ways, the five most important of which are described herewith. The reliability of these methods is in the following order: (5), (4), (1), (2), (3).

(1) *Adjustment upon an object of known range.*—This method is only suitable for occasional use, usually ashore, when a very accurate chart is available and the position of the instrument and of some suitable object can be located with sufficient accuracy. This will seldom be the case with near objects; but if the exact positions of a well-defined very distant object and of the instrument can be accurately located on a good chart, the distance as measured from the chart may be used as a known range.

In measuring distances upon a chart for the purpose of checking range-finders, it is important to remember that a sea mile is not 2000 yards, but 2027 yards, nearly. The position of the ship must be fixed very exactly by cross-bearings before the range-finder is adjusted on a distant object.

It must be understood that from the nature of the scale an error of 1 per cent at 1000 yards is not an error of 1 per cent at greater distances; *e. g.*:

1 per cent at 1,000 yards = 10 yards.

1 per cent at 1,500 yards = $15 \times 1.5 = 22.5$ yards.

1 per cent at 3,000 yards = $30 \times 3 = 90$ yards.

1 per cent at 10,000 yards = $100 \times 10 = 1,000$ yards.

Hence the great importance of correcting coincidence by very long range observations, and of being most careful to do it accurately.

(2) *Adjustment upon two objects at unknown ranges.*—This method can sometimes be adopted with advantage for the adjustment of range-finders when they can be taken ashore. Inasmuch as want of true alignment affects various ranges in proportion to their squares, the error at any range is four times that

on half the range, and use can be made of this fact for adjusting purposes as follows: Select two objects separated by a distance of more than twice the lowest range indicated by the range-finder scale. Suppose, for example, that two objects *A* and *B*, about 1500 yards apart, are selected (Fig. 2). With the instrument at *B*, measure the range *BA*. The mean of several observations may be, for example, 1580 yards. Then, when the range-finder is set at a position *C*, halfway between *A* and *B* (and in the line *AB*), the ranges of *A* and *B* should each be 790 yards.

Suppose that the position of *C*, which may be selected by pacing or by the use of the range-finder itself, is nearly midway between *A* and *B*; and suppose that the mean of several observations of *CA* is 815 yards, and of *CB* 790 yards. Then $815 + 790 = 1605$

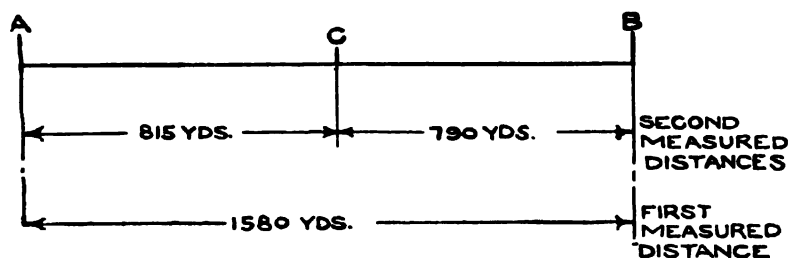


FIG. 2.—ILLUSTRATING ADJUSTMENT UPON TWO OBJECTS.

yards, and $1605 - 1580 = 25$ yards; and as the reading 1580 yards is more affected than the shorter readings, we see that in this case the instrument reads too low, and since the long range is affected about four times as much as each of the short ones, the true long range is approximately $1580 + 25 \times 2 = 1630$ yards. (Adding twice the difference would be exactly correct, if the two partial ranges were equal.)

The rule is, therefore, that if the long range obtained is less than the sum of the short ranges, the instrument reads low; and twice the difference must then be added to the long range to obtain the value of the range to which the instrument should be adjusted. If the long range is greater than the sum of the short ranges, twice the difference is to be subtracted from the long range. A second set of observations should be made to confirm or rectify the adjustment.

(3) *Adjustment upon artificial infinity.*—This may be accomplished by having two marks mounted upon an adjusting-bar or other suitable frame, the distance between *corresponding edges* of the marks being equal to the base-length of the range-finder. The images of the right-hand and left-hand marks produced by the right-hand and left-hand telescopes, respectively, are observed in the fields of view of the range-finder; and when the image of one mark in the upper field coincides with that of the other mark in the lower field, the instrument is adjusted for infinity (Fig. 3).

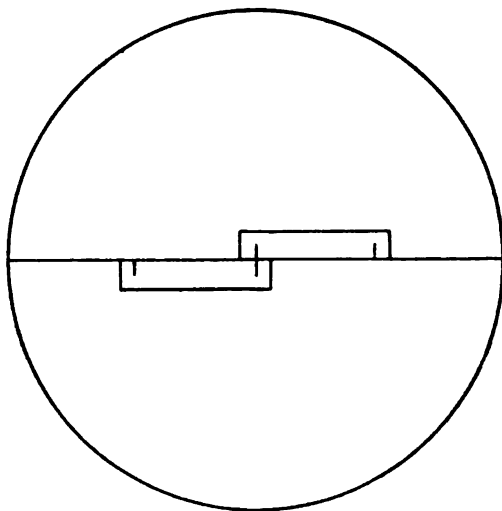


FIG. 3.—ILLUSTRATING THE USE OF THE ADJUSTING-BAR.

In using the adjusting-bar, the low magnification of 15 should be used, the bar should be accurately sighted at the center of the range-finder tripod-stand, and the marks on the bar should be brought into the center of the range-finder field as shown. This insures the parallelism of range-finder and adjusting-bar. The adjusting-bar should be placed far enough from the range-finder so that the halving-line is sharp and the adjusting-marks are in distinct focus at the same time (100 yards with the 15 magnification, 150 yards or more with the 28 magnification).

Careful experiments have shown that this method of adjustment is not reliable, owing to the constant changes in atmospheric con-

ditions. If possible, the temperature of the atmosphere at the range-finder, at the adjusting-bar, and at all points between them should be practically the same. If all these conditions cannot be obtained, the adjusting-bar should be used only as a last resort, as its use otherwise will be fairly certain to introduce an error into the instrument. If the above conditions can be obtained, the adjusting-bar will give a satisfactory method of adjusting the range-finder, but it is realized that these conditions are difficult to obtain aboard ship. As a consequence the adjusting-bar method is more suitable for use ashore.

All doubts as to the range of the object chosen may be avoided by working upon an object at an infinite distance, such as the moon or a star, or by using the self-contained adjuster when fitted; and whenever possible the adjustment should be tested and corrected, if necessary, upon such objects.

(4) *Adjustment upon a celestial object.*—As the range of any celestial body is, from the range-finding point of view, infinite, the sun, moon, or a star may be used for the adjustment of the infinity indication of the scale.

The sun is not usually a very suitable object unless partially obscured by mist or fog, and a bright sun at a considerable altitude is quite unsuitable, even if a dark glass be interposed between the eyepiece and the eye of the observer, because of the heating effect produced by the rays upon the optical parts of the instrument. The moon at low elevations is usually a very suitable object, provided the atmospheric conditions near the horizon are good. The moon is to be preferred to a star, owing to the fact that when working on the former it is not necessary to use the astigmatizer, which may introduce a small error, owing to slight defects of adjustment of the optical parts during the construction of the instrument. In practice, the weather and other conditions of observation are often such as to affect seriously the accuracy of night observations on the moon or stars, and if possible the adjustment should be made on a clear and calm night.

When adjusting upon the moon, care should be taken to work on its sharply defined edge, and the separating-line should cut the disk diametrically. The scale should be set to infinity (which is distinguished by " ∞ " or by a star), and any defect in the coincidence of the object should then be corrected, not by means of the

working-head, but by a rotation of the coincidence-adjustment head, or the coincidence should be obtained and the scale be then set to infinity, depending upon the type of instrument.

When the moon is not visible or not conveniently placed, a bright star, preferably lying not more than 30° above the horizon, where the observation can be made with comfort, may be chosen. It will be most convenient to use the astigmatizer in this case. The scale should be set to read infinity, and the alignment should be adjusted, if necessary, by the coincidence-adjustment head.

In some cases, satisfactory accuracy in setting is obtainable if the image of the star is slightly duplicated by means of the halving-adjustment, so that it appears above and below the separating-line, or if the range-finder is vibrated in altitude so as to make the star appear as a short streak of light. Neither of these methods should be adopted when it is possible to use the astigmatizer.

(5) *Adjustment by a self-contained adjuster.*—This is described in the detailed description of those instruments that have it.

The Care of the Range-Finder.

The instrument should not be continually shipped and unshipped. If mounted in an exposed place, it should be dismounted in bad weather or when it is not required for any length of time. When dismounted, it must be stored in its box in some well-protected location. The greatest care must be used while handling the instrument, and the work should always be supervised by a responsible person.

In damp weather, at night, when coaling, etc., the waterproof cover should be placed over it.

It should be cleaned externally daily by a careful and responsible man. He must be warned on no account to remove the end window glasses for cleaning purposes or to use any gritty substance for cleaning the tube of the instrument.

The waterproof cover should never be placed in the range-finder box. The interior of the box should be kept quite dry, and neither the range-finder nor cloths nor leathers should be put into the box unless they are dry.

The cloths provided for wiping the external surfaces of the glasses must not be used for any other purpose, and must be kept

perfectly clean. Care must be taken, both in washing and in drying them, that no sand or grit gets into them.

The leathers provided for cleaning the external parts of the instrument must not be used to clean the glasses.

The mounting of the range-finder should be kept clean and thoroughly lubricated with good oil in all its working-parts.

The securing-catches must be kept in working order.

If any looseness is found between the parts of the carriage and stand, it should be taken up. The rollers in the bearings should receive special attention and should always work quite freely.

The mounting, when not in use, should always be clamped against rotation in azimuth.

Inspect the instrument frequently, and never let it be handled except by responsible men detailed for the purpose, who have received instructions regarding its care and use. In packing for shipment, use a box somewhat larger than the one containing the instrument and fill the extra space between the boxes with excelsior or some other similar material. Unless the instrument is urgently needed, it should not be disassembled for repairs or adjustment by an officer who has not received practical instructions in so doing, and then only after he has read and understood everything contained in the accompanying pamphlet. This precaution is necessary, because any mistakes may result in breakage of parts, which can only be replaced by the makers, thus rendering the instrument useless for a considerable length of time.

Important Instructions.

Under no circumstances shall any range-finder be disassembled or adjusted except for halving or coincidence by anyone but an officer or man especially qualified for this work.

Cleaning.—It is particularly recommended that if the instrument is giving satisfactory results it should not be dismantled, and a small amount of dirt in the field or on the optical parts should be tolerated in preference to removing the frame and cleaning the optical surfaces.

If, however, the amount of dirt in the field is seriously affecting the efficiency of the instrument, it will be necessary to clean the range-finder internally, but the cleaning should only be undertaken

deliberately and under good weather conditions, or preferably under cover.

The presence of dirt on the optical parts of the range-finder will be more or less evident in the field of view according as the parts affected are more or less nearly in the focus of the eyepiece.

Particles of dirt on the windows, or on the pentaprism faces (or reflectors), or on the objectives will not be visible in the field of view, but will cause a general darkening of the whole field; greasy smears or finger-marks on these parts may, however, cause a very noticeable loss of definition of the images.

Particles on the nearer faces of the central prisms will be visible as indistinct blurs, while particles on the faces of the separating-prisms will appear clearly in focus and considerably magnified.

If the upper field alone appears dark, it may be assumed that only the one set of optical parts requires examination; and similarly, if the lower field is indistinct, the other set is in question.

A close examination may reveal a difference in the colors of the two fields, due to differences in the character of the optical parts; and this appearance, which is not of importance, must be distinguished from the darkening that results from the presence of dirt.

Finger-marks or dirt upon the astigmatizer may be readily recognized by the streaky appearance of the portions of the astigmatized image affected, and by the presence of reflected light.

It is important that the optical parts, and particularly the separating-prism, should be cleaned as seldom as possible; and when the necessity arises, the faces should be rubbed lightly, as otherwise the surfaces may be damaged to an extent sufficient to affect the definition of the images.

Glass windows and eyepieces of special hardness are provided, and it is therefore possible to clean these exposed parts more frequently.

When cleaning the separating-faces, a thoroughly clean and dry camel's-hair brush should first be used to remove any grit, which would scratch the faces if rubbed with a cloth. The surfaces should then be slightly breathed upon to fix the fine particles of dust, so that they may be removed by gently rubbing the prism faces with a clean cloth (linen or selvyt).

Special care should be taken to avoid injuring the fine separating-line, every defect of which appears highly magnified in the field of view, and the prism should only be removed for cleaning when the conditions are favorable; that is, when the entrance of grit, dirt, and moisture is not possible.

No difficulty will be experienced in cleaning the other optical surfaces, to which direct access has, where necessary, been provided. It is therefore unnecessary, for cleaning purposes, to remove any of the parts, with the exception of the separating-prism; and it is strongly recommended that they should not be disturbed.

Moisture should not be allowed to remain on the prism surfaces for any considerable time. If any moisture that may appear in the field is not removed, the surfaces may become corroded and spotted to an extent that can only be remedied by regrinding the faces.

If from any cause moisture is found to have collected on the inner surfaces of the windows or on the internal optical parts, the end plates (or the windows) should be removed for a short time to allow a current of air to pass through the tube, but this should only be done in dry weather, never in rain or fog, or if smoke or dust or spray is about the range-finder. In the event of the atmospheric conditions on deck being unsuitable, the instrument should be taken into the chart-house or elsewhere under cover while the interior is being aired. If this fails to remove the moisture, the inner frame may be taken out for cleaning, but the passage of dry air through the tube should always be tried first.



CHAPTER XXII.

DEMOLITIONS.

Such demolition work as may be attempted by the navy is not likely to be quite so extensive as that of the army engineers, and the equipment of the "gun-cotton party" is largely extemporized. While it would not be advisable to carry such materials on ship-board continually, it is probable that, in emergencies where very much demolition work had to be done, dynamite or ordinary blasting-powder would be acquired for that purpose. These materials are so widely used that they are cheap and readily obtainable in large quantities.

T. N. T. (trinitro-toluol) being a new service explosive, it may perhaps be used for demolition work. Loose T. N. T. can be made up in sausages in duck bags, and is very convenient in that form. Wire nails can be safely driven through it to attach such tubes around timbers in an encircling chain, and the detonators can be stuck in through slits made with a knife. These tubes are convenient to carry; they can be cut to desired length with a knife, and the ends can be tied with twine after dumping a little out. In blowing up flat shapes, a primer on each side should be used to insure good detonation, particularly if the tube is thin. Recent tests at Indian Head have shown that this works very well, even for hard oak timbers up to 12 by 16 inches, if a charge of 1 pound for each 20 square inches of sectional area is used for rectangular section, and for round timbers 1 pound for each 50 square inches of the area of the circumscribed square. The charge should be three-fourths of a pound or over in all cases.

Wrecking-mine charges, in brief, are tight sheet-copper boxes about 1 foot square and 9 inches high, filled with wet gun-cotton, but with a central case for a priming-charge of dry gun-cotton put in before using. The detonators are electric and the splice is made inside the case. The insulated firing-wire is packed with a spherical rubber washer where it leads through the screw cover. The charge is equivalent to 38 pounds of dry gun-cotton. T. N. T.

(trinitro-toluol) priming-charges are being adopted, because safer and more convenient than dry gun-cotton in requiring fewer inspections. A battery and firing-key with the outfit allow the simultaneous firing of several charges.

It would be out of place to describe the outfit further, because an ordnance pamphlet explains each part with illustrations, even to the exact kind of splice to be used. This descriptive pamphlet should be thoroughly understood before attempting to use the outfit, and should be followed.

The wrecking-mine outfit is designed especially for use in destroying derelicts and blowing up hulks such as may have been used to obstruct channels. Specific rules for this kind of work are difficult to give, except to say that one charge at the base of a mast should bring it down; that firing a number of charges simultaneously at different parts of the wreck is usually better practice than grouping all together, and that it is best first to blow the deck off lumber-laden wrecks, to let the cargo go. Charges should be as deeply submerged as practicable, and with a charge 10 feet deep the boat should be at least 35 feet away before firing. If only the mast is above water, the charges can be strung around it and lowered away to the deck.

Having spoken of the naval wrecking-mine outfit, it is well to remark that "demolitions" is a broad term, covering every form of destruction of the enemy's property which has come into our possession. Blowing things up is by no means invariably the best way. If time permits, and if there is little danger of fire spreading further than intended, it is easier and simpler to burn docks, buildings, etc. Explosives are specially suited for destroying brick or masonry bridges, etc. Again, a timber bridge will fall if cut, and explosives furnish a means of doing this without being on it at the time; but, if not pressed for time, burning is as good, or better.

The crippling of railroad transportation is a very important part of demolitions. Rails are torn up and heated over fires until they sag of their own weight. They can be bent around trees, or can be twisted by bars through the bolt-holes. Fish-plates are cracked with hammers, and bolts and nuts are removed. *Derailers* such as those seen about railways are ideal for wrecking trains at short notice, as they weigh only a few pounds and have merely

to be laid on one rail. Or sections disconnected can be turned over bodily (two men to a tie). A heavy obstruction should be 3 feet deep and 10 feet long to stop a train. Rails may be disconnected and moved about a foot out of line. Merely to remove the fish-plates and some of the spikes around a curve will usually cause a wreck. To blow up rails, use a stick of dynamite each side of the web, or a disk of gun-cotton, or half a pound of T. N. T. Rolling stock is burned. Locomotives are derailed or run into head-on collisions, preferably in a tunnel; or, if in haste, the boiler is destroyed by explosives inside of it, or by shooting a field-piece through it, or by building a fire under it when empty. Links and small parts are removed.

To destroy a telegraph line, poles are cut down and burned, wires are tangled and insulators are broken. To disable it temporarily, breaks, crosses, or grounds may be made.

There should be no difficulty in devising ways to cripple railroads and telegraphs. The above are given merely as a guide.

Precautions.—Priming-charges and detonators should not be put in before it is necessary to do so; firing-connections should be made only after all is clear; and explosives should not be exposed to sparks of fire or handled roughly. Everyone knows all this, and all safety precautions are merely these statements in various forms. A wholesome respect for explosives (which is not outgrown with experience) is what is needed. Accidents are commonest among the experienced, who take chances while knowing better. The unexperienced, if cautious, are relatively safe. Have the men handle explosives "like eggs."

There are, however, a few things that may be added to the above that one's caution would not of itself suggest. The principal of these has reference to dynamite, and particularly to its behavior in cold weather.

Dynamite comes in sticks, usually paper-covered. It is a mixture of nitro-glycerine and "dope" sometimes inert but more usually explosive. Sticks should be stowed horizontally to prevent exudation.

In cold weather it freezes and gets hard, and has to be thawed to restore sensitiveness. This should be done either in a special hot-water heater or in a box packed with manure, and should not be hurried; for if overheated or roughly handled during this

thawing process, it is very sensitive. It may be frozen inside while soft on the outside. There are some "non-freezing" dynamites.

In working with dynamite and handling it, one gets a "nitro-glycerine headache," Strong coffee cures this.

In placing a charge of dynamite, a detonator is struck in one end of a stick, and the ends of the wrapper are tied around with twine. The leading-wires are given a hitch round the stick to keep a strain from pulling out the detonator. The detonator should be located as near the center of the mass of the charge as convenient.

Tamping is not so necessary as with black powder, but it helps. It is the inertia of the tamping material that counts, and a plank with dirt on it laid over the explosive is quite effective. Earth tamping of a charge along the foot of a wall should be about one and one-half times as thick as the wall, for maximum effect.

Charges for hasty demolitions.—The following table is given by Weaver for charges for hasty demolitions:

SUMMARY OF CHARGES FOR HASTY DEMOLITIONS.

(Using dynamite or gun-cotton charges.)

 B = length of breech to be made, in feet. T = thickness of object to which charge is applied, in feet. t = thickness of iron plate, in inches.

These charges are for untamped conditions; if tamped, they may be reduced one-half.

When prepared in great haste in the presence of the enemy, increase the charges one-half.

Object.	Pounds.	Remarks.
Hard-wood trees, round.....	5 T^3	Also piles, masts, etc., encircling charge.
Hard-wood beam, rectangular.	3 BT^3	B = longer side of cross-section, encircling charge.
Hard-wood stockade or barrier	3 BT^3	B = length of breech; T = maximum thickness of stockade; single charge.
Earth and wood stockade or barrier.	4 per foot.	This is for breastworks 2 to 3 feet thick, made of earth rammed between planks or railway sleepers.
Iron-rail stockade or barrier..	7 per foot.	This is made of iron rails touching each other, placed in ground on end.
Hard-wood tree, round. (Soft-wood objects require only one-half of the charge required by the same object in hard-wood.)	$\frac{1}{2} T^3$	T = smallest diameter of tree; auger-hole charge. Hole bored radially, so that center of charge shall be at tree.
Brick and masonry revetments.	$\frac{1}{2} BT^3$	Charge placed behind revetment against its back surface; for scarp walls of forts and surfaces of tunnels.
Heavy gates.....	50.....	Gates of forts, armories, etc.
Iron plates, wrought or steel..	$\frac{1}{2} B t^3$	t = thickness in inches. Laminated plate: same as solid.
Detached masonry or brick wall, over 2 feet thick.	$\frac{1}{2} BT^3$	If over 2 feet thick.
Detached masonry or brick wall, less than 2 feet thick.	2 per foot.	Charge calculated by last formula would be too heavy, and would simply blow a hole through the wall.
Masonry piers of bridges.....	$\frac{1}{2} BT^3$	Placed against the pier in close contact.
Masonry arches of bridges....	$\frac{1}{2} BT^3$	Placed along the crown of haunches.
Field-guns or siege-guns, or R. F. guns.	1.....	Placed on the chase near the muzzle.
Large sea-coast guns.....	4.....	In bore tamped from the breech and muzzle with sand or earth.
Steel rails.....	$\frac{1}{2}$	Lashed tightly to web of rail.
Inflammable buildings or materials.	1 disk of dry gun-cotton.	Disk should be simply ignited, not detonated.

Explosive gelatine would require charges 20 per cent less than those above. Gunpowder would require charges four times greater than those above.

Army Methods of Demolition.

In the field manual of the army engineers the following comments appear:

"Weight of explosives.—All calculations of weights of charges are based on the use of an explosive equal in strength to a 50 per cent dynamite. A *stick* will be understood to mean a cylindrical cartridge $1\frac{1}{4}$ by 8 inches, which will weigh approximately .6 pound. A *chain* will be understood to mean a number of such sticks end to end, in close contact, and is taken at 1 pound per running foot. The cartridges of a *string* will usually be attached to a rope or pole. When two or more strings of cartridges are to be used, they may be lashed to the same support. In all the following formulæ, *C* represents the charge of 50 per cent dynamite, or its equal in strength, in pounds; *d*, the diameter in feet; *B*, the breadth of the section to be ruptured, in feet; and *T* and *t* the thickness in feet and inches, respectively.

"Timber.—A charge of $\frac{1}{2}$ pound per square foot of sectional area, placed in holes in the same cross-section, will cut off trees and round or squared timbers of usual proportions. The holes should be tamped with clay behind the cartridges. One, two, three, and four sticks will cut off trees or poles 13, 19, 23, and 27 inches in diameter, respectively. The center of the charge should be at the center of the section. If the holes meet, one primer at the middle will do. If they do not meet, as will usually happen in large trees, a fuse for each hole is required, and simultaneous ignition. If firing must be done with time-fuse, it may be well to charge and fire one hole, then bore another in the soundest part remaining, charge and fire it, and so on, until the tree falls.

"A round timber not over 12 inches in diameter may be cut by a chain completely encircling it in the same plane. It must set snug against the wood, and should be fired with primers on both sides.

"Such a charge fired 3 feet under water will cut any pile or trestle leg likely to be encountered. Close contact is not so necessary under water, and it is convenient to lash the charge to a wire ring or to a band or hoop, and slip it down.

"For squared timbers, the charge is placed in one or more parallel holes. The direction will depend on the dimensions

of the timber as compared with the length of a stick. The holes should not go entirely through, and should be somewhat deeper than the stick is long, to allow for tamping. Broadly speaking, the hole should be bored in the direction of the dimension which is nearest 12 inches for whole sticks, or in the direction which is nearest 8 inches, and charged with half sticks.

"It may be necessary to cut bridge timbers when there is not time to bore. The charge required is 4 pounds per square foot of section, and may be placed as a chain around, if square or nearly so; or, if the piece is thin as compared with its width, across one long side.

"Stockades and stockaded walls or palisades are destroyed by strings of cartridges covering so much of their length as it may be necessary to break down. The cartridge cannot be got close to the wood except in the case of square timbers, and more powder is required than the actual cross-section of wood calls for. Besides, it may not be known what the construction of the stockade is or what strength it may have from braces or other reinforcement.

"The charge is best placed along the foot of the wall, and should be tamped, especially in the intervals between timbers. So far as its flexibility suffices, the string should be bent to fit the contour of the logs as snugly as possible.

"If the demolition is deliberate and the structure can be examined, one or two strings well placed and tamped will throw down a single wall or one side of a double wall. If the work is to be done under fire, determine the minimum length of breech actually required and place and fire a charge of four strings, tamped as well as conditions permit.

"**Masonry.**—For ordinary walls, the charge per running foot varies with the square of the thickness, or $C = .85T^2$. The charge should be laid in chains along the foot of the walls. If a tamping equal in thickness to the wall is placed, the charge may be reduced one-third. If, besides the tamping, a groove is cut to hold the charge, the weight of the powder may be reduced one-half.



“The following table shows the number of chains required to throw down walls of usual thickness:

Thickness of wall.	Number of chains required.		
	Not tamped.	Tamped.	Grooved and tamped.
<i>Inches.</i>			
13	1	1	1
18	2	2	1
22	3	2	2
26	4	3	2

“The walls of a house may be blown down with charges taken from the above table. It is sufficient to charge the walls between windows only, preferably inside and with tamping. In haste, one or more charges of 50 pounds, in a central position, will demolish the house.

“Locks should be attacked at the miter sills, the lower first. Start the gates open slightly and place a concentrated charge between them and the upper edge of the sill.

“**Masonry bridges.**—A single arch is best attacked by charging across the extrados at the haunches, or across the crown. The charge should be one-half more than for a wall of the same thickness. Both methods require digging; and if the spandrel filling is of masonry, the former is scarcely practicable. Both methods also interrupt traffic on the bridge, which it may be important to use until the last moment. A thin arch may be broken by a heavy charge exploded on the roadway at the crown. It should be tamped by throwing a mound of earth over it. The charge should be not less than T^2 pounds per running foot, T being reckoned from the surface of roadway to soffit of arch.

“The charge may be placed in a trough and suspended under the crown. The sides of the trough should make an angle of 60° . Planks 12 inches wide will make a trough to hold 36 chains of $1\frac{1}{4}$ -inch cartridges, or 36 pounds to the running foot. If the number to be used will not completely fill the trough, earth must be placed in the bottom, so that the top tier of the cartridges will project slightly above the edges of the boards. The trough must not be allowed to sag away from the arch at the middle. If necessary, truss it up.

" Primers should be placed 3 or 4 feet apart in the middle chain of the top tier, and the wires or fuse should be led out through notches in the sides.

" It is for this kind of work that the wrecking-mine outfit would probably prove most useful on shore, a string of wet gun-cotton charges being used.

" A bridge of more than one arch is usually most easily attacked at the piers. The destruction of one pier throws down two arches. The charge should be placed where the pier is the thinnest and should extend across one face. If possible, a groove should be cut in the pier, or irregular voids should be made by prying out stones from the same course. This lessens T , partially tamps the charge, and furnishes a convenient support, which must otherwise be provided in the shape of a shelf, trough, or other device.

" **Metals.**—As soft steel so greatly predominates in structural work, statements under this head will relate to that metal.

" All charges will be external, as drilling or boring is not practicable. The standard formula is $C = 2.5 B t^2$, in which C equals the charge in pounds, B equals the width of the section in feet, and t its thickness in inches. The charge must extend entirely across the plate or sheet.

" The following table gives the charges necessary to cut through a plate 1 foot wide and of the thickness given. It is computed from the above formula for 50 per cent dynamite.

Thickness of plate.	Charge of 50% dynamite.	Thickness of plate.	Charge of 50% dynamite.
<i>Inches.</i>	<i>Pounds.</i>	<i>Inches.</i>	<i>Pounds.</i>
$\frac{1}{8}$	0.16	$1\frac{1}{8}$	3.90
$\frac{1}{4}$	0.62	$1\frac{1}{2}$	5.62
$\frac{3}{4}$	1.40	2	10.00
1	2.5	3	23.50

" A single chain will cut a plate up to $\frac{5}{8}$ inch thick. Two, three, and four chains will cut plates of $\frac{7}{8}$, $1\frac{1}{8}$, and $1\frac{1}{4}$ inches thickness, respectively. The charge must be held snugly against the plate by a piece of plank, lashed or wedged, and, whenever possible, must be tamped. For structural shapes, figure the width as the sum

of web and flange widths, and the thickness as the area of cross-section in square inches divided by this sum.

"The charge should be in three parts—one on the web and one on each flange. For channels, angles, and Z-bars, the entire charge may be on contiguous surfaces, and one primer will suffice. For I-beams, the flange charges should be on the outside and three primers are necessary.

"As one chain will cut up to $\frac{5}{8}$ inch thickness, and two chains up to $\frac{7}{8}$ inch, the choice will usually lie between the two, as few pieces of structural steel will be found with greater thickness than $\frac{7}{8}$ inch.

"For lattice girders, diagonals, and posts, all the longitudinal members should be cut. For plate girders, the web and both flanges should be cut. If short of powder, cut the lower flange and lower part of the web. For a box girder, figure all four sides as plates. If powder is scarce, omit the top. For a beam girder, figure the flange charge for the combined thickness of beam-flange and plate.

"**Cutting bridges.**—Wooden trusses are best cut near the middle of the power chord. Steel trusses and girders, if a complete fall is desired, should have every member cut on the same cross-section. Continuous girders or trusses must be cut near the end of the shore spans opposite the abutment.

"Metal girders and trusses are better cut near the abutments, where the cross-sections of chords and flanges are smaller. Where members meet or cross, as at panel points, etc., it is usually possible to place charges in a more or less acute angle, and then tamp by following earth upon them. The effect of the charge in such a situation is always greater than if placed against the side of a single member, and, unless the panel points are of very massive construction and so complicated as to make the effect of the charge uncertain, it will be better to choose them as the location for cutting, remembering that a complete rupture of the entire cross-section of the bridge is the object in view. Panel points and intersections will be selected so as to attain this object with the smallest number of charges.

"A cantilever bridge should be cut over the towers with especial attention to the complete rupture of the top chords.

"Wire cables of suspension-bridges are difficult to cut. The best place to work is between the cable and the top of the tower, near the saddle. There are no reliable data as to charges required. A French formula gives $C = .42 t^2$, in which t is the diameter of the cable in inches.

"To interrupt traffic, rails may be cut and frogs and other parts of switches broken. A stick fastened against the web of a rail up to 70 pounds, will cut a gap in it about a foot long; if the charge be tamped, a heavier rail may be cut. Such a cut may be made to produce derailments, but for other purposes two charges should be fired on opposite sides and a few feet apart, which will blow out a piece and distort the ends.

"A stick in the groove of a frog, and covered with ballast, will wreck a frog. A stick between the two rails, as, for example, a track and a guard-rail, or the main line and switch-rail, will cut both. In such a situation, tamping is easy and should always be done."