CHAPTER IV.

GUNS.

Section I.—Types, Classes, and Component Parts.

401. Types of guns.—A gun is a mechanical device, consisting of a tube closed at one end at the moment of firing, capable of containing a projectile and a propelling charge, and of so controlling the explosion of the charge as to discharge the projectile with a high velocity.

A rifle is a gun whose bore has cut in 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*. (See Plate I.)

A mortar is a short gun with a large bore and low velocity, capable of high angles of fire. Twelve-inch mortar carriages in the coast defenses permit firing only at angles of elevation between 45° and 65°.

A howitzer is a short heavy gun for high angle fire. The 16-inch howitzer carriage, U. S. Army 1920 model, permits a maximum elevation angle of 65°.

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 the 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 bore compression obtained by shrinkage, the exterior parts being heated to go over the interior parts; and (2) the "wire-wound" gun.

A radial-expansion monoblock gun is a gun composed of a single forging. In this gun the initial bore compression is obtained by the application of hydraulic pressure to the interior of the gun tube. It may be constructed with or without a separate liner. Larger radially expanded guns, however, are not necessarily monoblock (one piece).

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.

Breech-loading rifles and **rapid-fire guns** were terms previously used to designate different types of guns. However, all modern naval guns are breech-loading, all are rifled, and all are more or less rapid-firing; hence the terms have been abandoned. Instead the terms *bag guns* and *case guns* have been adopted.

Bag guns are 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.

Case 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 those used with field carriages on shore. Field guns in the Navy are commonly called *landing* guns. The Navy manufactures at present a 3-inch landing gun. During the World War a number of 7-inch naval guns were used on field carriages, as well as several 14-inch naval guns on *railway* carriages. Army field guns vary in size from the 75-mm. gun to the 240-mm. howitzer.

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 automatic rifles.

Small arms are guns of less than one inch caliber. They include rifles that are fired from the shoulder and pistols that are fired from the hand.

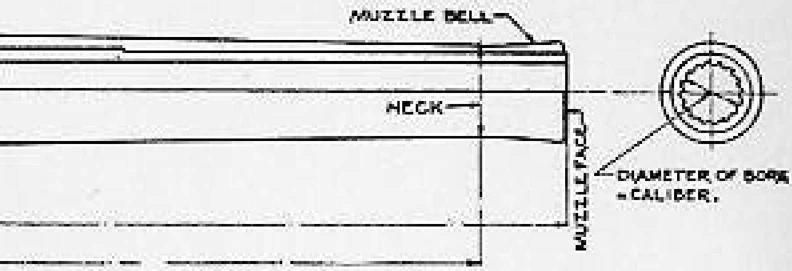
Sub-caliber guns.—A gun is called a *sub-caliber gun* when it is used mounted inside or outside a larger gun, for short-range gunnery practice, and for firing blanks in drills. One-pounders and small-arms rifles are used for this purpose.

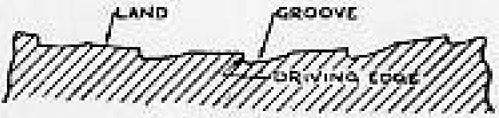
Saluting guns are guns used for saluting purposes.

Depth charge projectors are guns used for projecting depth charges. The *Y-gun* was a type employed during the World War.

402. Classification of guns aboard ship.—Guns aboard ship are classified as (a) turret, (b) broadside, (c) anti-aircraft, and (d) anti-aircraft machine guns. In addition, (e) double purpose guns are designed for use both against surface and aircraft targets.

403. Classification of batteries aboard ship.—(*a*) **The main battery** includes those guns of the largest caliber on board.

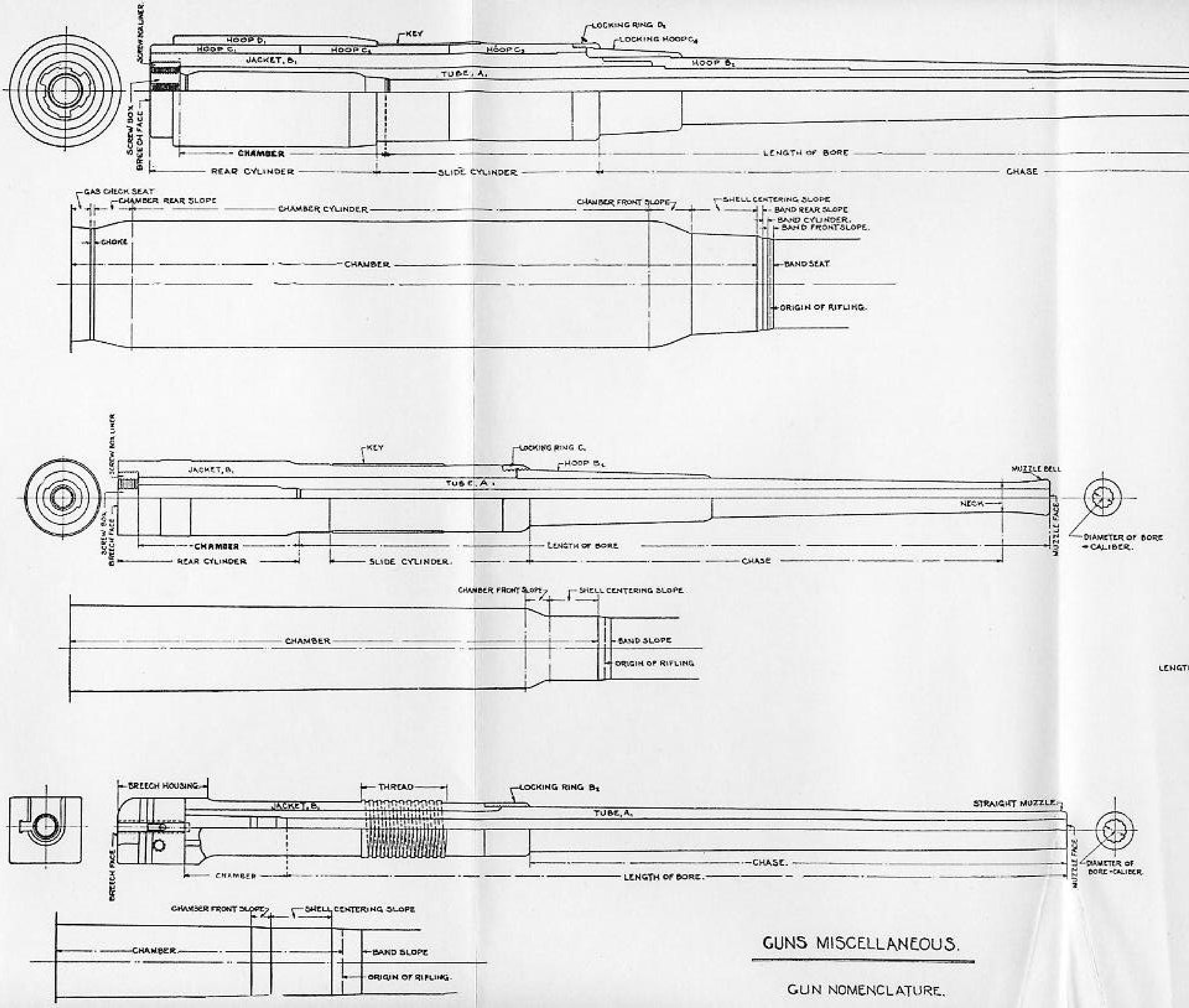




HOOK RIFLING.

RIB RIFLING.

$$\text{LENGTH IN CALIBERS} = \frac{\text{LENGTH OF GUN IN INCHES}}{\text{DIAMETER OF BORE IN INCHES}}$$



GUNS MISCELLANEOUS.

GUN NOMENCLATURE.

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(*b*) **Secondary battery.**—Only turret ships are considered to have a secondary battery; the secondary battery includes all except the turret guns and those guns specifically designated for use against aircraft. In ships having no broadside guns other than double purpose guns this battery may be designated as the secondary battery.

(*c*) **The anti-aircraft battery** includes all guns carried for primary use against aircraft.

404. Designation of guns.—Guns are usually named or designated either by (1) caliber in inches, followed by the length of gun 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. 1.

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. Thus the 14-inch, Mark I, gun, on being relined, would be designated as 14-inch, Mark I, Mod. 1 gun. This system of designating by marks and modifications is applied to all ordnance units, such as mounts, breech mechanisms, firing locks, powder tanks, sights, telescopes.

405. Component parts.—(1) *A built-up gun* is composed of a *liner*, *tube*, and *hoops*. The general scheme of naming hoops is to letter them from the bore outwards as A, B, C, D, etc. Their numbered designation is from the breech forward as C1, C2, C3, etc. The tube is designated as tube A1. (See Plate I.)

The B1 hoop, usually called the *jacket*, is immediately over the rear end of the tube and extends well forward of the powder chamber. Hoops over the jacket are called *jacket hoops*. The present tendency is to omit the term "jacket," using simply the term "hoops" with the proper designation.

Hoops over the forward or muzzle part of the tube are called *chase hoops*.

Locking hoops are those which hold two abutting hoops together and prevent their moving forward or aft in the finished gun. Inner locking hoops are split or made in semicircular halves and are fitted over shoulders on the two elements to be locked together. They are held in place by setscrews and an outer hoop is shrunk over them. Outer locking hoops are screwed on.

(2) *A wire-wound gun* is assembled by wrapping *wire* under tension

on a central *tube*. An outer cylinder, or jacket, is generally shrunk on over the wire.

(3) *A heavy radially-expanded gun*, such as the 8-inch, 55-caliber gun, is composed of a *tube* and a shrunk-on *jacket* that extends a little more than half way from breech to muzzle. When the rifling is worn out the entire tube may be renewed. Some radially expanded guns are constructed with liners.

406. Exterior parts (See Plate 1).—A gun as viewed from the outside has the following parts: *Breech, rear cylinder, slide cylinder, chase, neck, muzzle.*

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 moves through it in recoil. It is fitted with a key that is contained in a keyway in the slide which prevents the gun from turning in the slide, restricting it to longitudinal motion only. This part of the gun is made truly cylindrical to fit snugly in the slide.

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 neck is just in rear of the muzzle, where the chase reaches its smallest diameter.

The muzzle. 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 and to prevent enlargement of the bore due to high muzzle pressures.

The trunnions are two horizontal cylindrical projections at right angles to the axis of the bore of the gun, the purpose of which is to support the gun on the *carriage*. They are located at or near the center of gravity of the gun, and form the axis around which it moves in elevation. In the United States Navy it is customary to have the trunnions slightly towards the breech, thus making the gun "muzzle heavy" when empty, but balanced when loaded.

In cast guns the trunnions are in one with the gun. Built-up guns are made *trunnionless*, the gun being supported by the "slide" or "sleeve" within and through which the gun moves in recoil, the trunnions in this case being cast with the slide.

The trunnions rest in "seats" on the gun carriage.

407. Interior parts.—The bore of a gun is that part of the interior of the tube that is of uniform diameter from the *powder chamber* (origin of rifling) to the muzzle.

The caliber of a gun is the diameter of its bore in inches, measuring to the tops of the lands.

The caliber of a gun, as defined above, is used as a unit in expressing its length. For instance, a 14-inch, 50-caliber gun is a gun whose caliber is 14 inches and whose length is 50 calibers measured from muzzle face to the forward face of the breech plug when closed, that is, 50 units of 14 inches each. The expression "14-inch, 50-caliber" in this case would indicate that the A-tube of the gun, containing the powder chamber and rifled bore, is 700 inches in length. The over-all length of the gun would be 700 inches plus the length of the screw box.

The chamber of a gun is the space allotted to the powder charge, and is that part of the interior of the tube between the bore and the face of the breech plug when closed. The chamber is made larger in diameter than the bore in order to reduce its length, and so give a greater length of travel for the projectile in the bore. The ratio of the diameter of the chamber to the diameter of the bore is called *chambrage*.

The chamber cylinder is the cylindrical portion of the chamber, extending from the end of the chamber rear slope to the beginning of the chamber front slope.

The after end of bag gun chambers are built with a *choke*, a narrow cylindrical band of lesser diameter than the *chamber cylinder* (Plate I). The purpose of the choke is to keep the area of the mushroom face as small as possible to reduce the load carried by the screw threads on the breech mechanism, while at the same time permitting a proper chamber volume which is not too long. Extending from the choke to the chamber cylinder is the *chamber rear slope*. In rear of the choke is the *gas check seat*, which is reamed to form a perfect fit with the split rings and mushroom pad to prevent blowbacks. Case guns, of course, do not have a choke.

The *chamber front slope* is the slope from the forward end of the *chamber cylinder* to the *shell centering slope*, which extends to the rotating *band slopes*, *i.e.*, to the end of the chamber. The purpose of the shell centering slope is to guide and center the projectile into the bore.

The forms of chambers may vary, for instance, in some chambers there may be but one *band slope*, while in others the band slope may be composed of as many as three parts, as the *band rear slope*, the *band cylinder*, and the *band front slope*. Obviously the construction of these slopes depends upon the type of projectile rotating band, which must fit into corresponding seats.

Section II.—Principles Underlying Gun Design.

408. Modern requirements for gun power.—Present requirements for guns demand muzzle velocities of from 2,500 to 3,150 feet per second. Lower velocities give less striking energy, 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 a 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.

A gun may be considered as a tube designed to withstand a given pressure from within. 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.

409. Stresses.—Looking simply to the construction of a gun as a 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. (See Fig. 401.) It has been ascertained as the result of experiment that the

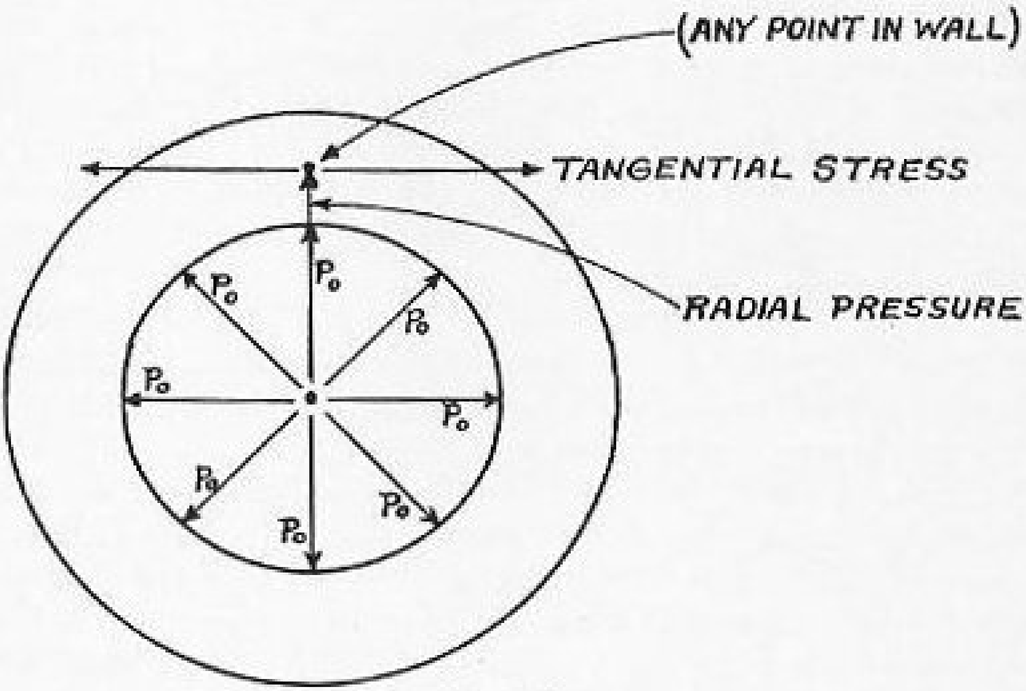

FIG. 401.

greatest stress experienced by the metal of the gun is the tensile stress set up in the direction of its circumference by pressure of the powder gases; in addition, it also experiences a longitudinal stress, which is relatively of small value. If this longitudinal stress may be considered constant (and it may be so considered in the case of guns, without great error) we may lay down the first of "Lamé's laws," as follows: *At any point whatever in a cylinder under fluid pressure, the sum of the tangential tension and the radial pressure varies inversely as the square of the radius.*

This law says, in effect, that in a simple hollow cylinder under internal pressure, points in the metal close to the bore experience a large proportion of the stress, whereas those remote from the bore, *i.e.*, at a great radius, experience only a small proportion. This means that in a simple hollow cylinder composed throughout of metal of homogeneous physical properties, we soon reach a limit beyond which *any 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 a 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.

410. The considerations of the two preceding articles, that is, modern gun pressures and the strength of simple hollow cylinders, bring out the fact that a modern gun would not be sufficiently strong to withstand the required pressure if made of a single simple hollow cylinder, however thick, and that the gun must be built on a principle which will enable it to withstand more internal pressure than could be withstood by the simple cylinder type of construction. The problem is to make the outer layers take a proper proportion of the stress. Two principles of construction present themselves in this connection. The first principle constructs the gun of layers of metal, the layer nearest the bore having the greatest elasticity and the succeeding layers outward having successively decreasing elasticity, so that when the gun is fired the inner layers, while resisting the pressure, expand sufficiently to transmit to the outer layers their due proportion of the stress. The second principle constructs the gun of layers of metal, the layers nearer the bore being held under an initial *compression* by the *tension* of the outer layers, so that when the gun is fired the inner layers must first be expanded sufficiently to remove the initial compression before they begin to experience a positive tension or stretch, the expansion being continuously resisted by the tension of the outer layers. These two principles may be stated as follows:

(1) **The principle of varying elasticities.**—This consists of 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, in a built-up gun, 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.

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 limit, is a matter for mathematical calculation, and is treated at length in works on the theory of gun construction.[1]

411. Guns built on the principle of varying elasticities, where composed of separate layers of different metals, are not used by the U. S. Navy and will not be discussed. Guns built on the principle of initial tensions are exemplified by the *built-up gun* and the *wire-wound gun*. Most guns now in use in the Navy are of the built-up type, and none is of the wire-wound type, although the Army uses this type. Of late years the *radial-expansion* process has been used to construct guns for naval use up to a caliber of eight inches. This process embodies both the principles of initial tensions and of varying elasticities while employing only a single piece of metal (necessarily) in the construction. The principles embodied in the construction of the built-up gun, the wire-wound gun, and the radial-expansion gun are hereafter discussed.

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[1] This section aims to present only an elementary discussion of the principles underlying gun construction. For a more complete treatment of construction on the principles of initial tensions, see "Elastic Strength of Guns," *Naval Ordnance, 1933.*

THE BUILT-UP GUN.

412. Gun steel, as well as other metals, is elastic in that, when a comparatively large stress is applied, the steel will receive a strain,[2] and upon the stress being removed, the steel will return to its former shape or dimensions. In such a case the steel is said to have been strained within its elastic limit. On the other hand, if the steel is stressed up to its elastic limit of strain, and the stress is then increased, it will take up a permanent strain and will not return to its former shape or dimensions upon release of the stress. It is then said to have been strained beyond its elastic limit. Application of continually increasing stress in such case will eventually result in fracture of the steel, at a stress whose value will depend upon the strength and qualities of the particular steel being considered.

The above statements apply to steel in which the only strains present are those caused by the applied stress. In the simplest built-up gun we take an inner steel tube of *outer* diameter d, and place around it a cylindrical jacket of *inner* diameter d-s, s being small, on the order of 0.″01; s is called *the shrinkage*. The usual method of doing this is to heat the jacket, thereby expanding it, and to slip it over the cold tube, allowing it to cool and shrink in place. The result is that the tube receives a strain in compression (negative extension), because of the shrinkage of the jacket upon it, and the jacket receives a strain in extension, being unable to shrink to its former size. These strains are well within the elastic limit of strain of the steel. We have here, then, not an initially unstrained steel, but a compound cylinder of two members, the inner of which has an initial strain in compression (negative) and the outer an initial strain in extension (positive).

When powder pressure (stress) is applied in the bore of such a compound cylinder, the pressure must first expand the tube enough to remove the initial strain of compression before it can continue the expansion toward the elastic limit of extension of the tube. Such expansion is continuously opposed by the jacket, which is pressing inward. This action may be stated in the following principle: *If any pressure be applied to a compound cylinder, the strain at each point will be the* **algebraic sum** *of the strain at the point before the pressure was applied and the strain which the same pressure could cause at the corresponding point in a simple cylinder of the same dimensions as the compound one.* In a compound cylinder, according to this rule, the inner layer receives less strain in firing than would be received by the corresponding layer in a simple cylinder, for the original compression must

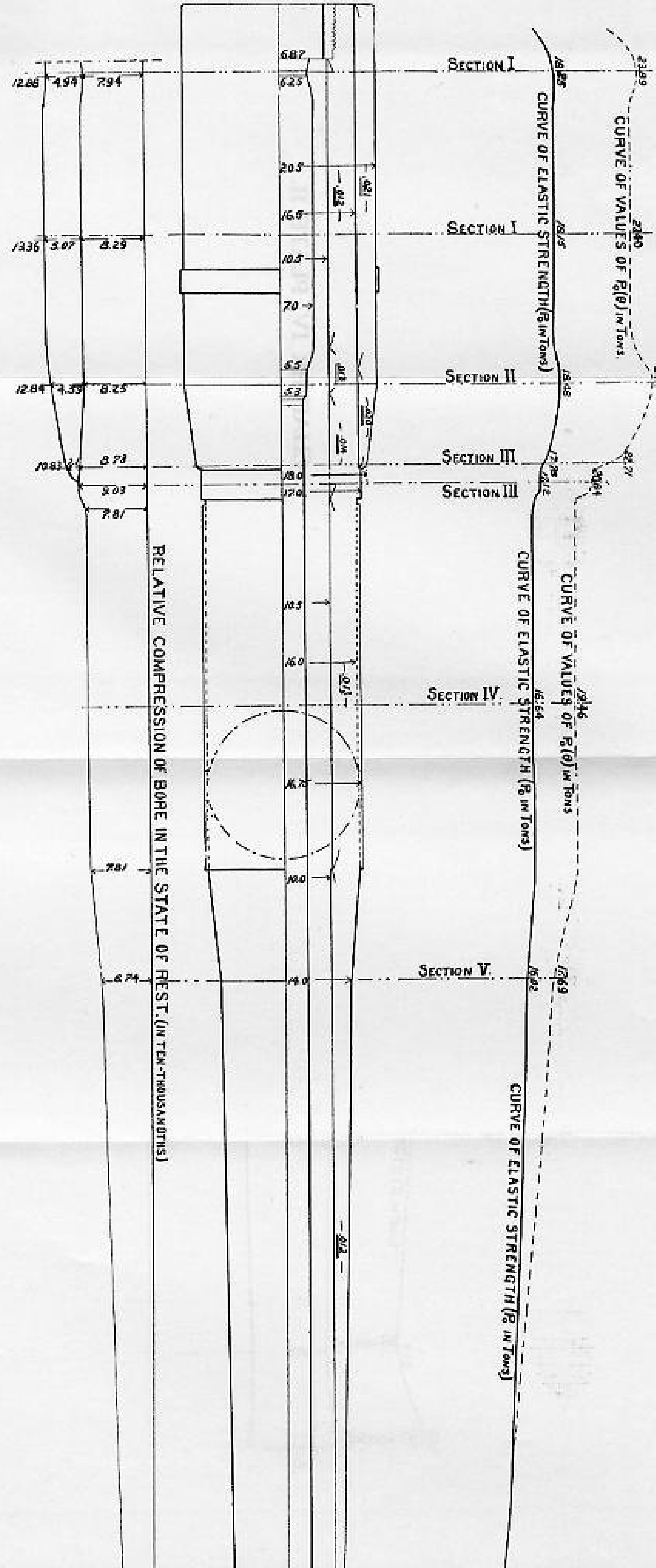
[2] Synonyms for strain: Deformation, compression or extension.

first be overcome before any positive strain (extension) can be introduced. Correspondingly, the outer layer receives more strain than it would in a simple cylinder, for it receives the strain it would receive in the simple cylinder *plus* the original strain in extension that it receives in construction. In this way the disadvantage of the simple cylinder, as stated in Lamé's law, Art. 409, is obviated, the stress felt by the different layers of the gun being no longer inversely proportional to the square of the radius, but instead, more evenly apportioned among the layers of metal. The following axiomatic and fundamental law must always be observed, however, both as to strains set up by shrinkage and as to strains set up by firing:

Basic law of built-up gun construction.—*No fiber of any cylinder of a built-up gun must be strained beyond the elastic limit of the metal of that cylinder.*

413. In a built-up gun the outer cylinder, in cooling and contracting, 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*. 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. It is 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.

414. Layers and thicknesses.—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, the difficulty of obtaining sound forgings of large diameter and length, and the greatly increased cost; for these reasons it is not considered practicable to use more than four layers in the case of guns now designed. Neither may all of these layers extend all the way to the muzzle, because of weight and forging considerations. It is not, in fact, necessary to have them that long. The inner member, the tube, extends in one piece from breech to muzzle, and in some guns the next layer (*B* layer) does also, but in two or more pieces. The *C* and *D* layers extend from the breech only a part of the


SECTION I
SECTION I
SECTION II
SECTION III
SECTION III
SECTION IV.
SECTION V.
CURVE OF ELASTIC STRENGTH (P_0 IN TONS)
CURVE OF VALUES OF $P_0(\theta)$ IN TONS.
CURVE OF ELASTIC STRENGTH (P_0 IN TONS)
CURVE OF VALUES OF $P_0(\theta)$ IN TONS
CURVE OF ELASTIC STRENGTH (P_0 IN TONS)
RELATIVE COMPRESSION OF BORE IN THE STATE OF REST. (IN TEN-THOUSANDTHS)
12.86
4.94
7.94
13.36
3.07
8.29
12.84
4.39
8.25
10.83
8.73
9.03
7.81
7.81
6.74
6.87
6.25
20.5
16.5
10.5
7.0
6.5
5.3
18.0
17.0
10.5
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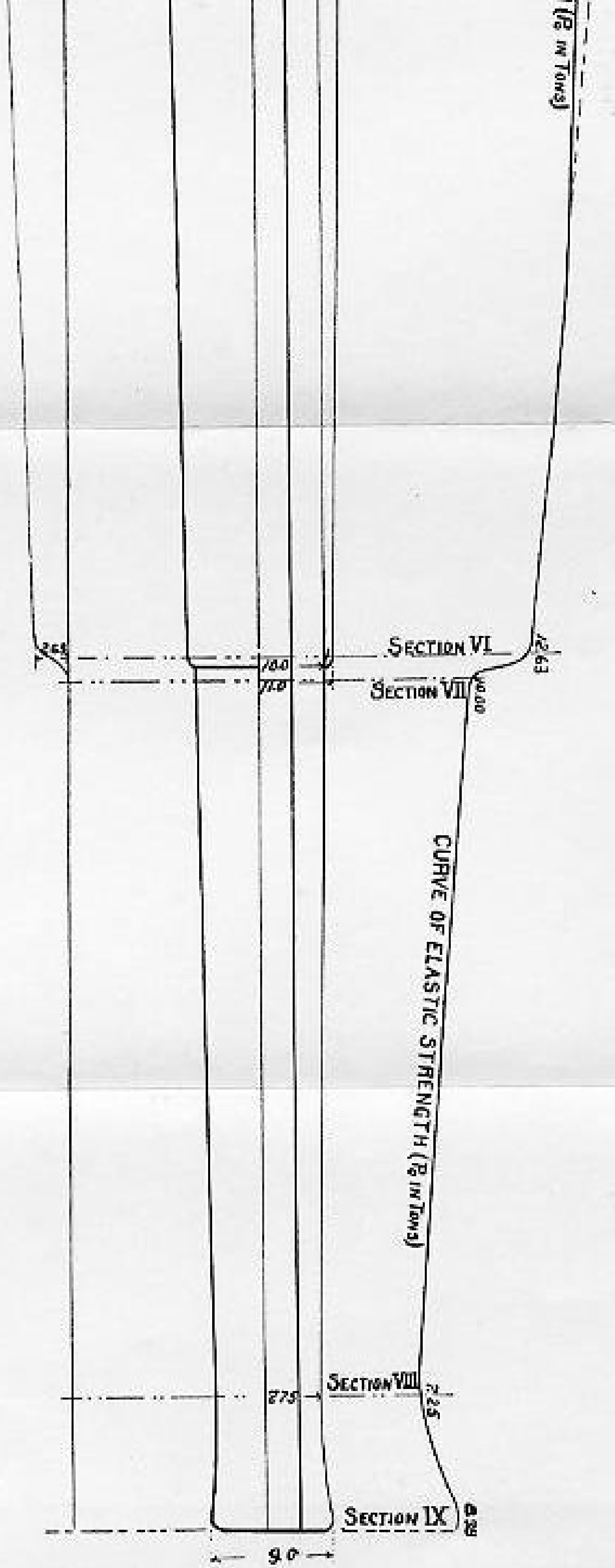
23.40
24.75
22.71



SECTION VI
12.63
10.0
11.0
SECTION VII
10.00
CURVE OF ELASTIC STRENGTH (P IN TONS)
2.75
SECTION VIII
7.25
SECTION IX
9.0

way toward the muzzle. This is possible because of the following considerations:

Shortly after the projectile begins to move, the pressure inside the gun decreases, and continues to decrease as the projectile approaches the muzzle. By the principles and formulas of "Interior Ballistics," Chapter III, we can find the pressure of the powder gases at any point of travel of the projectile through the bore. By solving for a number of points and plotting them on the axis of the gun, with the pressures as ordinates and the travel of the projectile as abscissas a curve of pressures can be constructed for a given powder that will approximate 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. An example of a pressure curve plotted with a strength of gun curve is shown in Chapter III, Plate II.

THE WIRE-WOUND GUN.

415. The wire-wound gun 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 uniform tension of the wire, and each exerts a compression on the layers which are inside of it. The wire is of square cross section, perhaps 0".1 on a side, or of ribbon shape. The wire having been wound in place, the gun is finished with an outer layer of steel, shrunk on over the wire. 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. The Navy does not use this system because of the droop in such guns.

THE RADIAL-EXPANSION GUN.

416. Before considering the principle of construction of the radial-expansion gun, it will be necessary to examine some of the properties of gun steel which have not yet been considered. In the discussion of built-up gun construction, it was stated that gun steel is elastic within limits, in that if a stress is applied so as to set up a strain not exceeding the elastic limit of strain of the steel, then the steel will return to its original shape and dimensions when the stress is removed. It is then said to have been worked within its elastic range. If, however, when the elastic limit of strain has been reached, the stress is *increased*, the steel will yield rather suddenly and suffer a comparatively large strain without further increase in stress. Thereafter increase in stress will still further increase the strain. The steel is now being worked in its semi-plastic range.[3] The important point is that the steel has now received a permanent set or deformation, *but nevertheless, will attempt to return to its former dimensions when the stress is removed*. In other words, it has suffered a deformation that is permanent but elastic.

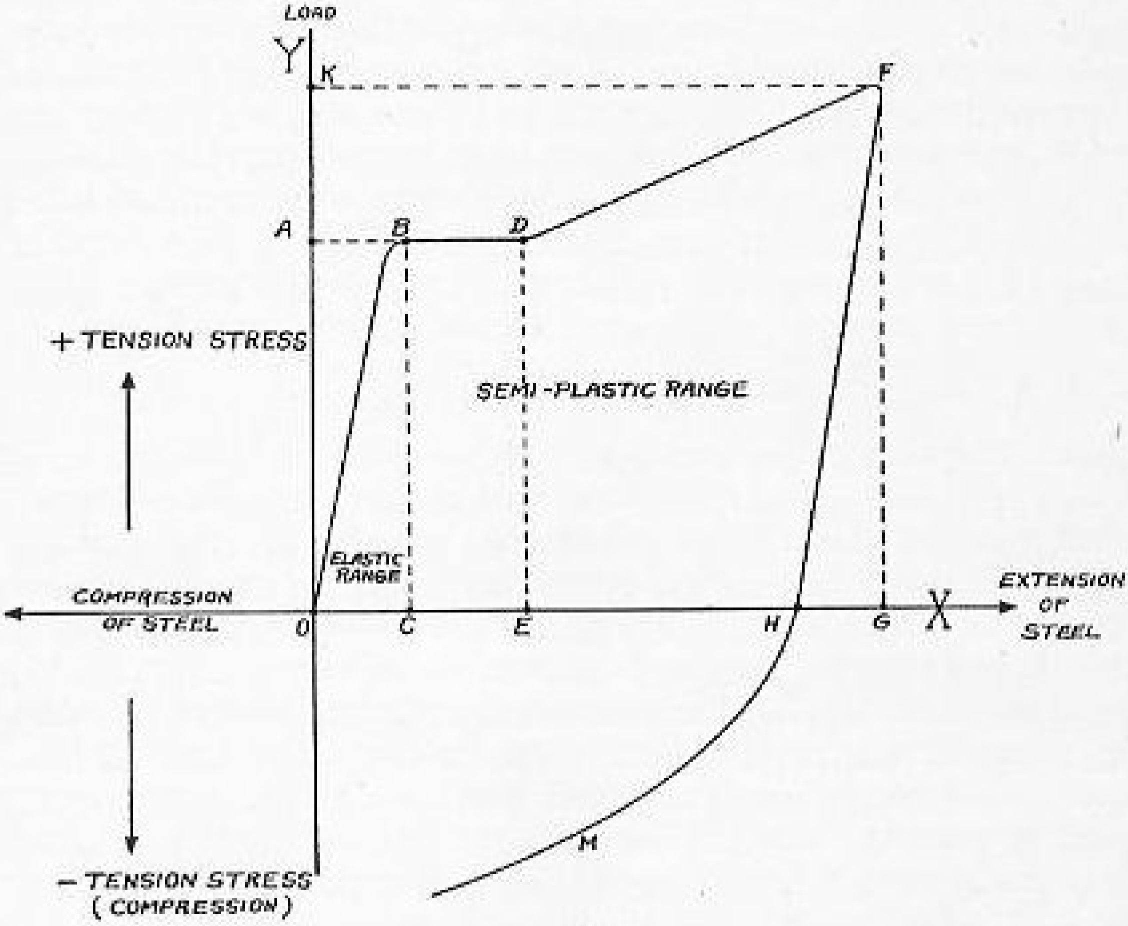


FIG. 402.

The above properties of gun steel are plotted in Fig. 402, in which the ordinates, measured along OY, represent the stresses applied to a test piece, and the abscissas, measured along OX, represent the corresponding strains set up. The curve is drawn only to show tension stresses causing extension strain in the steel, but it could be shown that the steel behaves similarly under compression stresses causing compressive strains. It is seen that as the stress is raised from O to A, the steel is strained by the amount OC. If the load is increased slightly,

[3] If the stress is still further increased the strain will go beyond the semi-plastic range and the steel will give rapidly and fracture, even with decrease of load.

the steel is seen to yield suddenly and suffer the additional strain CE at practically constant load. A further increase in the load to K causes an additional strain EG. The behavior of the steel thus far is represented by the curve $OBDF$. If the load is now removed, the curve is seen to return, not to the origin but to the point H, the line FH being about parallel to OB. The steel has taken the permanent deformation, or strain, OH but still has elastic properties, as is shown by the decrease in strain from G to H upon removal of the load. HG is somewhat larger than OC. If the same test piece is again stressed, a stress equal to OK will be required to strain it by the amount HG; for purposes of such a second stress, H may be considered to be at the origin.

From the above, it may be seen that the steel has acquired two important new properties:

(1) It has received a permanent deformation, or strain, and *will resist* a compression stress tending to compress it to its former dimension (Curve HM shows this action).

(2) It has changed its physical qualities in that the application of a stress beyond its original elastic limit, has given it a new elastic limit practically equal to the stress it has sustained.

417. The foregoing properties of gun steel are made use of in constructing a monoblock (one-piece) gun by the radial-expansion process. In this process the gun forging is bored to a diameter somewhat less than the finished dimension and turned down on the outside to something greater than its finished diameter. Hydraulic pressure is then applied to the bore. By Lamé's law, as given in Art. 409, the metal at various points through the wall of the gun will experience stresses which are inversely proportional to the square of their radii. The pressure in the bore is increased in steps, until a thin, indefinite layer of metal nearest the bore is brought to its elastic limit of strain. At this time all the other (imaginary) layers of metal in the forging are also strained, but all within their elastic limit, and the amount of strain decreases regularly as we consider layers of the metal more and more remote from the bore.

The pressure is now increased so that the bore layer is strained beyond its elastic limit, the layer next outside the bore layer is brought just to its elastic limit, and the tension in all the other layers is increased. Still further increase of pressure increases the permanent strain in the bore layer (which is now being worked in the portion of the curve BDF, Fig. 402), strains the second layer beyond its elastic limit, brings a third layer up to its elastic limit, and increases the tension in all the other layers. The increase in pressure is continued until the outside layer of metal just reaches its elastic limit of strain, and this pressure is held for a time. This pressure is considerably greater than the pressure which the gun will be called upon to withstand when fired.

When the pressure is removed and the metal allowed to return to a state of rest, the physical condition of the forging is as follows: The bore layer, having experienced the greatest stress and therefore received *the greatest permanent strain*, is pressing outward upon the second layer, for it tends to be larger than the second layer. Having received the greatest stress, it has a greater permanent-and-elastic limit than the second layer and a greater elasticity. Conversely, the second layer, having received slightly less stress, is strained slightly less, has less elasticity, and is pressing inward upon the first layer. Continuing outward, the third layer bears the same relation to the second layer as the second does to the first, and so on. The result is that the inner layers are being pressed upon by the outer layers and receive a strain in compression, as in the curve *HM*, Fig. 402; but they resist this pressing inward by pressing outward, and thereby place the outer layers in a state of tension. We then have a gun constructed by a process of self-hooping (*autofrettage* is the French term), made as if composed of an infinite number of infinitely thin hoops shrunk together and therefore demonstrating the principle of initial tensions. And because in this cold-working process, the successive layers have received successively decreasing elasticity, the bore layer having the greatest, the gun may be said to demonstrate the principle of varying elasticities.

418. The radial-expansion process produces a gun which, like the built-up gun, distributes the internal pressure (stress) more or less evenly throughout the layers of metal of the gun walls, rather than to require the inner layers to withstand the major portions of the stress, as in the case of a simple single hollow cylinder. The radially expanded gun distributes the stresses much more uniformly, however, than does the built-up gun. When considering two guns of equal strength manufactured by these two processes, the radially-expanded gun will be much the lighter, or, if of equal weight, the radially expanded gun will be much the stronger.

Although to date most radially expanded guns are of monoblock construction, this process is not confined to the use of a single forging. Where the size of the gun would require a single forging so large as to throw doubt on its soundness, the gun may be made of a radially expanded jacket shrunk upon a radially expanded tube, thus combining the built-up and radial-expansion processes. Eight-inch guns are now being constructed in this way. The details of manufacture of radially expanded guns are given in Chapter VI, Section III.

Section III.—Practical Gun Design.

419. In making up the design of a new gun, three major considerations must be kept in mind. They are:

(1) **The ballistic conditions.**—The gun must produce a given ballistic result, *i.e.*, must deliver a certain muzzle velocity to a projectile of given weight, within the practicable maximum pressures derived from experience in gun design.

(2) **The mechanical conditions.**—Its construction must be such as to withstand the pressures produced by the burning of the propelling charge, *i.e.*, it must be strong enough, but not unnecessarily strong or heavy, and with proper strength distribution.

(3) **The service conditions.**—The gun must fulfill the necessities of the service relating to mount installations, working of the breech, loading, training and elevating.

420. So many variables enter into gun design that experience, based on a sound understanding of the principles of gun construction, can be the only safe guide. The consequences of the bursting of a gun in service are so grave that all possibility of such an accident must be avoided, and yet the gun must not be made excessively heavy nor of a form that cannot be mounted in turrets or mounts that have proved the most satisfactory. Experience has shown the general form a gun must take to give the best results with the powders in use at present, and no radical changes in this form can be made without inviting disaster. With any new design it is attempted to retain the advantages of previous types and to eliminate any defects that have shown up in service or may seem to be indicated by carefully tested theories. Therefore, in laying down a gun the previous designs are closely followed as regards the general outline, thickness and length of elements, mode of attachment of the various parts to each other, manner of assembly and approved practice in general where it appears to answer the purpose. The radical change of too many variables being inadmissible, it follows that progress is necessarily slow, and that at one stroke all previous defects may not be eliminated and a gun produced that will be perfect for all future time.

With these considerations in mind the outline of the new gun will follow closely the outline of a previous gun that seems best adapted to the purpose; changes in the outer dimensions will be made where it seems necessary and thus the form of the gun will be arbitrarily fixed. It may be that a gun of the same caliber will not be chosen as a pattern, but one of a smaller or larger caliber type that seems to have fulfilled certain of the requirements for the new type.

The following brief discussion of the manner in which a design is made up applies to a built-up gun, but most of the principles are applicable to the design of other types of guns.

421. General considerations.—The built-up, high-powered gun is essentially a compound cylinder designed to withstand rapidly varying but not instantaneous internal pressures. The object of the subdivision of the gun into various elements is twofold: 1st, to increase the range through which the metal of the gun may be worked and thus increase the magnitude of the resisting elastic forces by assembling the elements with shrinkage; and 2d, to insure the homogeneity of the metal and thus the safety of the gun by its subdivision into sufficiently small elements. It is a principle of metallurgy, in the present state of the art, that there is a practical limit to the size of cast-steel ingots. If this size, which may be determined solely by experience for each kind of steel, is exceeded, the ingot will have unsound areas which no subsequent forging can entirely cure. This unsound metal, in the forms commonly known as segregations, sand splits, streaks, and blowholes, must be carefully avoided during manufacture if the guns are to merit a proper degree of confidence. Manufacturing processes are undergoing constant improvement, but at the present time two principles must be invariably considered in gun construction: 1st, that in high-powered guns there should be at least two elements resisting stresses whose character is definitely known; and 2d, that a sound forging cannot be obtained if its wall thickness, its length, and its diameter are all very great. Furthermore, the weight of a gun has an important bearing on its mounting on board ship, and since the weight increases nearly proportionally to the cube of the caliber, this fact and the above two considerations tend to limit the caliber and power of naval guns.

If a pressure curve is drawn from the formulas of interior ballistics, it is seen that the whole gun in rear of the base of the projectile is subjected to the pressure represented by the successive ordinates passed by the projectile during its travel down the bore. When the base is opposite the maximum ordinate the whole gun in rear of this ordinate is subjected to the maximum pressure and should therefore be cylindrical from the breech to this point. The forward portion of the gun, however, is subjected to continuously decreasing pressures and may therefore continuously decrease in thickness. This decrease in thickness may be theoretically proportional to the decrease in height of the pressure ordinates. For this reason the gun is made smaller at the muzzle than at the breech and thus an economy in weight and cost is effected. The muzzle itself is flared out in the form of a bell because the metal at that point is not supported on the forward side and it is thought that the absence of slightly extra strength might induce splitting. We know that the resistance formulas do not tell the whole truth, since they take into consideration neither the supporting nor the shearing effect due to the continuation of the metal beyond the particular section considered, but experience has shown that the formulas in use give the best approximate mathematical measure of the strength of the gun as a whole, at least relatively to guns of proved worth.

For two reasons the breech cylinder over the powder chamber is usually larger than the slide cylinder. The first reason is that the chamber diameter under the breech cylinder is larger than the bore diameter under the slide cylinder, and there must therefore be an increased outside diameter for strength. The second reason is that if the gun is heavier at the breech its center of gravity will be farther from the muzzle and a smaller length need be put inside the turret or mount, barbette dimensions and weights will be correspondingly reduced, and higher angles of elevation made possible. The gun usually has an approximately constant slope from the slide cylinder to the neck cylinder just in rear of the muzzle.

422. Gun projects.—The preliminary design of a gun is called a *project*. It includes tentative sketches and rough computation as to maximum strength, muzzle velocity, and chamber capacity. When a new man-of-war is decided upon, the Navy General Board fixes the offensive armament: viz., the calibers of the guns, the weight of the projectile, and the muzzle velocity, or else the calibers of the guns and the desired ranges, from which latter data the muzzle velocity can be derived.[4] Progress being usually along lines of greater power, reduction of erosion, ease of operation, rapidity of fire, or increase in striking energy, it is probable that as many improvements as possible along each of these lines will be incorporated in the new gun. The caliber is first settled upon, and then the approximate length in calibers. In the case of small guns the muzzle velocity is tentatively fixed, but since erosion is proportionately larger for large guns it usually seems more desirable in the case of large calibers to fix the limit of pressure and with that pressure to get as high a velocity as possible.

With the three elements of caliber, length, and powder pressure several chamber capacities are chosen and calculations made as to the effects of several powders in them. From previous experience as to the limits of allowable densities of loading, the weight of powder to be used is approximated and then the various elements varied until sev-

[4] The weight of the projectile is, with few exceptions, constant for each caliber of gun in the United States Navy, $w = d^3/2$. For example, all 14″ guns use 1400-lb. projectiles and all 4″ guns 33-lb. projectiles.

eral reasonable combinations of chamber capacity, weight of charge, muzzle velocity, and maximum pressure have been obtained.[5] The fixed data are now: weight of projectile, muzzle velocity, travel of projectile, and chamber volume. From these data a final adjustment of charge, maximum powder pressure, and density of loading is made. In computing the interior ballistics of the gun, the deductions by Le Duc of the principles of nitrocellulose powder are adhered to. It is emphasized that a number of solutions are made, and that the one which is considered most suitable for the purpose is selected.

For several years the allowable densities of loading have risen in value, due to the use of more progressive powders and the tendency toward a reduction in the size of chambers for a given powder. It is desirable to have a short chamber so as to lose as little of the travel of the projectile as possible and also to get more uniform ignition, and to have a small chambrage in order that the outside dimensions of the gun need not be too great. As a general rule, though a rule that is departed from without hesitation, it may be stated that the length of the chamber is usually between 6 and 7 calibers, and the chambrage is about 1.20. At least the ratio of chamber length to chambrage is kept near these approximate proportions.

423. When the interior dimensions of the gun have been decided upon, the powder pressure curve, showing the pressure at all points in the travel of the projectile, is computed. The parts of the gun must now be designed in such a manner that the elastic strength of the gun at any point is greater than 1.4 times the greatest powder pressure which will be exerted at that point, when firing a service charge.

The question next arises as to the number of layers of metal to use. Generally large calibers have either four or five layers: four if the tube is later to be bored for the insertion of a liner and five if the liner is to be included in the gun as originally built. This rule is by no means rigid, however, as witness the 14-inch Mark IV gun with four layers, liner included. The practice most in favor at the present time is to build five-layer guns with a liner tapered from breech to muzzle for easy removal.

The problem, then, is to apportion the metal among four layers, the inner and outer radii being given. For the greatest theoretical transverse strength the law of thickness requires that if R_0, r, R_1, R_2 and R_3 are the respective radii from the bore outward, they must be connected together by the following relations:

[5] The first requirement of the powder is that the individual grains are completely burned before the projectile reaches the muzzle. Powders of different quickness can be used and, in general, a quicker powder will give the desired muzzle velocity to the projectile with a smaller charge and higher pressure than a slower powder.

$$r^2 = R_0R_1, \quad R_1^2 = R_2r, \quad R_2^2 = R_1R_3.$$

These ratios may not be rigidly adhered to for the following reasons:

(1) For large-caliber guns the breech diameter of the liner must be great enough to allow for at least three shoulders having a height of from 0″.2 to 0″.25 and the proper taper and yet leave sufficient metal at the muzzle for rigidity and for the prevention of creep due to the mandreling effect of the projectile.

(2) It is desirable to have a heavy tube so as to provide rigidity for the gun and so prevent droop of the muzzle.

(3) The layer carrying the screw-box liner must have enough additional thickness to provide for taking the longitudinal stresses without impairing the transverse resistance of the gun. The usual rule is to compute this layer for longitudinal strength and then make it from 2.5 to 3 times as thick as necessary to carry the longitudinal stress. The extra thickness is taken about equally from the contiguous layers on both sides.

(4) The thickness of the outside layers must not be so great that it will be impossible to get good forgings.

(5) Sudden and great changes in the diameter of the gun or its component parts must be avoided.

It is apparent that in the case of a large gun with a large number of elements, as, for instance, the Mark VII 12-inch 50-caliber gun, which has 12 parts, considerable juggling will be necessary before the above conditions can be satisfied and yet obtain sufficient transverse strength.

424. Having decided upon the various diameters near the breech, at the forward end of the slide cylinder, and at the neck, the related questions of the manner of assembly and the character of the joints and shoulders are taken up. The following principles in this connection must be rigidly observed:

(1) Joints must be of such a character as to allow the elements to be easily assembled.

(2) The tube and liner must be locked to prevent crawl, and all other elements must be locked both ways to prevent movement in either direction.

The tube and liner are so long that ordinarily the shrinkage friction will prevent rearward motion, but shoulders must be provided to keep them from going out at the muzzle.

Locking is accomplished by means of locking rings, locking hoops, and shoulders. Locking rings are relatively short and thin rings either hooked or screwed to the elements of the gun; they are not assembled with shrinkage and do not contribute to the gun strength. Locking hoops ordinarily attach to the other elements by hook joints and are assembled with shrinkage; they are longer and heavier than the rings.

Shoulders are turned on an element to prevent relative longitudinal movement between it and the element shrunk over it. The distance between shoulders varies as experience dictates. Their height may be from 0".2 to 1".0, the usual height being about 0".5 where possible. As a general rule two shoulders are not put in the same transverse plane, because a plane of rupture is most likely to form at a shoulder, and it is best to scatter the weakest parts so that one plane will not include the weak points of several layers. The same rule is followed with joints.

Butt joints are avoided when it is possible to use a lap joint. The latter are preferable because they distribute the weakness over a greater length, they assist locking and contribute to the stiffness. Joints at the outside of the gun in particular must be designed so as to prevent droop, as droop is due partly to stretch of the metal and partly to working at the joints.

The general design and method of attachment of the screw-box liner are selected. Its length has usually been fixed at about one caliber, but the tendency at present seems to be toward an increase in this dimension. An attempt is made to eliminate defects that may have appeared in previous designs.

425. Several drawings are worked up to embody the various ideas that have been expressed.[6] If there are three drawings, for example, one may show a heavy gun, one a light gun, and one a gun of medium weight, and in each the arrangement will be slightly different. Possibly one drawing will be of a four-layer unlined gun, one of a four-layer lined gun, and one of a five-layer lined gun. Or, in one the joints and layers may be arranged according to previous designs and in one they may be laid down on a new plan. During their construction the drawings are subjected to continuous criticisms and change and new ideas are included as they may occur to those in charge of the project.

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[6] The drawings include:

(1) Shrinkages, strength, velocity, and pressure curves.
(2) General arrangement.
(3) Details.
(4) Chamber and breech.
(5) Rough forgings.
(6) Shrinkage sheet.
(7) Center of gravity for shrinkage pit.
(8) Rifling.

Other drawings may sometimes be required, but these drawings are always made, though not always in the above order.

The breech-mechanism drawings and computations constitute a separate set.

Finally, after several weeks' work, when the various projects seem to answer the requirements determined upon, the total weight, location of the center of gravity, and an approximate strength curve are computed for each. They are then submitted for final criticism and decision.

Usually one of the projects is decided upon, though it may be desirable to make a few minor changes in it. The exact chamber is definitely selected and, as a rule, the maximum bore pressure and the muzzle velocity are fixed, together with the desired weight of charge. Orders are then issued for the definite working up of the design, and a decision is made as to whether the batteries of one or more ships are to be built at once or a type gun only. It is the usual practice to build a type gun when a new caliber is in question or when the changes have been numerous and radical as compared with existing guns.

A mark is then assigned to the design selected.

Section IV.—Rifling of Guns.

426. Rifling.—It is essential that the oblong projectile should keep point foremost in flight in order to secure range, accuracy, and penetration. This is accomplished by giving the projectile a high rotary velocity about its axis which results in securing steadiness of flight by keeping its geometrical axis in the tangent to the trajectory.

The *rifling* cut in the bore of a gun consists of spiral grooves whose function is to engrave the rotating band immediately after the projectile begins its motion and then to cause rotation as the motion continues. For engraving the band the rifling is slightly coned at the origin, to fit the conical part of the band, and this is called the *band slope.*

Most U. S. naval guns now in service contain rifling in which the grooves occupy, at the muzzle, about half the circumference, or, in other words, lands and grooves are of about equal width. This practice is by no means universal, and there are frequent instances where the grooves are as much as twice the width of the lands. It will be noted that the ratio between width of lands and grooves has been qualified by specifying *at the muzzle*. The reason is that grooves are generally tapered in width, being wider at the origin of rifling than at the muzzle. In other words, the land is wider at the muzzle than at the origin of rifling; this widening is called the "increased forcing" of the projectile. This is done to assist in maintaining the gas seal. It is easily appreciated that the maximum wear of band occurs against the driving edge of the land. If the land widens as the projectile moves down the bore, the increase in width may compensate for the wear. This question is intimately connected with the question of "increasing" and "uniform" twist, which is discussed later. It will be apparent that if the twist i variable, or increasing, the change of angularity of the land with re spect to the band may have about the same effect on the gas seal a will the widening of the land. Many guns in service of 5-inch calibe

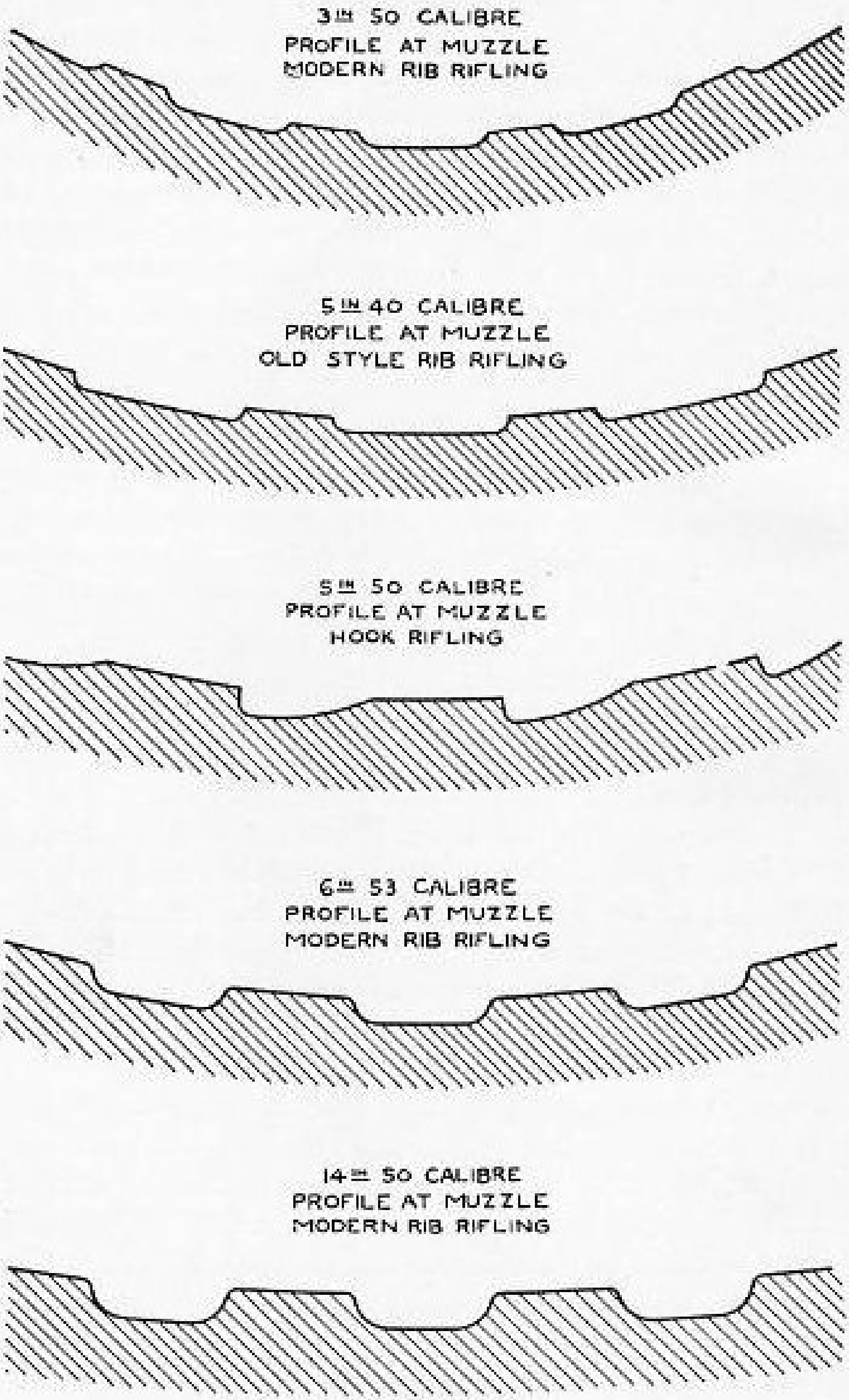


FIG. 403.

and above, with both uniform and increasing twist, have lands of increasing width. This increase has gone as high as 0.40 inch in 1,000 inches of length. At present it is the practice to maintain a constant ratio between width of land and groove in increasing twist guns, and to widen the land at the rate of 0.08 inch per 1,000 inches in uniform twist guns.

Where the bottoms of the grooves are concentric with the bore and their edges are approximately radial, the rifling is said to be *plain-section* and is usually spoken of as "ribbed" rifling. *Hook-section* or "hooked" rifling is the same as "ribbed" rifling except that the non-driving edge of the land is not radial but is joined to the bottom of the groove by a fillet of large radius. Ribbed rifling has been adopted for all large caliber guns and most small caliber guns in the U. S. Navy. (Plate I and Fig. 403.)

Sharp corners at the bottoms of grooves are considered injurious, the theory being that they facilitate the formation of heat cracks and accelerate erosion. Liberal fillets are, therefore, provided at the bottoms of grooves. Sharp corners at the corners of the lands are also eliminated but with fillets of smaller radius.

427. The depth of the groove depends on several factors; the muzzle velocity, pressure, width of band, type of rifling, sectional density of projectile, and caliber of the gun, all require due consideration. In a gun designed for high pressures, or high rotation of projectile, the driving area must be large and this can only be secured by deepening the groove or widening the band. Very deep grooves are injurious as such a form is considered to be conducive to the formation of heat cracks and the acceleration of erosion. No simple rule can be given, therefore, to govern the depth of grooves, although, speaking generally, the depth will lie between ½ and 1 per cent of the caliber.

428. As is the case with the depth of grooves, no fixed rule can be given for their number. The number of grooves is generally expressed as a function of the caliber in inches; thus 7.5 grooves per caliber would give 30 grooves for a 4-inch gun. There are certain guns of almost every caliber in the U. S. Navy where the grooves number six times the caliber and that number not only expresses the average past practice, *but is also the present practice*. In small guns the factor is increased and has gone as high as 10. Many old guns in our service from 5-inch to 13-inch inclusive, were, however, as low as four grooves per inch of caliber. Some of the most successful ordnance engineers in Europe are now using about 7.5 grooves per inch of caliber.

429. The amount of "twist" is generally expressed in America by the number of calibers traveled during one revolution of the projectile, as, for instance, *one turn in 25 calibers.* In continental Europe, the twist is frequently expressed by the angle between the groove and a plane passing through the axis of the bore. The relation between these two quantities may be expressed as follows:

$$\tan\theta = \frac{\pi}{\text{calibers for 1 turn}}, \quad \text{where } \theta = \text{angle of twist.}$$

As the tangent of small angles is approximately equal to the angle in radians, this relation can be approximated by the thumb rule of dividing 180 by the number of calibers required for one turn to secure the angularity. Thus a twist of 1 in 25 is approximately 7°. The twist of rifling is also frequently called "*pitch.*"

430. The rotation of a projectile is seldom expressed in r.p.m., but we can compare it with that of other rotating machinery, as follows:

$$\text{r.p.m.} = \frac{(\text{muzzle velocity in f. s.} \times 720)}{(\text{twist in cal. per rev.}) \times \text{caliber in inches}}.$$

Thus, a 6-inch gun, at 2,800 f.s., rifled 1 in 30, gives its projectile 11,200 r.p.m.

431. Twist can be either *uniform* or *increasing.* In *uniform twist* the grooves follow a uniform spiral, or, in other words, are inclined at a constant angle to the axis of the bore. In *increasing twist* the grooves possess little or no twist at the origin, but gradually increase the twist toward the muzzle. When the rifling begins with zero twist and *uniformly increases*, the developed curve is a parabola, and such a twist is generally called "parabolic twist." Increasing twist may be a combination of various uniform twists, connected by parabolic or easy curves. All increasing twists in U. S. Navy guns are semi-cubic parabolas. Figure 404 shows the developed curves of three forms of rifling—*A*, being uniform twist; *B*, a parabolic twist; and *C*, a combination, 1 in 50 to 1 in 32 twist, the final twist in all three being the same.

432. When rifling was first applied to cannon design it was, without exception, made uniform. At that time slow-burning powders, as we now know them, were unknown, and in uniform pitch the instant at which maximum torque is applied to the projectile coincides with the instant of maximum chamber pressure. These two factors imposed a very sudden and large torque early in the travel. It is quite evident, therefore, that under these conditions a reduction in the initial twist effected a reduction in the maximum torque. Also, a delay in the instant of maximum torque results in a slight slowing down of the powder. These influences led to the introduction and development of increasing twist, and combinations of increasing and uniform twist.

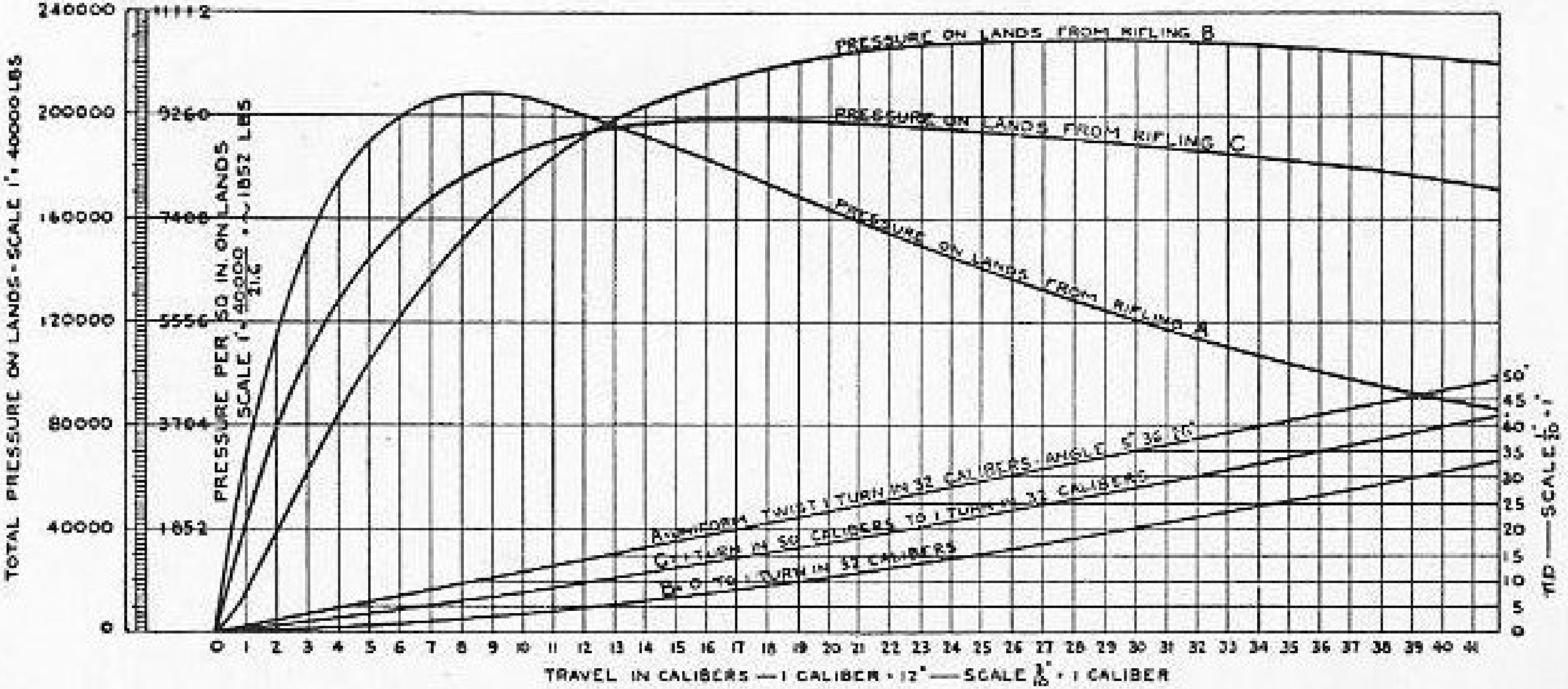


Fig. 404.—Rifle Curves for 12-Inch Gun Mark VII, Mod. I. M. V. 2900 f. s., Weight of Projectile 870 Lbs.

433. Progress in gun and ammunition design is, however, gradually diminishing, if it has not already eliminated, the advantages of increasing twist over uniform twist. Guns are longer, pressures higher, power greater, and muzzle velocity higher; while powder is being made to burn slower and increase the muzzle pressure. As applied to a modern high-powered gun, the relative merits of the two systems may be summarized as follows:

INCREASING TWIST.

1. Reduces the maximum torque on the projectile.
2. Is considered to reduce erosion, by reducing the work on the lands where the erosion is greatest, that is, near the origin of rifling.
3. Necessitates as narrow a band as possible, and consequently one band.
4. Results in considerable shearing of the band, especially in long high-powered guns, with wide bands on the projectile.
5. Probably causes additional copper deposit in the middle third of the bore.

UNIFORM PITCH.

1. Permits a band of any width or as many bands as desired.
2. Reduces the torsional strain on the muzzle of the gun.
3. Gives a clean-cut engraving to the rotating band.

434. The riflings of most American, and many European, cannon were tabulated by Mr. C. F. Jeansen, of the Bureau of Ordnance, who deduced therefrom the following empirical formula:

$$T=\frac{v}{d}\times\frac{w}{A}\times\frac{1}{K}.$$

Where T = twist in calibers at muzzle.
v = muzzle velocity in f. s.
d = diameter of bore in feet.
w = weight of projectile in pounds.
A = area of bore in sq. in. (including grooves).
K = factor of reduction.

The application of this formula to the tabulation of guns gives an average value for K of 640. Such guns as have shown the most satisfactory accuracy and life give a value very close to this figure, and it has been suggested therefore that the value of (640 ± 150) be given for future design.

This formula, while useful, is not capable of mathematical demonstration. Applying it to a 6-inch 2,800 f. s. gun, with a 105-pound projectile, we would get a final twist of about 1 in 33.5 calibers.

CHAPTER VI.

CONSTRUCTION OF NAVAL GUNS.

Section I.—Manufacture of Gun Forgings.

601. **Furnace practice.**—Nickel steel and gun steel for gun forgings are made in acid open-hearth furnaces and in electric furnaces, because of the increased probability of blowholes and gas bubbles in steel converted by the basic open-hearth 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 $2\frac{1}{2}$ per cent nickel.

From 6 to 8 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 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 a carbon 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 $Fe_2O_3+3C=2Fe+3CO$. 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. Ferromanganese or spiegeleisen is added to increase the carbon and manganese, the former being used when a smaller increase of carbon is desired. Ferrochrome 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. Ferrosilicon 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.

The following table gives the average chemical composition of gun forgings:

	Gun Steel.	Nickel Steel
Carbon	.50%	.40%
Manganese	.70 "	.70 "
Silicon	.27 "	.27 "
Phosphorus	.03 "	.03 "
Sulphur	.03 "	.03 "
Nickel	.....	3.00 "

602. Ingots.—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.

603. 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 2,300 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 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.

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 1,400° 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.

604. **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 2,100° 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, 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 1,550° 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 reforging, 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.

605. 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.

606. 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 twelve hours are generally required to thoroughly soak a forging to the desired temperature.

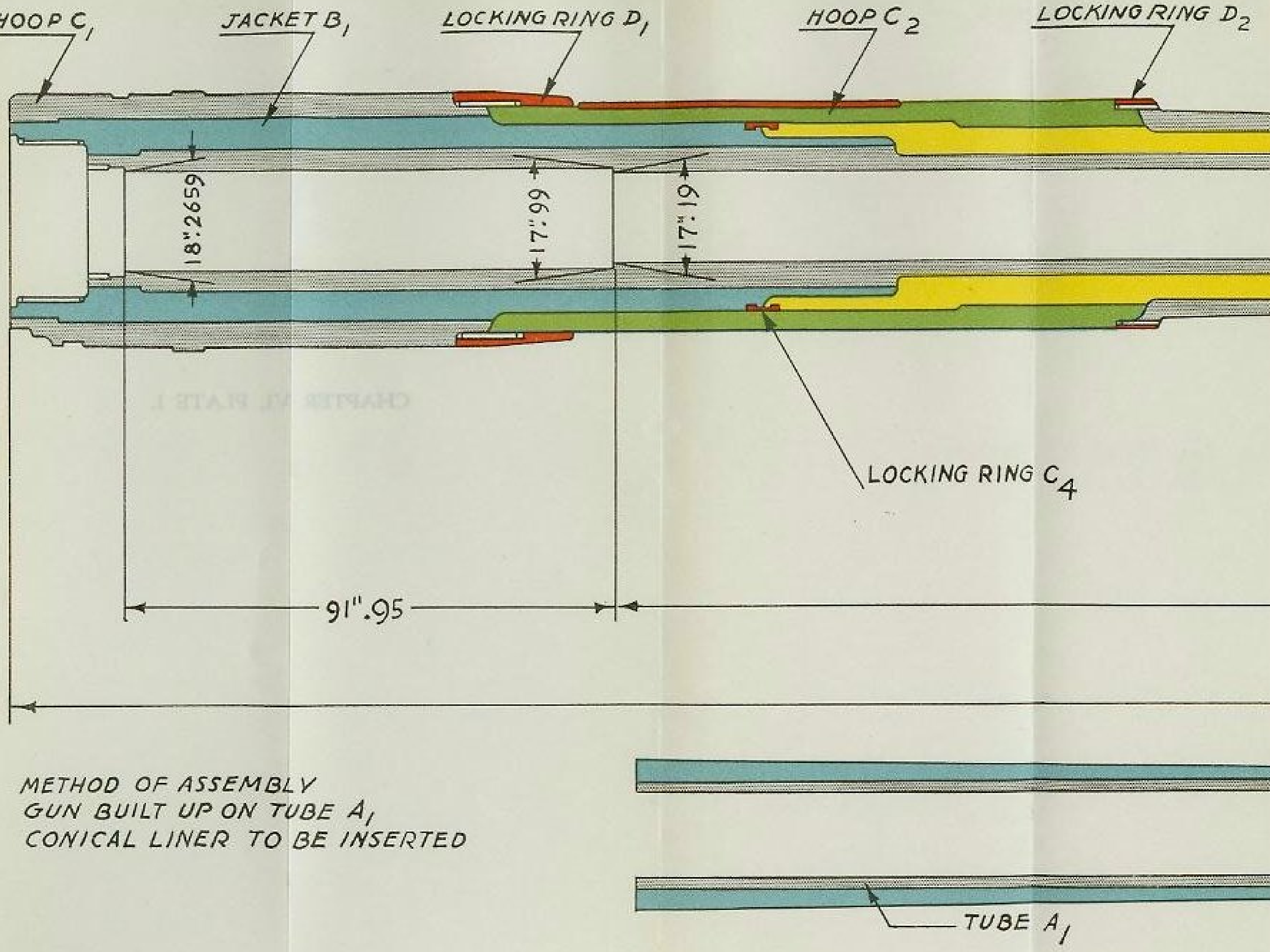
The oil wells into which the forging is immediately immersed after removal from the furnace are about the same size as the heating pits, and are also sunk in the ground. Forgings are immersed in the direction of their longitudinal axis. The oil is kept continually in circulation by means of a pump which 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 temperature. After being brought to proper heat, the forging is allowed to cool slowly. 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.

607. Determination of physical properties.—When steel for any of the above purposes is produced, tests are made to establish its suitability for the particular purpose for which it was intended. These tests involve subjecting specimens of the metal to the action of different stresses in testing machines, and observing, by means of accurate measuring instruments, the deformations produced by these stresses.

608. 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.

609. Test specimens are usually prepared to an adopted shape. In the case of gun forgings 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



METHOD OF ASSEMBLY
GUN BUILT UP ON TUBE A_1
CONICAL LINER TO BE INSERTED

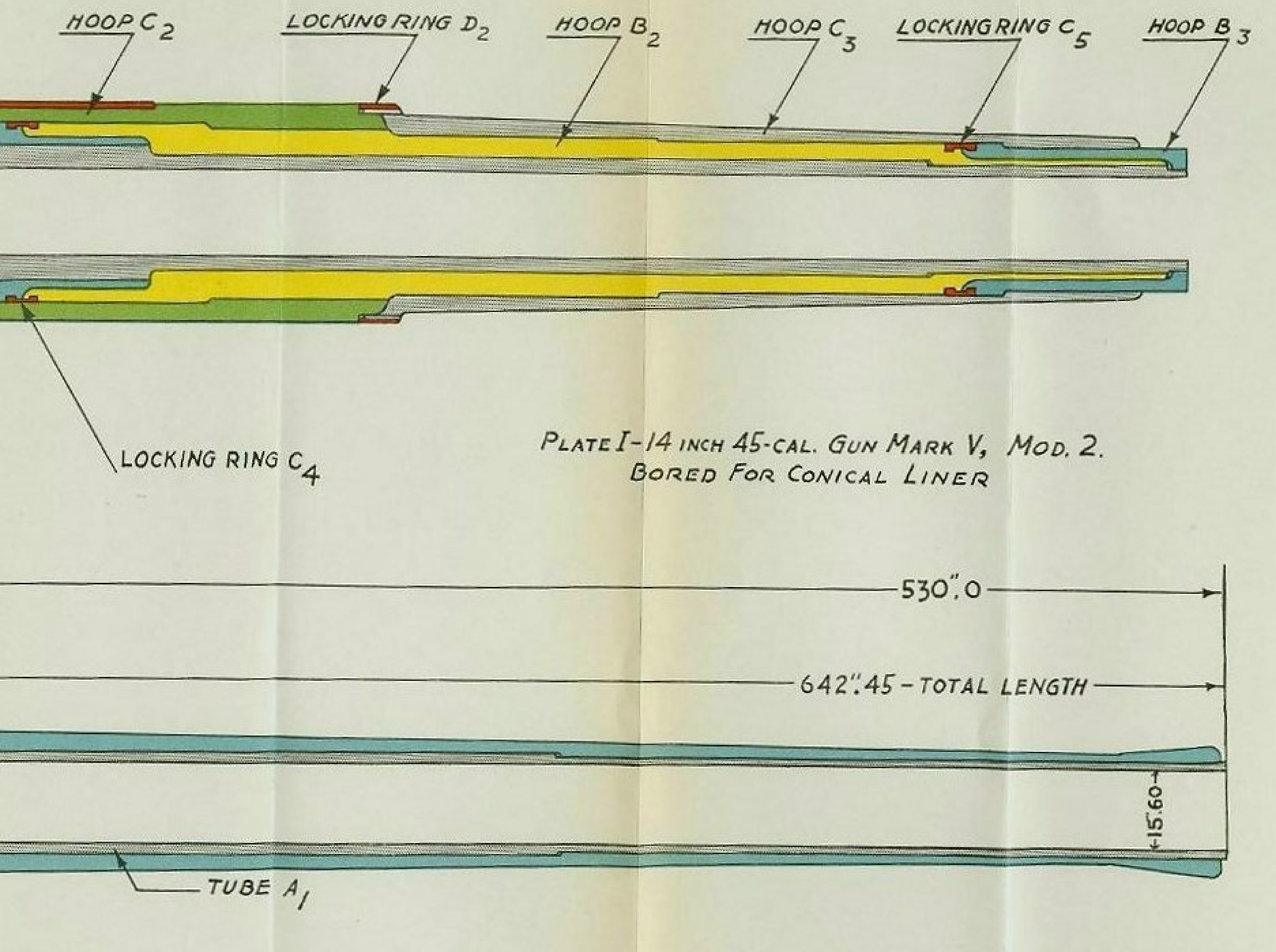


PLATE I - 14 INCH 45-CAL. GUN MARK V, MOD. 2.
BORED FOR CONICAL LINER

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.

610. Specifications governing the manufacture of ordnance material, which are changed from time to time to keep abreast of the best metallurgical practices and results, state the physical requirements the material must fulfill, and these requirements are carefully checked by inspections, by analysis, in the testing machines, and by various proof tests at the Proving Ground.

Section II.—The Manufacture of Built-up Guns.[1]

611. Introduction.—In this section there will be given briefly a general description of gun shop practice in the manufacture of built-up guns from the receipt of the rough forgings to the finished gun. As the subject of design has been previously discussed, it will not be again considered. The description given is, in general, that followed at the Naval Gun Factory, Washington, D.C.

612. Places of manufacture.—Guns for the naval service are manufactured at the Naval Gun Factory, at private plants, such as the Bethlehem Steel Company and the Midvale Steel Company, 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.

613. Summary of the various steps of manufacture of a built-up gun.—The following is a summary of the steps of manufacture:

(1) Receipt and inspection of forgings.
(2) Machining the forgings to the required dimensions.
(3) Assembling the various parts in the shrinkage pit.
(4) Finishing the gun:
  (a) Machining the bore to final diameter.
  (b) Machining the chamber.
  (c) Machining the outside surface to finished dimensions.
  (d) Rifling the bore.

[1] For additional details of the construction of built-up guns, reference is made to Chapter IX, *Naval Ordnance 1933*. Many details of the latter chapter have been omitted in this edition as unnecessary in the course of instruction for midshipmen.

(e) Determining the droop.
(f) Cutting the screw-box liner thread.
(g) Lapping the bore.
(h) Fitting the breech mechanism and reaming the gas-check seat.
(i) Milling the keyway and inserting the key.
(j) Installing the yoke.
(k) Final inspection prior to proof.

(5) Sending to the Proving Ground for proof. Returning to Gun Factory for inspection prior to issue to service.

MACHINING THE FORGINGS.

614. Receipt and inspection of forgings.—Forgings, when received at the gun factory, are examined for the marks required to be placed on them by the Naval Inspector of Ordnance at the place of manufacture. They are measured to see if they are within the allowed tolerance, weighed, and inspected for defects. Except for the smaller forgings they are rough bored by the manufacturer.

615. Turning.—After a forging has been centered in the turning lathe, a light cut is taken just deep enough to remove the scale. The work is revolved while the tool is fed along in its carriage. This cut is the only *outside* cut taken until the parts to be assembled over it have been bored and star-gauged (see Art. 619), and the shrinkage sheets completed.

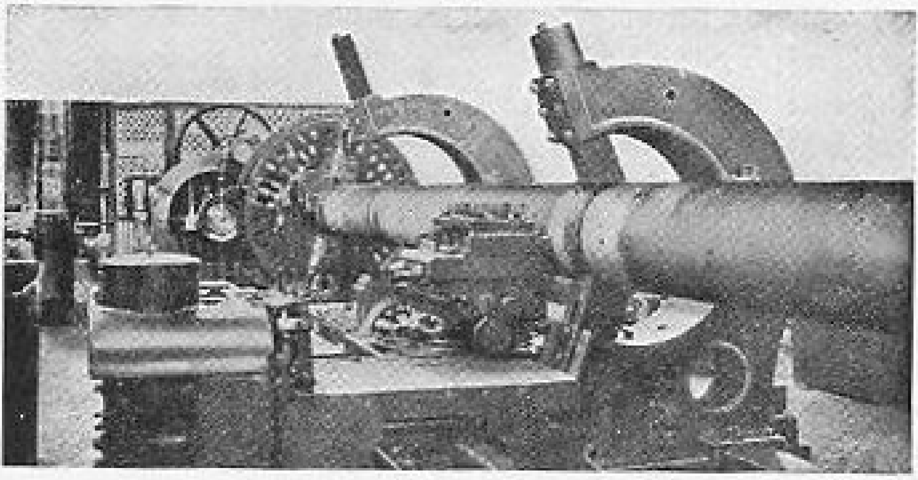
After the shrinkage sheets have been made out, the turning is continued, sometimes as many as four tools being employed at the same time on two or more carriages. For finishing cuts, tools 1 to 2 inches wide are used. Dimensions are kept within the tolerance specified on the shrinkage sheet, usually within 0.001 inch. Snap-gauges, set by rods of known length, or beam-calipers, are used to check the diameters.

Plate II shows the forging for a 14-inch tube set for turning.

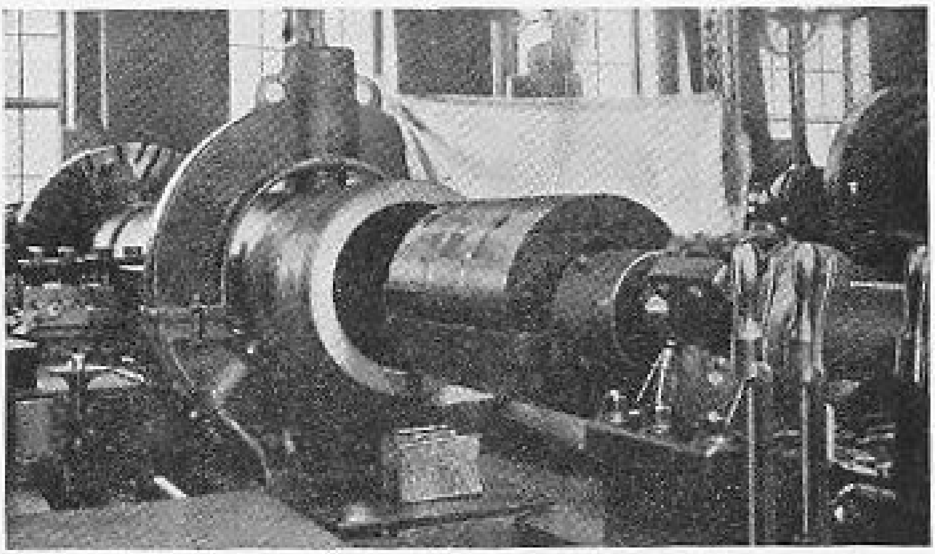
616. Boring.—For boring short hoops a *boring bar* with a cutting tool attached at its end is used. The bar is held and fed along by a carriage as the forging is revolved.

For long cylinders, owing to the sag and spring of a boring bar, a *packed bit* is necessary. A packed bit, as shown in Plates III, IV, and V, consists of a cylinder of oak, about 4 calibers long, built on a steel frame. Two cutters, diametrically opposite, are set in a frame at its forward edge to the size of the hole it is intended to bore. The diameter of the wood packing is maintained a few thousandths greater than the diameter of the cutters in order, by its forced fit in the bore, to furnish

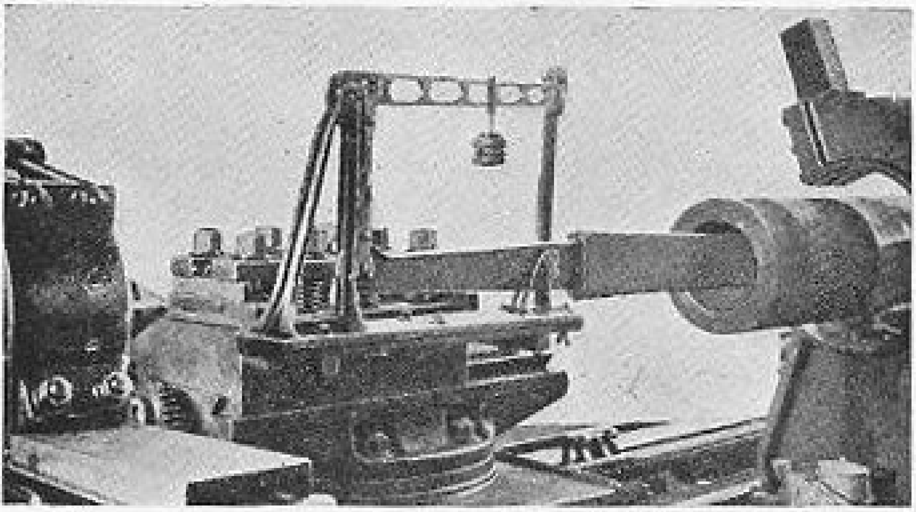
CHAPTER VI, PLATE II.



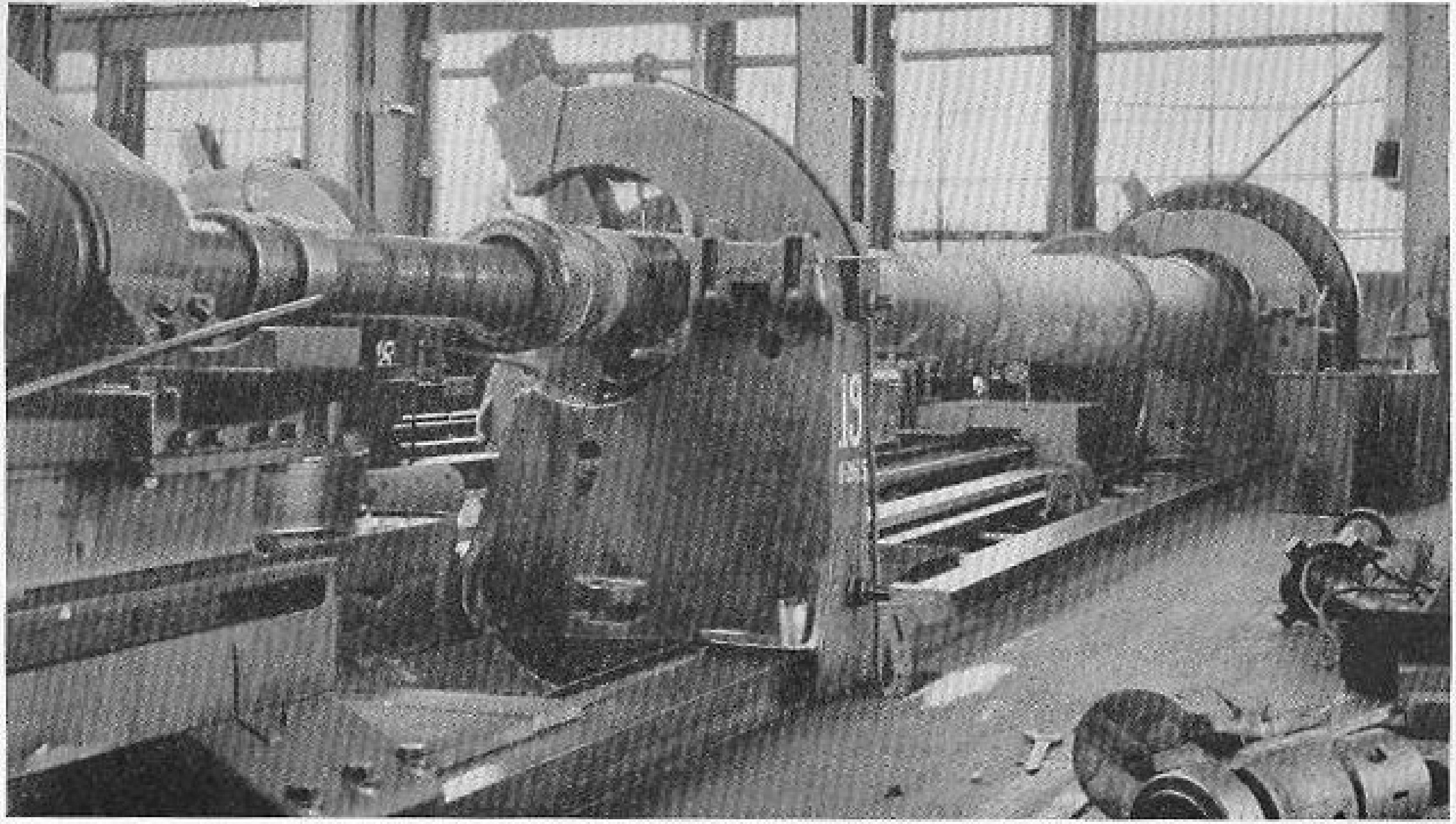
14-INCH TUBE IN LATHE FOR TURNING.



14-INCH C1 HOOP, SET FOR BORING, SHOWING PACKED BIT.

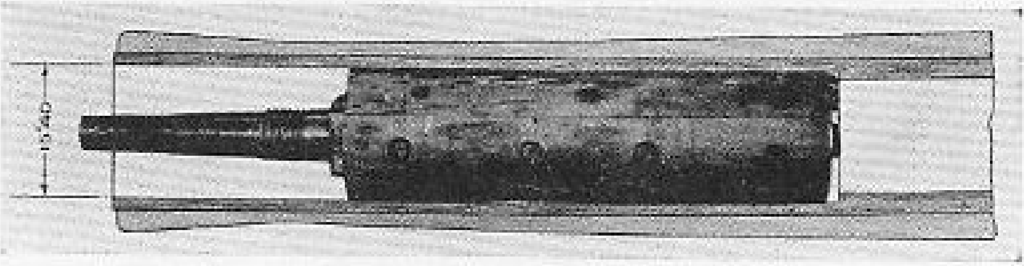


INDICATOR MOUNTED ON TOOL CARRIAGE.

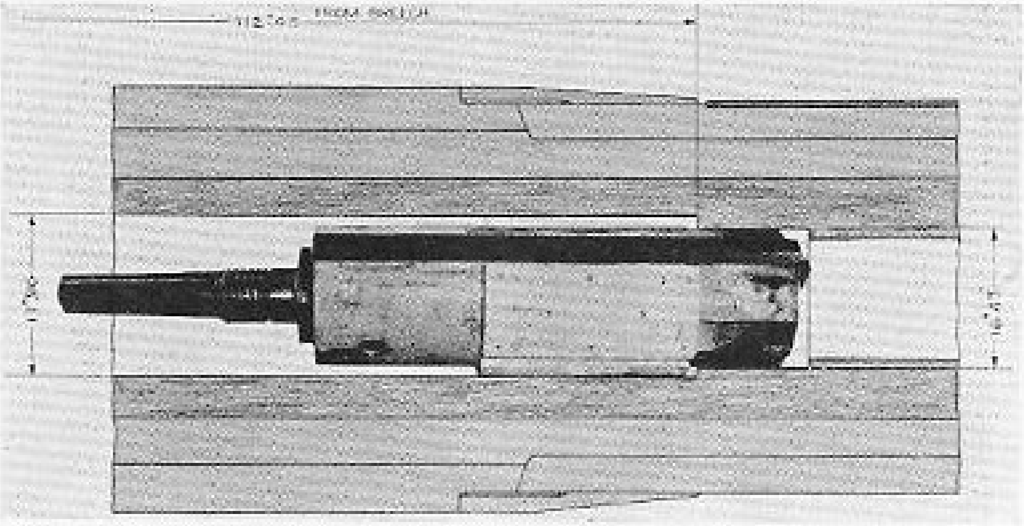


Boring a 14-Inch Gun.

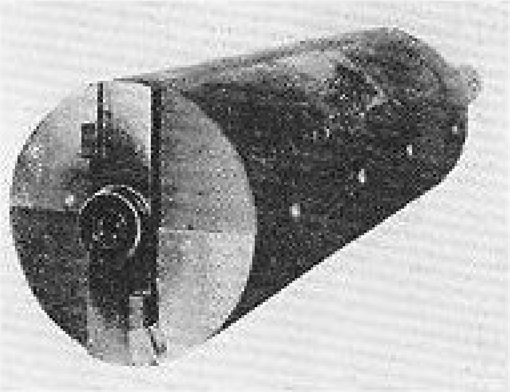
CHAPTER VI, PLATE IV.



1st CYLINDRICAL BORING FROM MUZZLE END 15".40 DIAMETER THROUGH TO CHAMBER OF GUN.

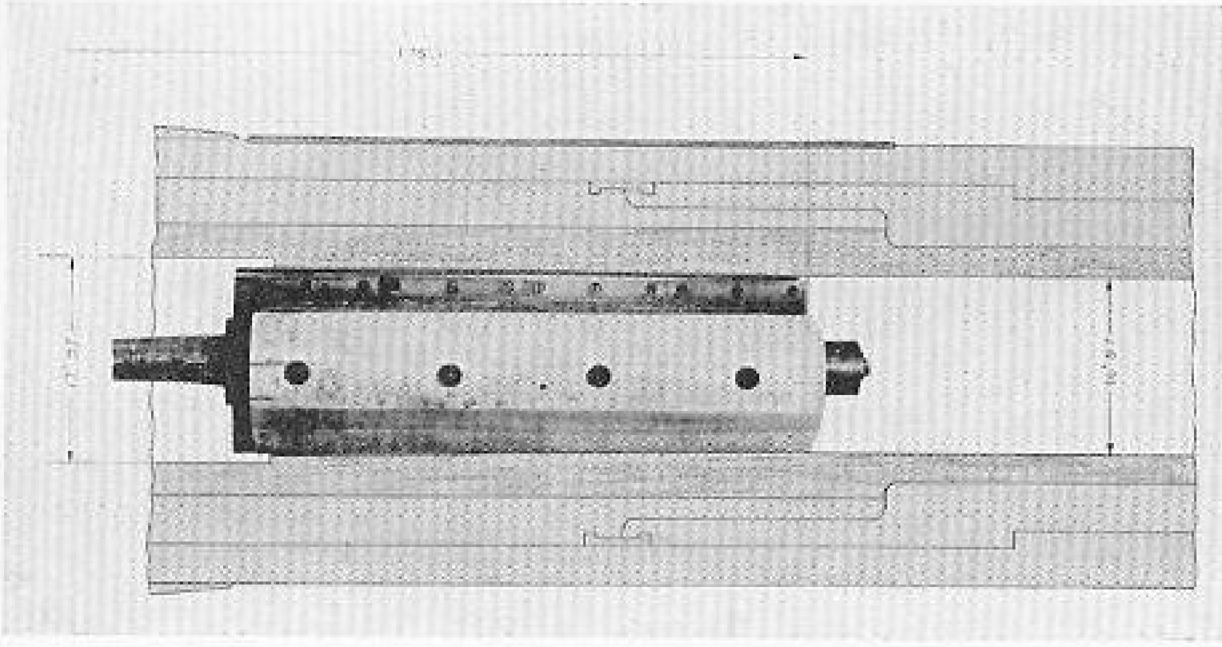


3d CYLINDRICAL BIT BORING FROM BREECH END 16".47 DIAMETER LAGGED FROM 17".9 BORE.

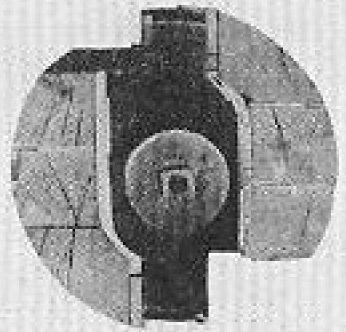


CYLINDRICAL BORING BIT AFTER LAGGING IS REMOVED. SHOWING CONSTRUCTION OF BIT.

CYLINDRICAL BORING OF 14-INCH, 45-CAL. GUN.

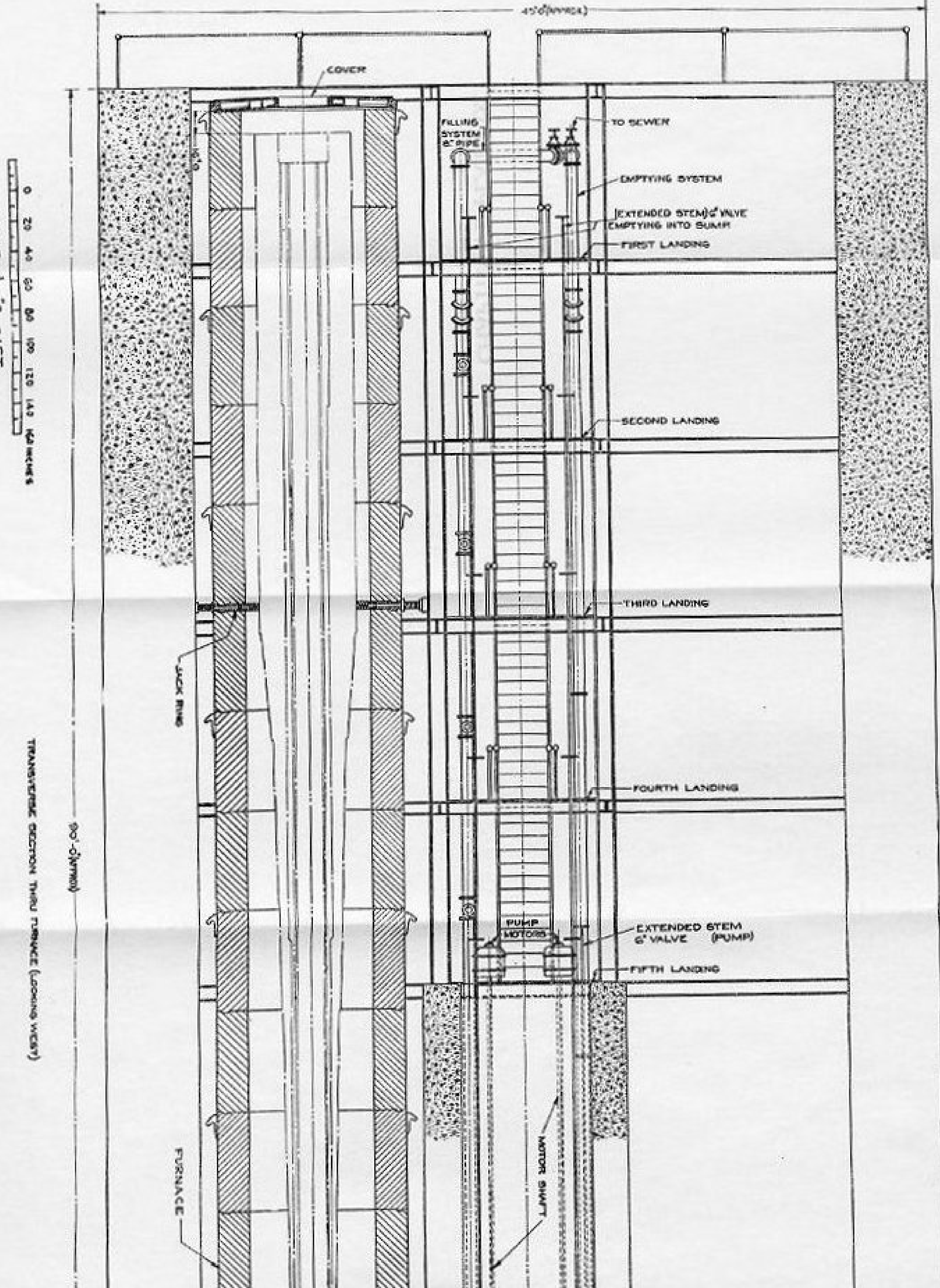


No. 3 Conical Bit, First Conical Bore 175".11 from Breech.
Diametral Taper = ".003 per Inch of Length.

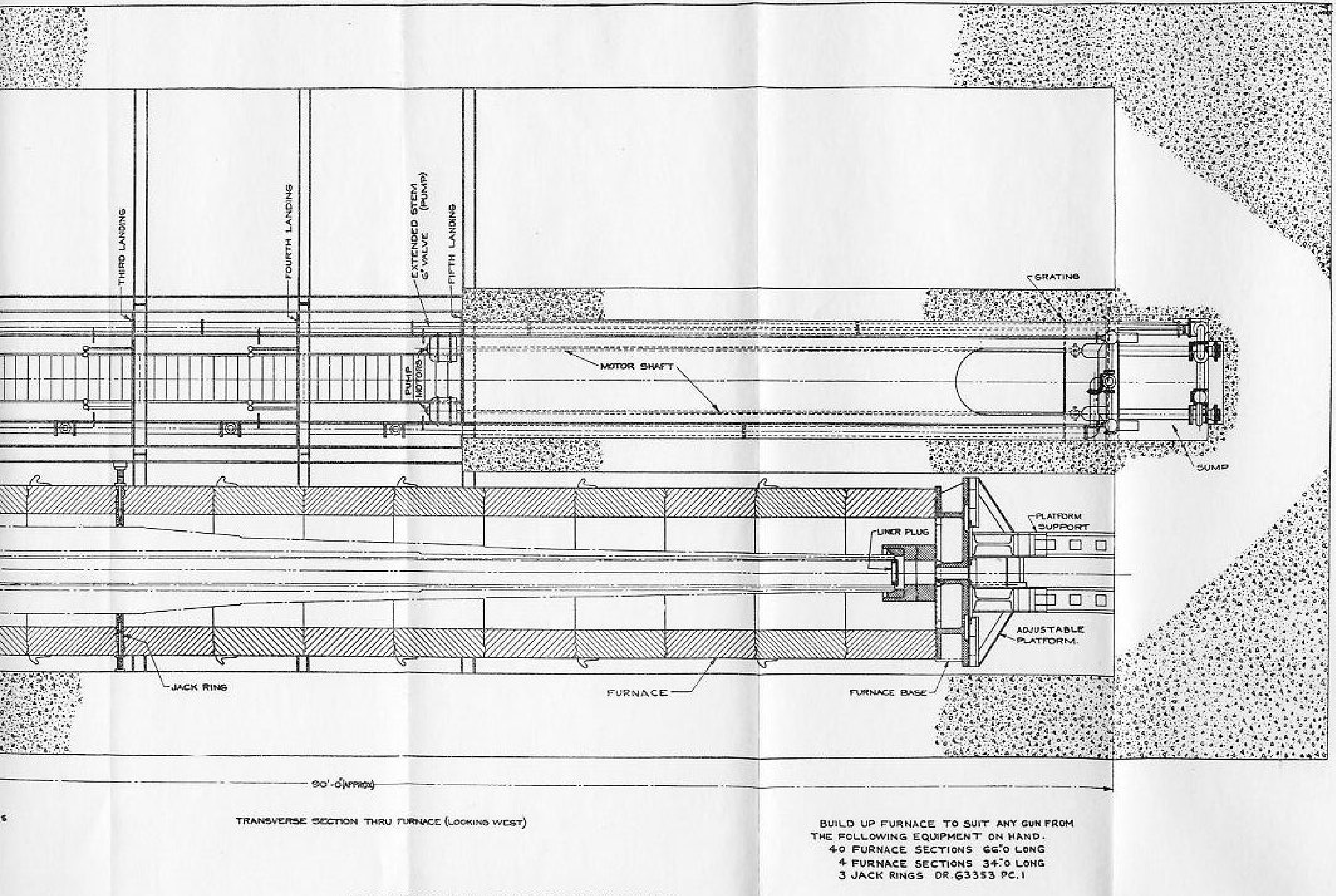


Conical Boring Bit, Showing Construction.

Conical Boring of 14-Inch, 45-Cal. Gun.



SHRINKAGE PIT, TRANSVERSE SECTION.



SHRINKAGE PIT, TRANSVERSE SECTION.

a steady bearing for the cutters. In boring out cylinders which have two or more internal diameters, the after end of the bit is fitted with pieces of wood lagging turned to the diameter of the larger bore. A *conical* or *tapered bit* (see Art. 624) is used for boring the tube to the required taper to receive the liner. The shank of the bit is secured to a boring bar by means of a threaded section. The packed bit boring bar is a long bar which is supported in several bearings and which is driven longitudinally by a motor drive.

Frequent inspections are made during the boring to see that the hole is true. Every few inches the bit is withdrawn and the hole is *indicated* and tested by star-gauging. Four cuts are usually required to finish a bore, two rough and two fine.

617. Indicators.—To ascertain whether a bore has been turned true, it is *indicated* for eccentricity by the use of a *balance rod*, an *indicator*, or a *dial indicator*.

The principle of the *balance rod* is shown in Fig. 601. The end of the

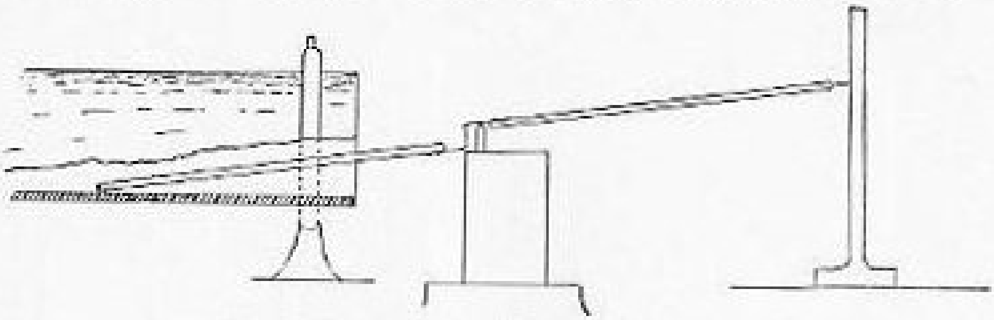


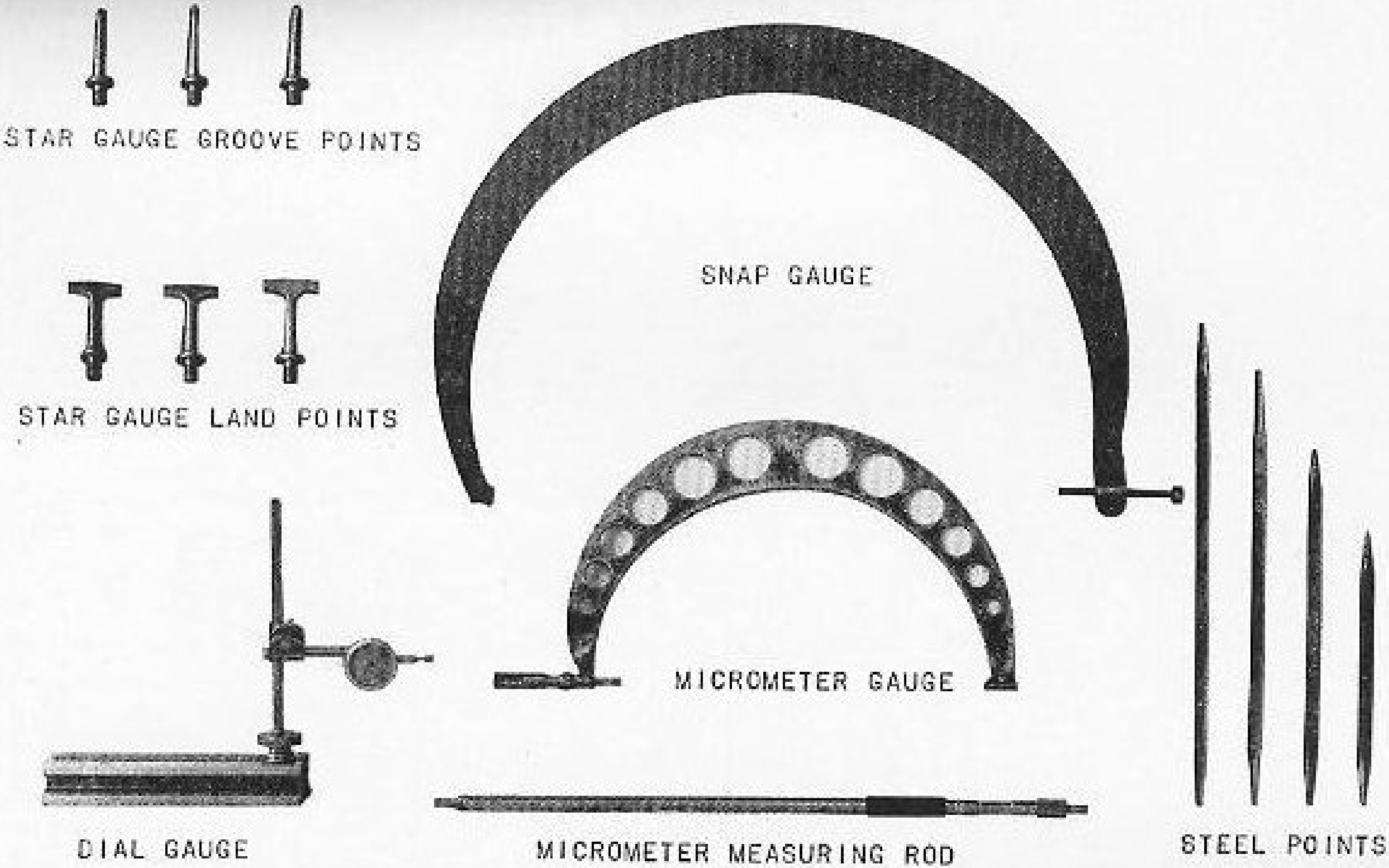
FIG. 601.—BALANCE-ROD, OR INDICATOR.

rod in the bore is fitted with a small roller and the other end with a pointer. An arbitrary zero mark is established for the pointer, and, if the bore is not eccentric, the pointer will not move from the zero mark as the forging is revolved. The bore is indicated every few inches.

The *indicator* operates on the same principle as the balance rod, but is more compact. It is shown in the lower picture of Plate II. The long pointer of the balance rod is replaced by a short arm whose movement is multiplied by a series of levers. The weight of the long arm in the bore is compensated by a counterweight.

For more accurate indication a *dial indicator* (see Plate VI), which is mounted on the end of a long telescopic pipe placed in the bore, is used. As the forging is revolved, the eccentricities of the bore, pressing against a spring-loaded arm, cause a hand on the face of the dial to rotate in either direction, giving plus or minus readings in thousandths of an inch. A telescope enables the observer to read the illuminated dial face.

618. Bore searching.—After every cut the bore is inspected by means of a *bore searcher* for discoloration, cracks, streaks, or other flaws



MEASURING INSTRUMENTS USED IN GUN CONSTRUCTION.

that may have developed. A bore searcher, as shown in Plate VII, consists of a long handle holding a mirror inclined 45° to the axis of the handle and incandescent electric lights, which are hooded to throw their rays out radially. The observer, sighting through a telescope, observes the side of the bore reflected in the mirror. If any flaws are noticed, they may be scratched with a *pricker* to determine their depth. A pricker is a sharp steel point mounted on a light wooden rod and at right angles to it.

619. Star guage.—A *star gauge* (Plate VIII) is used to measure accurately the inner diameters of any large cylinder. It consists of a head, at the end of a long tube, with three metal points extending radially through it, 120° apart. Different points of lengths suitable to the bore to be measured are employed. Springs keep the bases of the points in contact with a cone inside the head. As the cone is advanced axially by means of a rod passing through the length of the tube, it forces the points radially outward, the amount of movement being read on a vernier on the handle end of the rod. The zero mark of the vernier is checked by pressing the points into a ring of known diameter. A first set of readings is taken with the points set thus: ⅄⃝, and a second set with the points thus: Y⃝. The average of the two readings is taken as the average diameter of the bore at that point. Three-pointed centering rests are clamped to the tube at intervals properly to support it. Both the tube and rod come in sections to adapt the gauge to any required length.

After a gun has been rifled (see Art. 628), the grooves and the lands are star-gauged. Special points with ends shaped to fit either the grooves or the surface of the lands, respectively, are employed (see Plate VI).

All star-gauge readings are entered on a gun record sheet.

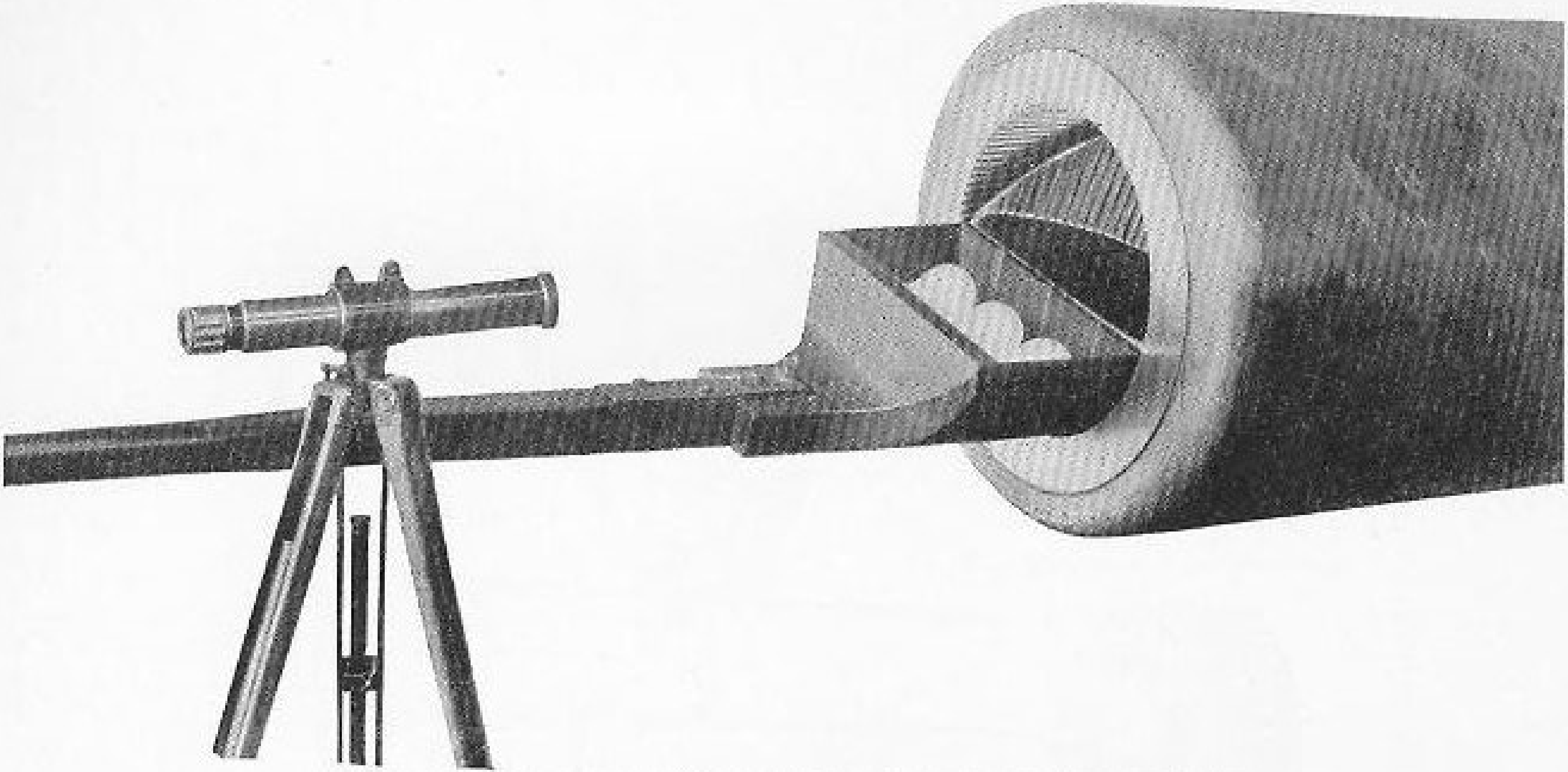
620. Shrinkage.—The *shrinkages* between the various cylinders are worked out in the design of the gun. Shrinkage between two cylinders is the difference, before assembly and when both parts are cold, between the internal diameter of the outer one and the external diameter of the inner one. The shrinkage between two cylinders is not necessarily the same throughout their lengths, but may, and usually does, vary.

ASSEMBLING THE GUN.

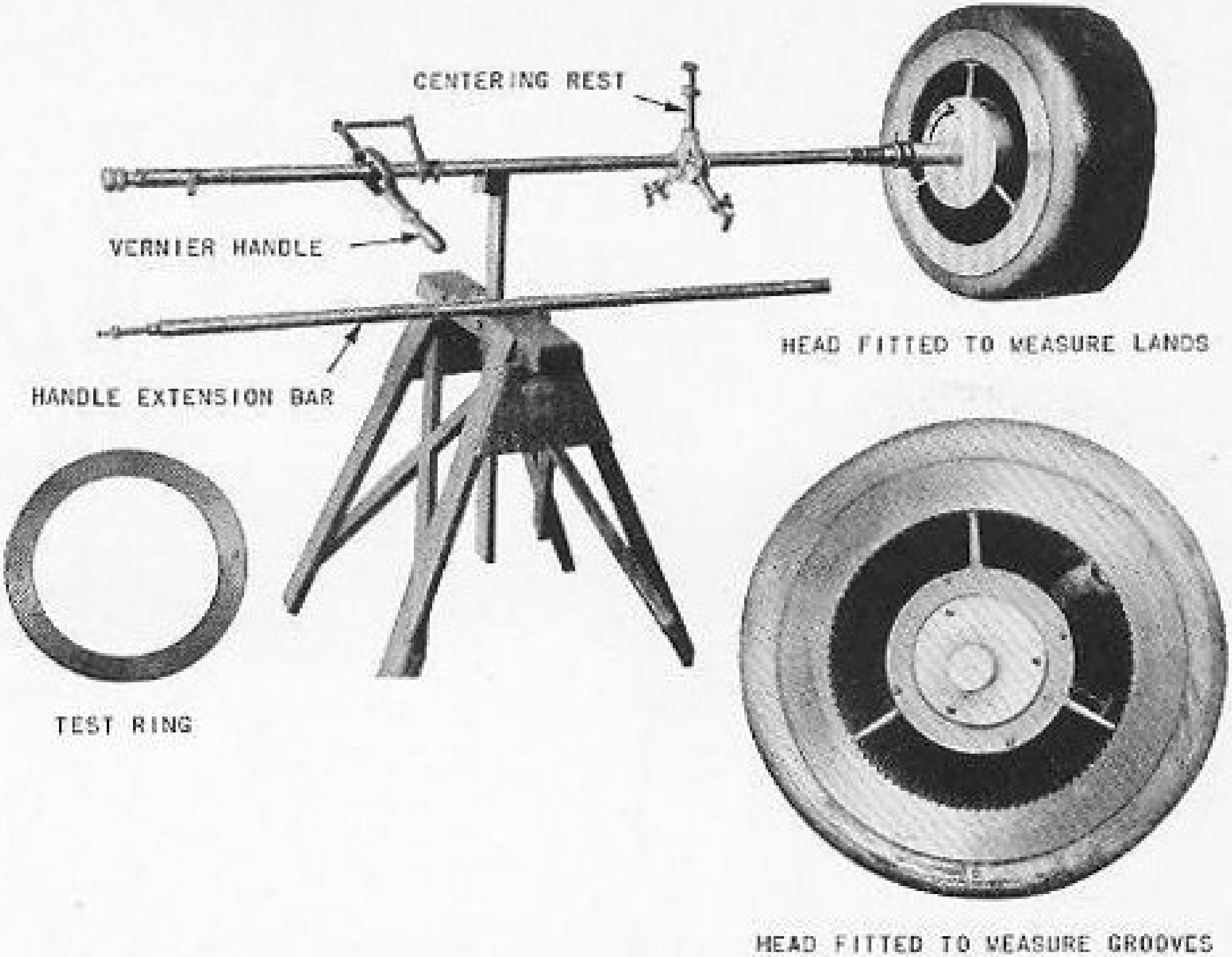
621. The modern heavy built-up naval guns are designed and constructed with shrunk-in conical liners. This design expedites the reconditioning of the gun by relining after it has been worn out in service.

The steps in building up the gun are as follows:

(a) Assembling the B hoops on the tube A1.



BORE SEARCHER AND TELESCOPE MOUNTED FOR INSPECTING A 16-INCH GUN.



STAR GAUGE INSTRUMENT MOUNTED AND READY FOR USE.

(b) Assembling the C hoops on the B hoops; and then the D hoops, if any, on the C hoops.

(c) Conical boring of the tube.

(d) Assembling the conical liner in the gun.

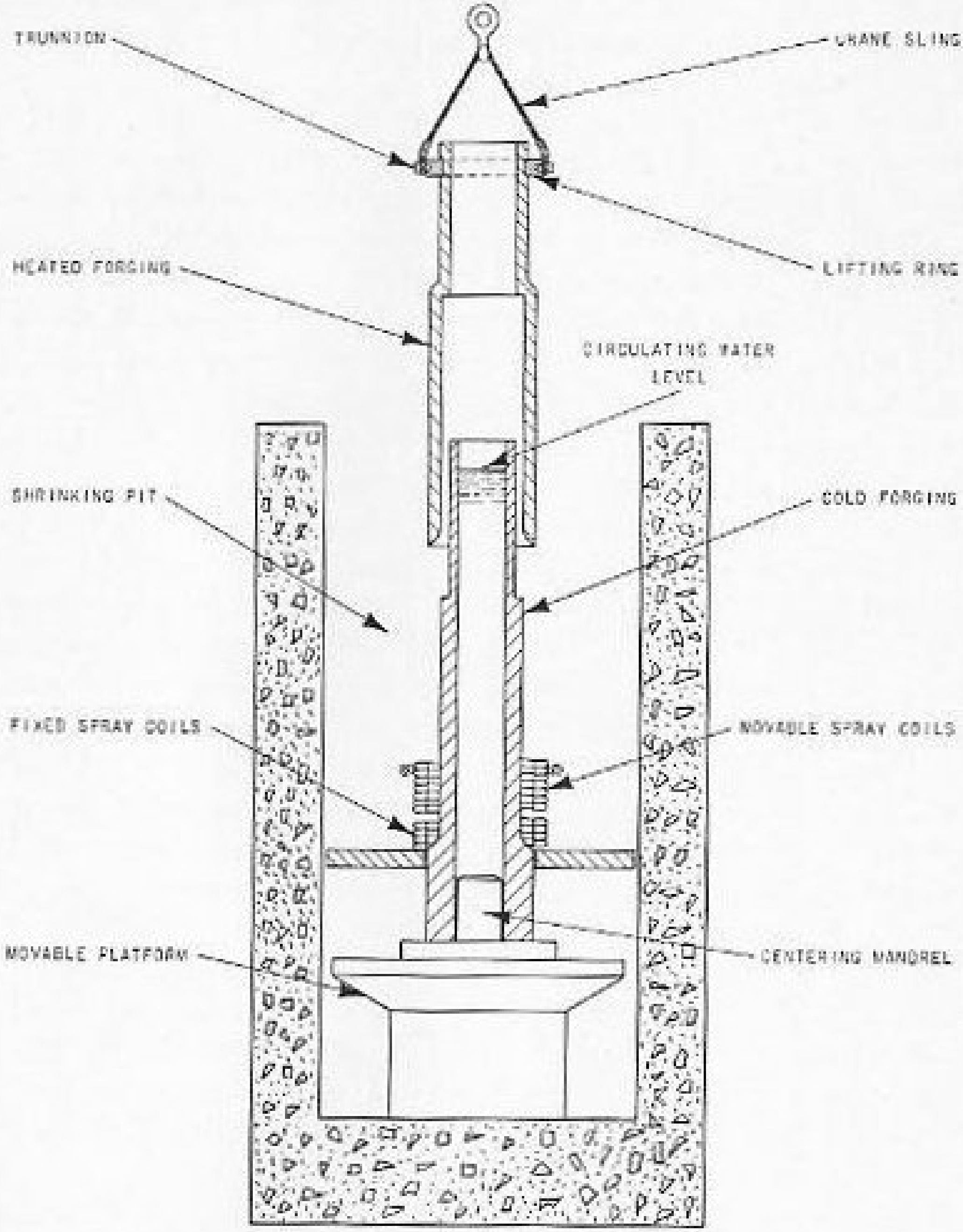


FIG. 602.—SHRINKAGE PIT—SHOWING HEATED FORGING SUSPENDED AND READY FOR ASSEMBLY.

622. Shrinkage pit.—The parts of a gun are assembled in a deep rectangular *shrinkage pit* (Fig. 602 and Plate IX). At the bottom of the pit is an adjustable platform, capable of being set at various levels to suit the length of the forgings to be assembled. Above this platform is the floor, in the middle of which is located a metal pot or centering mandrel into which the end of the tube or gun is placed. Holes in the center of the pot permit pipes for cooling water to enter the bored forging. The length of the electric cylindrical furnace, which is built in sections, may be varied to suit the forging to be heated. Temperatures as high as 800° F. are used, depending upon the size of the forging and the shrinkage desired.

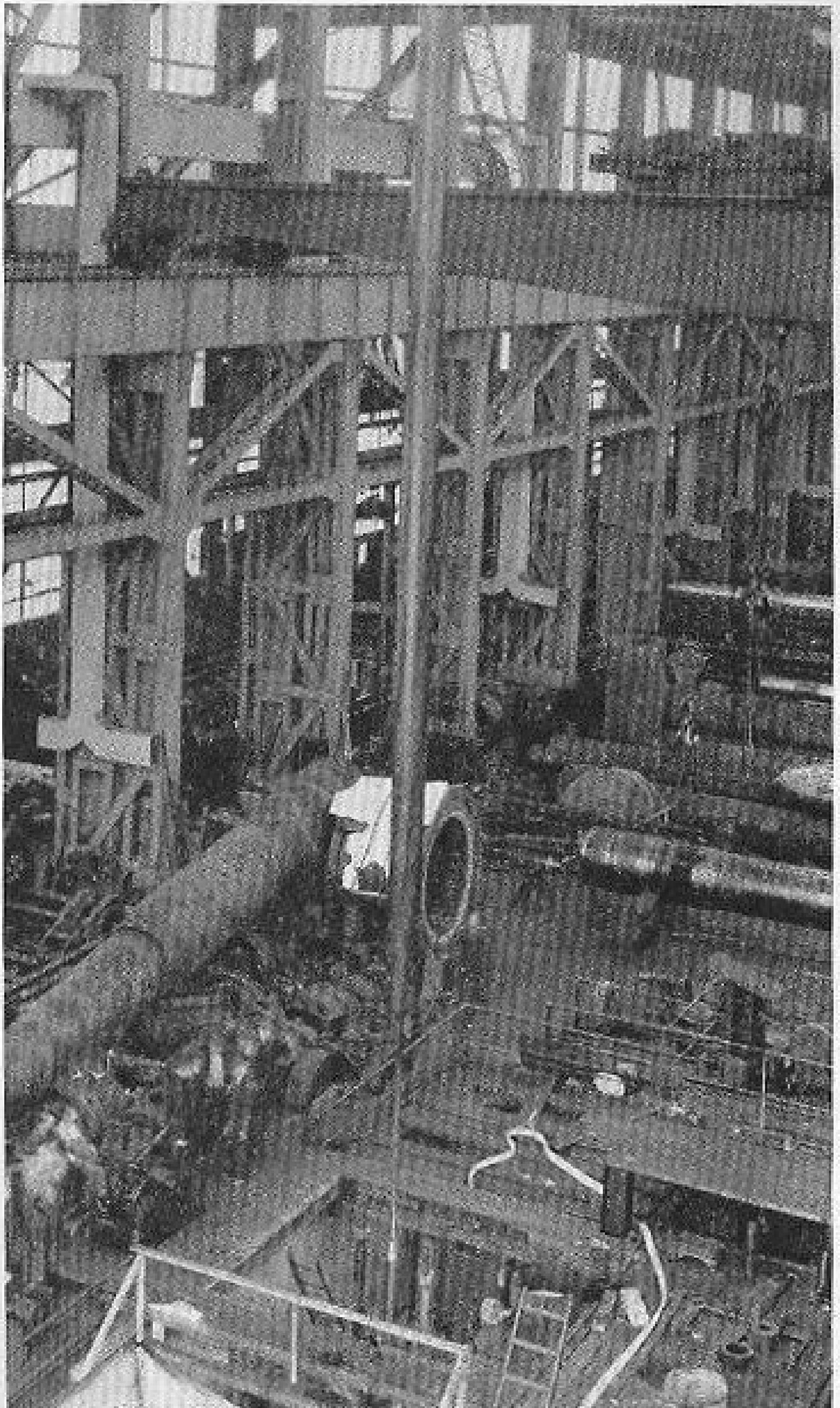
One pit at the Naval Gun Factory is sunk to a depth of 100 feet (Plate IX) and is divided into ten wells or platform levels, five on a side, which are served by a stairway and an elevator. A sump tank collects the drainage water used in cooling the assemblies. Electric pumps are employed for carrying off this water.

623. Assembling the parts.—The gun is built up around the tube, which is placed breech end down in a cold pit, its end resting in a pot which has a short mandrel extending up into the bore of the tube to steady it. No other support is given the tube. The outer surface is given a coat of a mixture of graphite and light oil. In the meantime the B hoops are placed in furnaces and brought up to heat. The B1 hoop is then removed from its pit and its internal diameter tested by cross-points of known lengths, which are mounted on a long handle. It is then lowered over the tube. To prevent undue absorption of heat in the tube as the hot jacket is lowered over it, circulating water, coming from and discharging through the pipes extending through the mandrel, is constantly run through the tube to keep it cool. Were this not done, the tube might expand and grip the jacket unevenly. When the jacket is in position, a cold water spray from a circular perforated pipe is turned on the breech over the tube shoulder to insure that the jacket will grip there first. A spray from a cage of circular perforated water pipes is then turned on, beginning at the breech end. The spraying cage is then lifted slowly in accordance with a prescribed water schedule along the length of the jacket, gradually cooling the hot forging toward the muzzle. When cool the longitudinal contraction and the diametrical expansion are measured and compared with the calculated values. The other hoops are put on in a similar manner.

When the gun is assembled it is removed from the pit, placed in a lathe, threaded at the joining of the D or outside hoops, and the locking rings screwed on.

624. Lining the gun.—The gun is now ready for conical boring of the tube preparatory to assembling the liner. The boring is accomplished in a boring lathe with a series of conical packed bits, tapering from the diameter at the breech end of the bore to that at the muzzle end. Each of these bits is equipped with two cutting tools spaced 180°

CHAPTER VI, PLATE X.



LINER POSITIONED OVER FURNACE READY FOR ASSEMBLY.

apart and extending throughout the entire length of the bit. After boring the gun is star-gauged for each inch of its length and bore-searched. The shrinkage sheet to be used for machining the liner is then prepared.

The liner is turned, bored, measured, and inspected, similarly to the preparation of other parts, except that the turning lathe is geared so that it will taper the liner the required amount.

The assembly is made by heating the gun in the furnace, muzzle end down. When the gun is heated, the liner and its fittings are suspended from a crane, and held in a standby position near the furnace (Plate X). The liner, having previously been fitted with a water-tight muzzle plug, is then filled with water to prevent undue absorption of heat and expansion while being lowered in the tube. After a center section of the furnace top has been removed and the liner has been centered over the tube bore it is slowly lowered in the gun until it is seated (Plate XI). The holding down yoke and jack are then positioned and hydraulic pressure is applied to hold the liner on the tube shoulder during cooling (Plate XII).

The water is lowered in the liner at a pre-determined time-distance water schedule by lowering the overflow pipe. It is thus possible to control the progress of contact between the liner and tube. The upper section, from which the water is lowered, is permitted to absorb heat, expand, and engage the tube progressively.

The gun is now completely built up and ready for finishing.

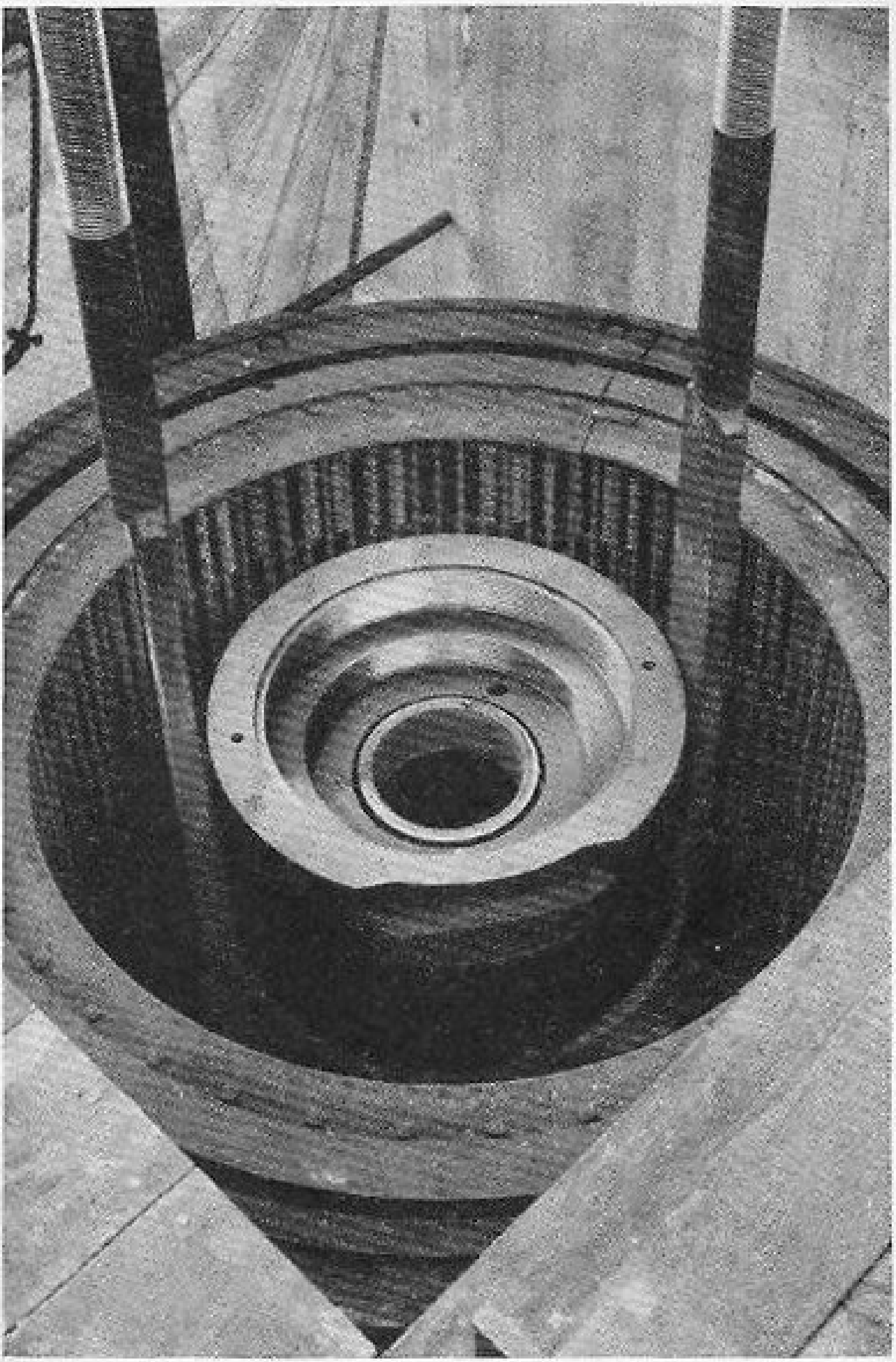
FINISHING THE GUN.

625. Machining the bore to final diameter.—When the gun has cooled to shop temperature, it is star-gauged, the compressions due to shrinkage are recorded, and it is then turned in a turning lathe to within approximately 0″.2 of the finished diameters. The bore is next finished to the required diameters, two cuts with packed bits being required. The allowed tolerance in the finish boring is only 0″.002 oversize and zero undersize.

626. Chambering.—The chamber is next bored to the finished size. There are two general designs for powder chambers: those for bag guns and those for cartridge-case guns.

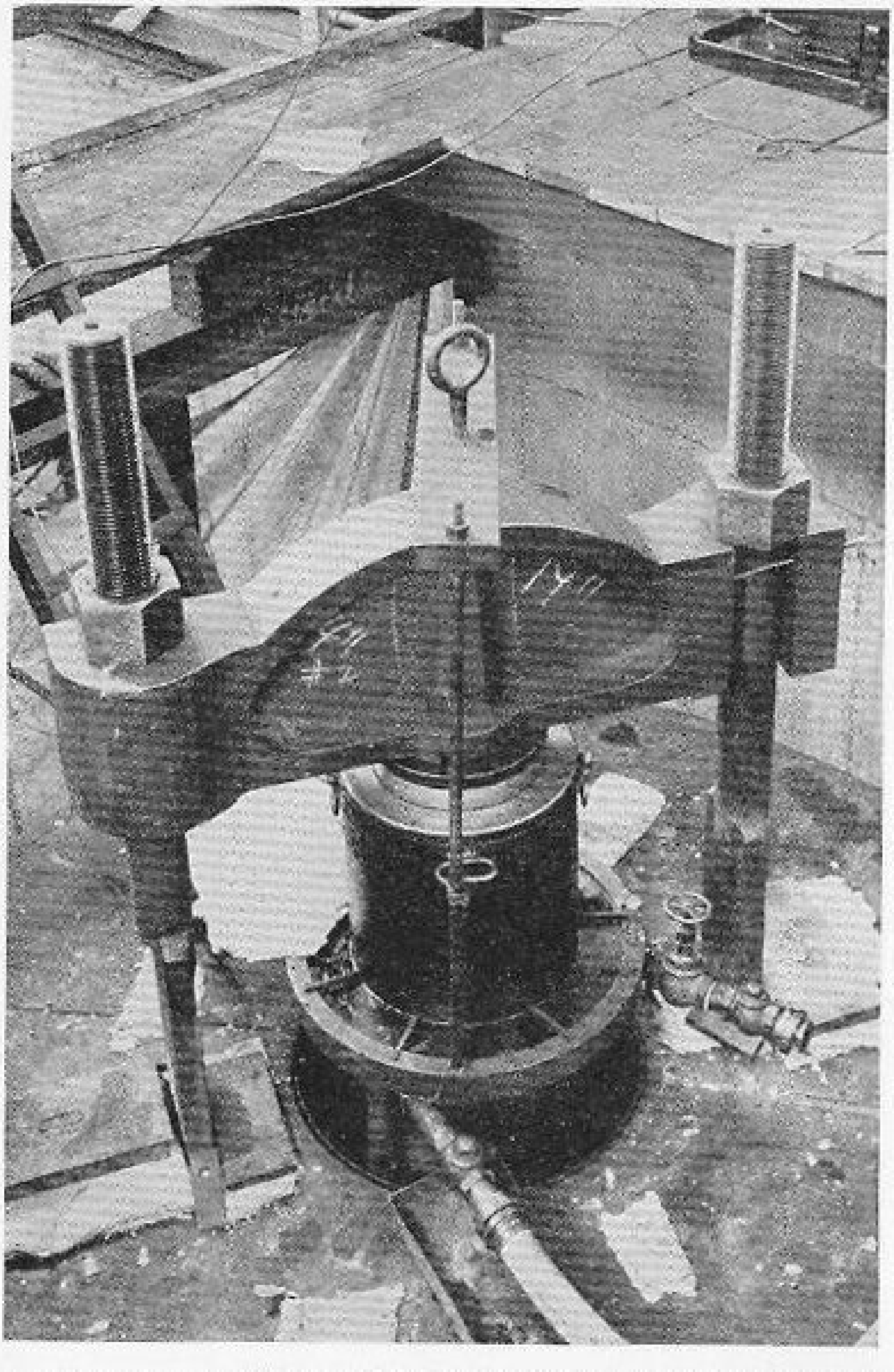
In the former the chamber, during the machining of the bore, is bored out to the diameter of the *choke* (Chapter IV, Plate I). Beginning just forward of the location of the chamber rear slope, the diameter is next enlarged to its full chamber diameter for several inches. The rear slope is then machined by a tool held in the tool carriage. The chamber cylinder is then machined out as far as the chamber front slope. The front slope, the shell centering slope, and the band slopes

CHAPTER VI, PLATE XI.



Liner Assembled in Gun, Furnace Top Removed Showing Electric Heating Elements, Gun Cooling Before Removal.

CHAPTER VI, PLATE XII.



LINER ASSEMBLED AND SEATED. HYDRAULIC JACK PRESSURE APPLIED TO HOLD LINER ON SHOULDER DURING COOLING. WATER CIRCULATING THROUGH BORE OF LINER AS A COOLING AGENT.

are then bored by formed cutters. Chambers for cartridge-case guns, which have no choke, are much simpler to bore.

Bag gun chambers are checked by star-gauging and by length rods, while cartridge-case guns are checked by fitting in a gauge made to the maximum dimensions allowed for the cartridge case.

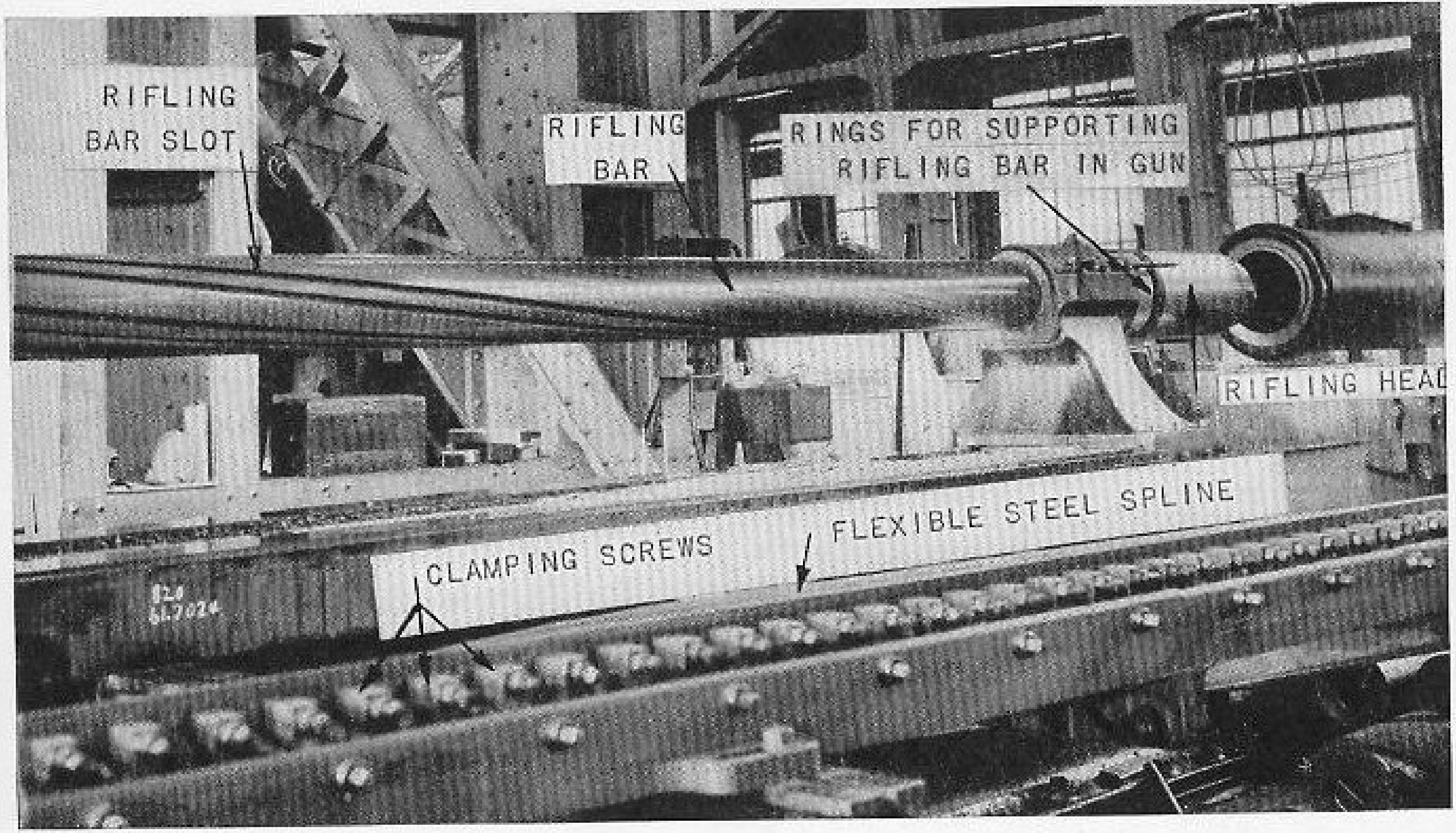
627. Final turning.—Before rifling, the gun is turned down to the finished dimensions, the *bell muzzle* is finished, and the gun is faced off to the correct length. Extra metal during the construction of the gun was left on the outside hoop at the muzzle for the purpose of machining the bell muzzle. The purpose of flaring out the muzzle in the form of a bell is to add extra strength to prevent splitting, as the metal at the extremity of the gun is not supported on the forward side. In guns which are hooped to the muzzle, the tube and liner project about 0.25 inch beyond the end of the hoop.

628. Rifling.—The mechanical process of cutting grooves in the finished bore surface of a gun is known as rifling. They are cut from the *compression slope*, which is known as the *origin of rifling*, to the muzzle. (See Chapter IV, Plate I.) Rifling is done in a machine resembling a boring lathe, except that the rifling bar, which takes the place of the boring bar, has a spiral slot cut in its surface, the pitch of which corresponds to the pitch of the rifling it is desired to cut (Plates XIII and XIV). A different rifling bar, therefore, is required for each type of gun.

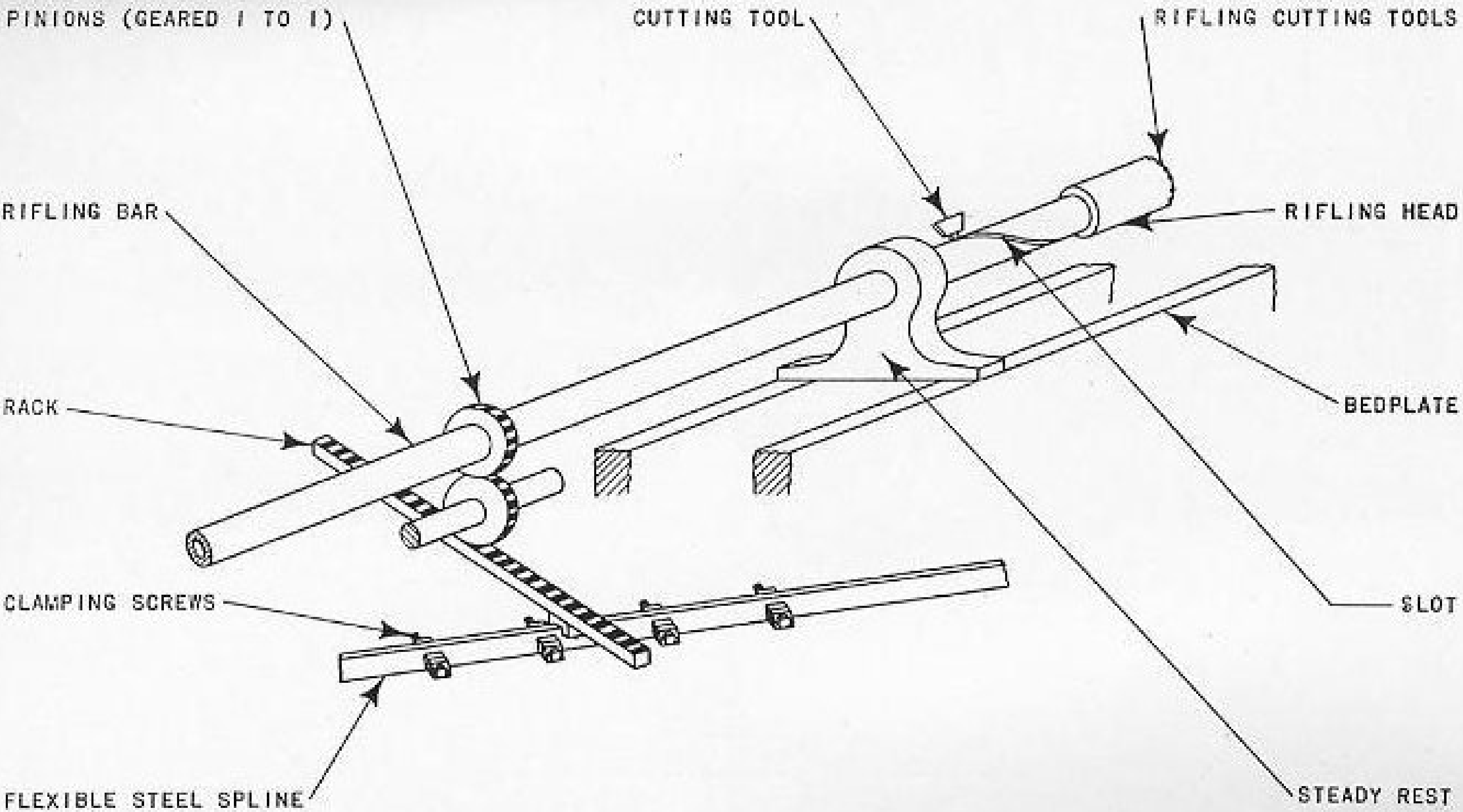
The method of cutting the slot in a rifling bar is shown schematically on Plate XIV. An extension of the bed plate alongside the rifling bar carries a steel spline (Plate XIII), which is set to the form of the developed rifling by setscrews. For rifling of uniform twist the development is a straight line; for increasing twist, a curve. By means of the spline, the pinion gearing, and the rack, one end of which is kept pressed against the spline, the rifling bar is revolved at the proper rate as it is fed past the stationary cutting tool.

The *rifling head*, a hollow cylinder slightly smaller than the bore of the gun, is keyed in a socket in the end of the rifling bar (Plate XV). The cutting tools are set in pockets placed at equal intervals circumferentially around the forward edge of the head, the number of tools being half the number of grooves to be cut. A cone, which is moved axially inside the head by a screw, is employed to move the tools outward. The screw, which has a vernier to indicate the position of the cutting tools, is reached through an opening in the side of the head. A pin, projecting through the front face of the head, when pushed in, causes the cutters to collapse inward, thus enabling the head to be withdrawn without danger of scoring the bore.

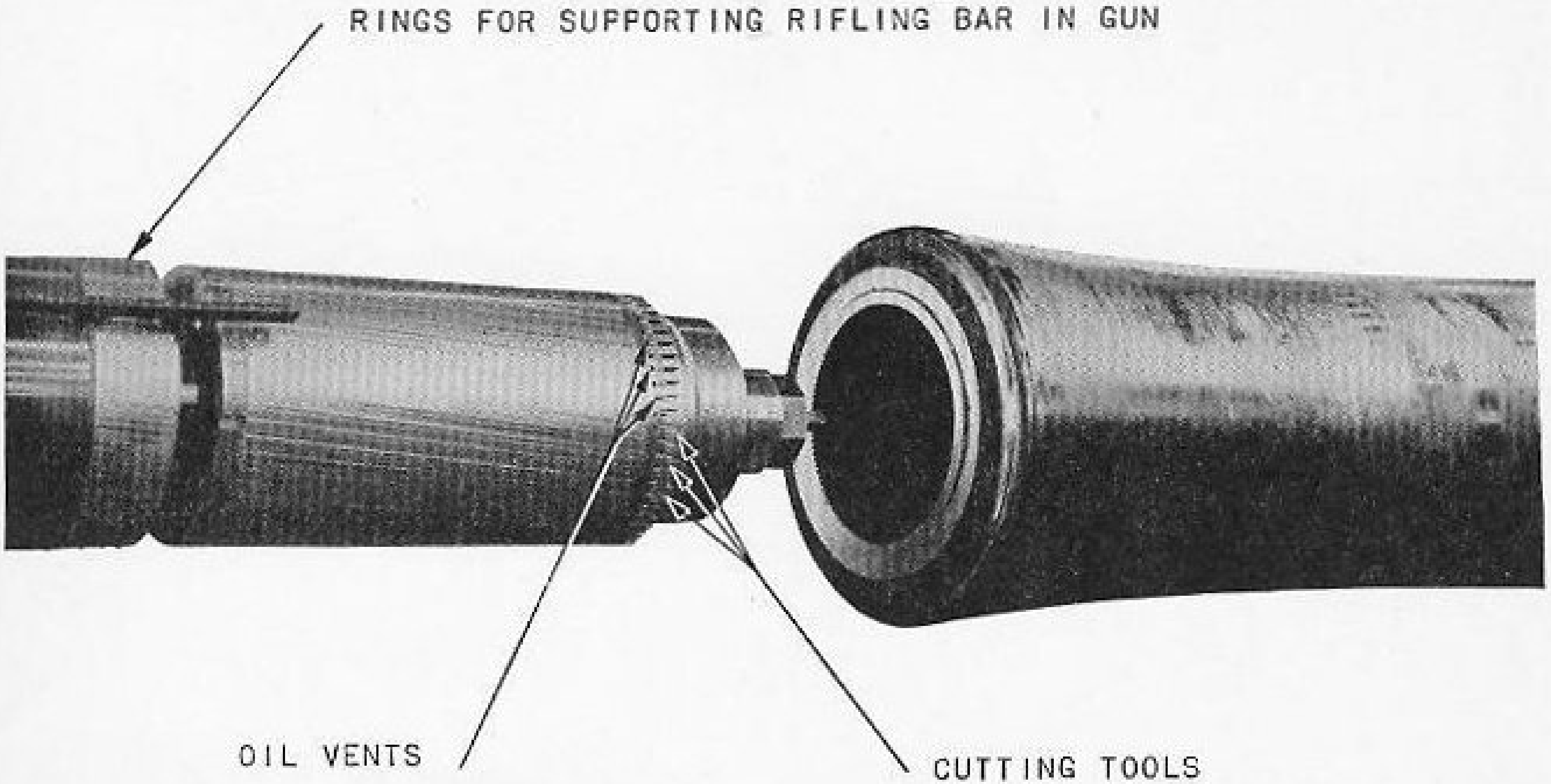
All rifling is done from the muzzle end. After the head has been trued



RIFLING MACHINE, SHOWING RIFLING BAR ABOUT TO ENTER 14-INCH, 45-CAL. GUN.



Fixture for Cutting Rifling Bar Slot. Schematic Diagram.



RIFLING HEAD READY TO ENTER 14-INCH, 45-CAL. GUN.

with the bar, the bar is advanced for the first cut. A lug in the forward steady rest bearing engages in the rifling bar slot and rotates the bar as the head is fed into the gun, cutting the grooves with the correct pitch. About 100 to 150 runs of the rifling head are required to complete one-half the grooves in a 14-inch gun. When the first half of the rifling is finished, the head is rotated to bring the cutters into position for the second set of grooves. The cutting tools are reset and the rifling operation begins anew.

After rifling, the lands and grooves are star-gauged.

629. Determination of droop.—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. The position of the gun in which it shows least droop is noted and marked as the top. The threads for the screw-box liner are located from this line so that the gun and the top of the breech mechanism will correspond when assembled.

630. Chasing thread for screw-box liner.—In all guns from 3 to 16 inches, inclusive, the screw-box threads are cut in a separate liner 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.

Assuming that a 14-inch gun is being constructed the gun is placed in the lathe, muzzle end to the face plate. The after ends of the tube and jacket are faced off as one surface, the C1 hoop faced off an exact distance in rear of the tube and jacket, and finally the D1 hoop faced off an accurately gauged distance in rear of the C1 hoop.

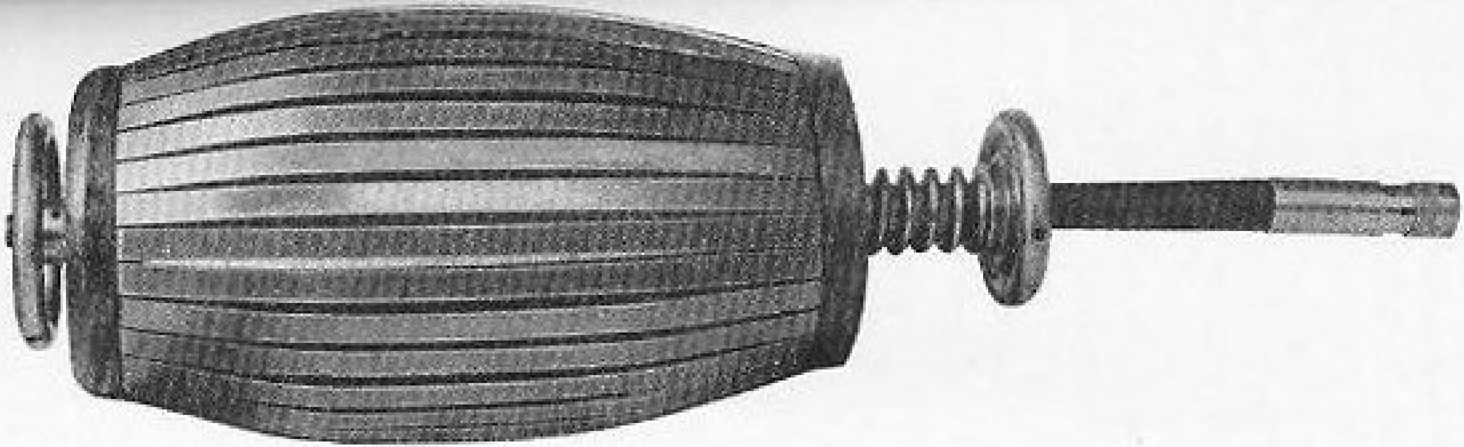
The C1 and D1 hoops are then bored out to exact diameters. The thread is then chased, starting at the point determined by the droop measurements, so that when the screw-box liner is screwed home the correct part of the gun will be up.

The screw-box liner is then fitted to the gun, the liner firmly taking up against the tube, the jacket, and the hoops. When seated properly, two holes are drilled and threaded for large keeper screws which lock the screw-box liner in the gun.

631. Lapping.—The bore is given a final cleaning and polishing known as *lapping*. The gun is placed in rests, and the *lapping head* (Plate XVI) is drawn back and forth on a wire cable which automatically reverses itself at the end of travel. To lap the lands a head is used which has several segments of wood covered with emery cloth held out against the bore by springs. To lap the grooves, a head having segments of lead cut to fit the grooves is used. The groove lapping head is first smeared with fine emery and oil. Finally, a head, such as the squirrel-cage bore cleaner, covered with burlap and waste is run through to clean the bore. The squirrel-cage cleaner, constructed of flexible strips, may be adjusted to fit bores of various sizes by setting up or slackening a threaded hand-wheel nut.

Though not connected with the subject of gun construction, it is well to mention here the question of lapping guns aboard ship. Quite frequently the bores of guns in service become constricted to such an extent that a bore gauge of the same diameter as the projectiles to be fired cannot be pulled through the guns. Ordinarily this constriction is due to an accumulation of copper from the projectiles' rotating bands, and as such is not considered especially harmful or dangerous to the gun. However a constriction is sometimes caused by a shoulder on the liner over-riding the corresponding shoulder on the tube, or by the mandreling effect of the projectile already mentioned, that is, its tendency to "squeeze" before it the metal of the liner, and thus to elongate the tube. The end of the tube thus elongated is caused to project from the muzzle, but is not harmful, and the projection may be faced off when necessary. The gun liners sometimes creep to the rear or breech end. When this occurs it will frequently be found impossible to close the breech plug. The only remedy then is to face off the rear end of the liner and take a light cut off the gas check seat sufficient to permit plug closure. If this liner should subsequently creep forward, in a bag gun, the danger of a blowback is greatly increased. In guns now in service the following methods have been employed to prevent rearward creep of gun liners: (a) Some liners are prevented from creeping to the rear only by the compression of the tube; (b) some liners are welded at the after end to the tube; (c) some liners are secured to the tube at the after end by a locking ring; (d) some liners are held in position at the after end by abutment against the screw-box liner so that the gun liner cannot creep aft except with the tube.

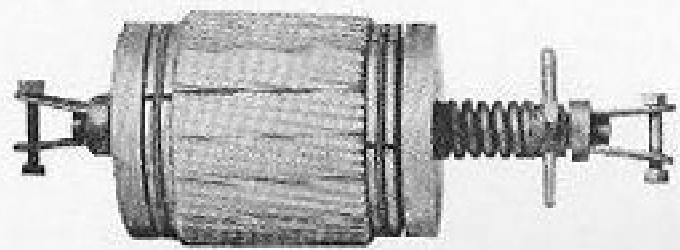
The "squeezing" of the metal is resisted at the shoulders, causing the metal to "pile up" at these points, thus reducing the diameter of the bore. A knowledge of the positions of the shoulders in a gun liner, which may be obtained from the drawing of the gun furnished the vessel, will, therefore, give an indication of the nature of an obstruction disclosed by the bore gauge, that is, whether it is due to copper fouling or to constriction of the liner. In the case of a constriction of the liner it becomes necessary to remove the obstruction by lapping the tops of



SQUIRREL-CAGE BORE CLEANER

SPONGE

BORE LAP



GROOVE LAPPING HEAD

LAPPING HEAD AND BORE SPONGE.

the lands. For this purpose it was customary for ships to construct their own lapping heads, usually of blocks of wood set outward by springs against the bore of the gun, the whole head being then covered with emery cloth. A line was attached to each end of the lapping head and drawn back and forth by members of the gun's crew. Care had to be taken not to draw the lapping head beyond the actual limits of the constriction, as shown by measurement of the points where the bore gauge stuck, in order to avoid unnecessary wear on the gun. Such lapping heads were more or less crude in construction, and when possible the work was done at navy yards. The latter are now provided with the necessary equipment and measures are being taken also to supply lapping heads afloat.

632. Fitting the breech mechanism.—(1) The necessary holes for fitting the breech mechanism are drilled, the hinge lugs are put in place, and the breech block fitted. Previous to fitting the breech block, it is tried in a dummy gun so that, when the final fitting takes place, the work will not be so difficult. There is always a great deal of hand work required in fitting every breech mechanism.

(2) After the breech plug is in place, the gas-check seat is reamed. This is a most particular operation in the process of fitting the breech mechanism. A perfect fit of the split rings and gas-check pad is necessary to prevent blowbacks. A blowback is the wire drawing of the hot gases of firing to the rear over the gas-check system with the consequent burning of the split rings, pad, and gas-check seat. Such a casualty may readily put a gun out of service. To test the accuracy of the fit, Prussian blue is smeared lightly on the gas-check seat, and the plug closed. A perfect fit is indicated by the split rings and pad showing a light even coating of blue when the plug is again opened. High or low spots in an imperfect fit are, of course, denoted by the presence or absence of blue.

633. Milling the keyway.—The keyway on top of the gun is milled out and the key, which keeps the gun from turning in its slide, is inserted and held in place by countersunk screws.

634. Putting on yoke.—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 D1 hoop which prevents its forward movement. Just in rear 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.

The rear cylinder and the slide cylinder of late 8-inch guns are of the same diameter so that these guns may be mounted and dismounted through the face plate of the turret, leaving the slide in place. These guns have an annular slot near the breech for securing the gun yoke. A forged steel ring which projects above the gun rear cylinder and which is made up of two 180° sections is secured in this annular slot. The yoke has a shoulder on its forward side which rests against the after side of this steel ring. The yoke is held in place by a bronze locking ring screwed into the yoke from the forward side. The locking ring

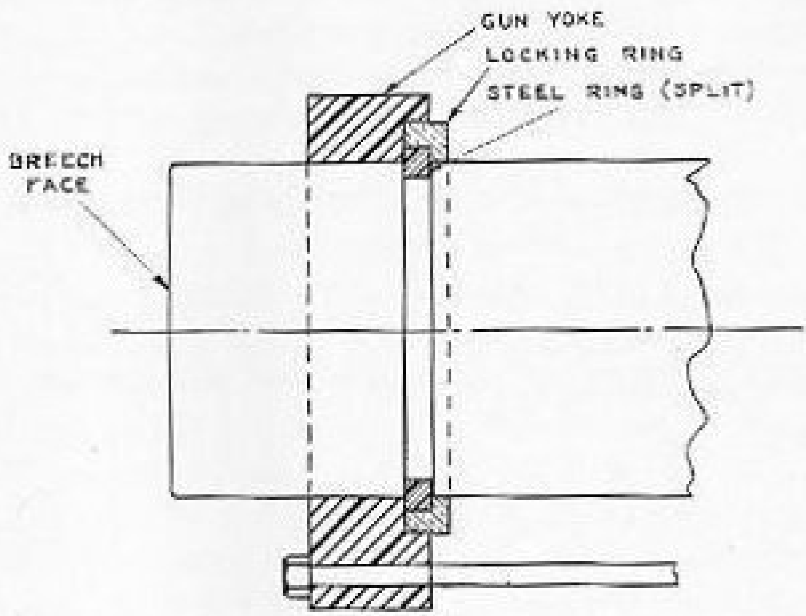


FIG. 603.

has a shoulder on its after side which brings up against the forward side of the steel ring set in the slot (see Fig. 603).

635. Center of gravity.—For the first gun of a type the computed center of gravity is checked by balancing the gun, with its breech mechanism, projectile and charge, on knife-edges.

636. Weight.—The gun, without the breech mechanism, is weighed and the weight stamped on the breech face.

637. Final inspection.—It is given a final inspection, and if satisfactory, marked with the place of manufacture, year, mark, number, weight, and the initials of the superintendent and inspecting officer.

638. Proof.—It is fitted to its slide, and then sent to the Proving Ground for proof. If satisfactory on proof, it is returned to the Gun Factory where it is relapped, bore-searched, star-gauged and issued to service.

639. Relining.—(1) When a gun has fired a considerable number of rounds, the actual number depending on the caliber of the gun and powder pressures used, the bore becomes eroded to such an extent that the gun gives undue dispersion. It then becomes necessary to reline the gun in order to recondition the bore. When relining, the worn liner is withdrawn from the breech end and a new one inserted in its place. The procedure for assembling the new liner is the same as previously described.

(2) To withdraw the liner, the breech end of the liner is threaded and the pulling apparatus is assembled on the gun. The gun is then heated in the furnace to a temperature of 600° F. and 550° F. at the muzzle and breech, respectively. When the gun is heated, the liner is chilled by water circulating rapidly through the bore, causing contraction of the liner relative to the gun. The liner is then unseated by means of hydraulic jacks and lifted clear by a crane.

Section III.—The Manufacture of Guns by Radial Expansion.

640. Preparation of the forging.—After acceptance tests the hollow steel forging is turned down nearly to the maximum outside circumference of the finished gun and is accurately bored slightly smaller than the finished diameter. The breech end is drilled and tapped to receive a high pressure pipe connection from the pressure intensifier, and the muzzle end, a connection to a high pressure gauge. Each end of the forging is prepared to receive packing and screwed-in plugs.

641. Equipment.—An intensifier is a unit where the pressure of an hydraulic pump is conducted into a large cylinder having a piston connected to a plunger of smaller diameter which works in another cylin-

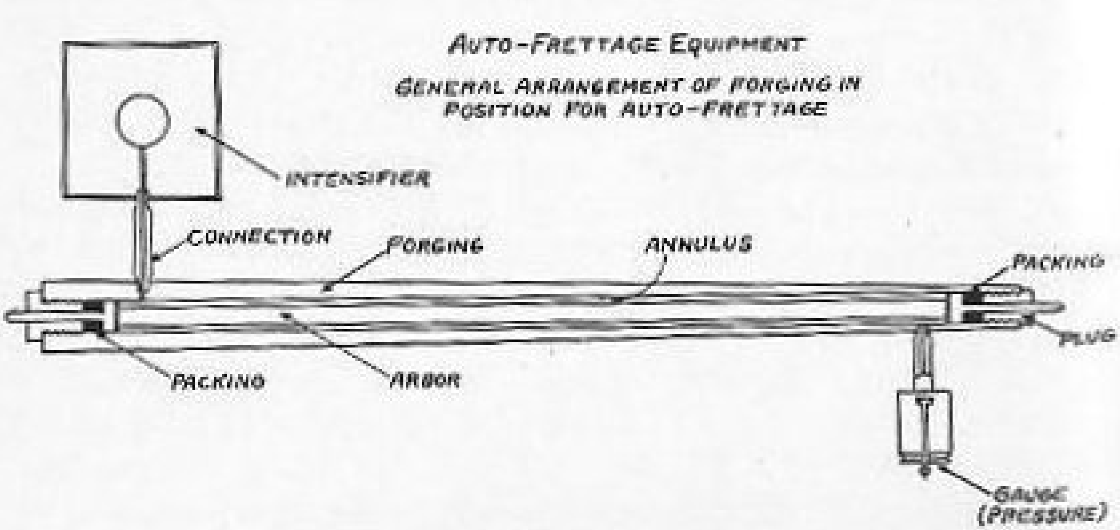


FIG. 604.

der, and is employed to create the great pressures necessary for radial expansion. The liquid, glycerine, from the intensifier passes through a high pressure pipe connection to an annulus between the *arbor* or core-bar and the forging. The arbor, several hundredths of an inch less in diameter than the bore of the forging, is inserted in the bore, thus reducing the amount of liquid necessary for expansion. Packing, at each end of the bore, is held in position by screwed-in plugs to seal the liquid under pressure.

642. Radial Expansion.—The intensifier sets up a pressure between about 45,000 and 100,000 pounds in the connection, the annulus, the gauge connection, and the gauge. As the pressure is applied, the dilations of the forging are measured and checked against a theoretical curve showing the relation between the bore pressure and the dilation of the outside diameter. When the internal pressure has reached such a value that the metal of the outer surface of the forging has been brought to its elastic limit in circumferential tension, the end of the semi-plastic period is reached and the pressure is not further increased. The pumps are stopped and this pressure is held for several minutes. On release of the pressure, which is done by lowering the ram of the hydraulic pump and allowing the plunger of the intensifier to be forced out, the interior wall of the forging closes in, but is unable to return to its original dimensions. The bore and the external diameters will have been slightly enlarged because of the permanent deformations set up by the liquid pressure, but the release of the pressure leaves the inner half of the forging under a compressive stress, which is a maximum at the bore, the outer half under a stress of tension, which is a maximum at the outside, and at the center of the forging a point of zero stress.

A mild heat treatment is then given to the forging, which has the effect of making permanent the increased elastic strength acquired by the autofrettage pressure.

The forging is again set up and the autofrettage pressure is reapplied several times. The bore, the outside diameter, and the length are measured to find what alterations in size have taken place. The surplus material at each end of the forging is cut off, and the forging is then finished bored, turned, and rifled similarly to the process described for built-up guns.

643. Present limits of the radial expansion process.—At present the radial expansion process, as applied to monoblock (1-piece) guns, has been limited in our service to 6-inch guns and those of smaller calibers, because of the difficulty in obtaining the required physical characters (*i.e.*, elastic limit and ductility), and homogeneous metal, in a larger single forging. There are no physical limitations, however, to extending the process to the manufacture of guns having *more* than one layer. Such guns would still have fewer layers, each of much greater thickness, than the present built-up guns whose members are assembled by heating and shrinkage. On this basis the Navy has built 8-inch, 2-piece guns, composed of a jacket shrunk over a radially expanded tube. The jacket acts as an additional strength member and serves to stiffen the gun to prevent excessive droop. The weight of the jacket also maintains the center of gravity at about the same point as in the built-up gun. Furthermore, the additional weight is necessary in order to avoid excessive recoil forces, for it must be realized that the force of recoil of a lighter gun will require a correspondingly heavier mount structure. The 8-inch radially expanded gun weighs roughly 28,000 pounds less than the 8-inch built-up gun designed for the same muzzle velocity, and it is not necessary to sacrifice all this saving in weight for a heavier mount.

644. Advantages of radially expanded guns.—When compared with a built-up gun of similar caliber, length, muzzle velocity and rifling, the radially expanded gun is stronger, and, hence, will withstand higher explosive pressures. The latter permits a smaller chamber volume, smaller chambrage, and a slightly smaller charge. A smaller charge will reduce slightly the erosion rate. The outside of the gun is smaller. Most important of all, the weight is considerably less. The cost and time to build is greatly reduced. Less labor is required. Less machine and other work is necessary. The construction output may be greater.

CHAPTER VII.

BREECH MECHANISMS.

701. Definition.—*A breech mechanism* 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.

702. 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 prevented from escaping to the rear; this sealing, or obturation, must be automatic, greater pressure increasing the sealing or obturation. (b) Fitting of the breech mechanism should reduce the gun strength by a minimum amount, never below an adequate factor of safety. (c) The parts must have ample strength to prevent any portion from being broken or 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.**—This is necessary for rapid continuous fire. Hence, this should include facility of loading, and certainty of extraction for rapid-fire guns.

3. **Not easily put out of order.**—It must be able to meet service conditions and hard usage. Parts should have a reserve of strength. All parts of the mechanism should be so designed as to be protected against injury.

4. **Ease of repair.**—Parts most exposed to wear should be so designed as to permit easy replacement. This should also include accessibility of parts, so that breakage of any part will not disable the mechanism for any length of 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.

703. The breech block or plug is the movable piece closing the breech of a gun. In most built-up guns it is carried by the jacket; in the latest large guns, however, it is carried within a screw-box liner, or bushing. The above term applies to any shape of piece, or for any system of closure. 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."

704. Systems of breech blocks.—The following are the principal systems of breech blocks that have been used in the Navy: (1) the rotating block with interrupted screw, (2) vertical sliding wedge, (3) horizontal sliding wedge, (4) combined sliding and rotary systems, (5) the sliding bolt system. (Plates I and II.)

System (1), the rotating block with interrupted screw, is used for all major and intermediate caliber guns now in service except for the 5-inch anti-aircraft guns. Systems (1), (2), and (3) are used on the various 3-inch guns. Secondary rapid-fire or cartridge-case guns, such as the various field guns, boat guns, saluting guns, and sub-caliber guns, use systems (2), (3), and (4). Military rifles, as well as certain automatic guns and machine guns, generally use the sliding-bolt system.

Special guns, such as automatic guns and machine guns, more properly use a "breech action," in which the different steps in closing the breech and operating the entire mechanism are very intimately connected. The system in these cases is defined by the name of the gun.

705. An interrupted-screw plug is a plug which 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 it in the screw box. The rotating block may be: (a) eccentric for use in guns firing case ammunition so that the firing pin will not be in line with the cartridge case primer until the block has been completely rotated and locked, (b) concentric for use in guns firing bag ammunition. 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.

The French interrupted screw at one time was the most common system of fermeture. The breech plug, cylindrical in shape, has cut on its circumference a male 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; a minimum of 50 per cent of the holding strength of the screw thread is thus sacrificed in the slotted sections. 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 mechanism, to the proper distance; and a fraction of a turn to the right or left is given, to interlock the threaded sections, the amount of turn necessary depending upon the number of sections into which the circumference has been divided. Six sections (three threaded and three blank) require 60°; eight sections (four threaded and four blank) require 45°, etc. The system is independent of the method of operating the mechanism. (Plate II, Fig. 1.)

The Elswick interrupted screw differs from the French type, in that the forward part of the plug is conical and the rear part cylindrical. The threaded sections of the coned portion and the threaded sections of the cylindrical part are staggered. The advantages claimed for this arrangement are: (1) The working of the mechanism is facilitated, as the plug can be swung clear of the screw box without translation; (2) arrangement of the threaded sections distributes the strain around the entire circumference of the plug; (3) the cone-shaped plug increases the cross-section of the jacket at the forward end of the plug where the stresses in the gun are greatest. (Plate II, Fig. 2.)

The Welin interrupted screw or *stepped-thread* system has the block divided circumferentially into a number of groups of blanks and threaded sectors of increasing radius, so disposed that when the plug is unlocked the smaller threaded sectors of the plug clear the next larger threaded sectors of the screw box. Each group of sectors consists of one blank and two or more threaded sectors. Three or four such groups of sectors are arranged around the circumference of the plug. This arrangement of threads gives a larger percentage of holding strength for a given length of plug and requires a minimum amount of rotation. (Plate II, Fig. 3.)

706. The vertical sliding-wedge system, exemplified in the Hotchkiss and 3-inch semi-automatic 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. (Plate I, Fig. 2.)

The horizontal sliding-wedge mechanism is similar to the vertical sliding-wedge system except the block moves in a horizontal direction. This form of breech plug is used in 3-inch 23-cal. AA guns. (Plate I, Fig. 2.)

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

CHAPTER VII. PLATE I.

FIG. 1. INTERRUPTED SCREW.
ALL MAIN BATTERIES.
4" PLUG.

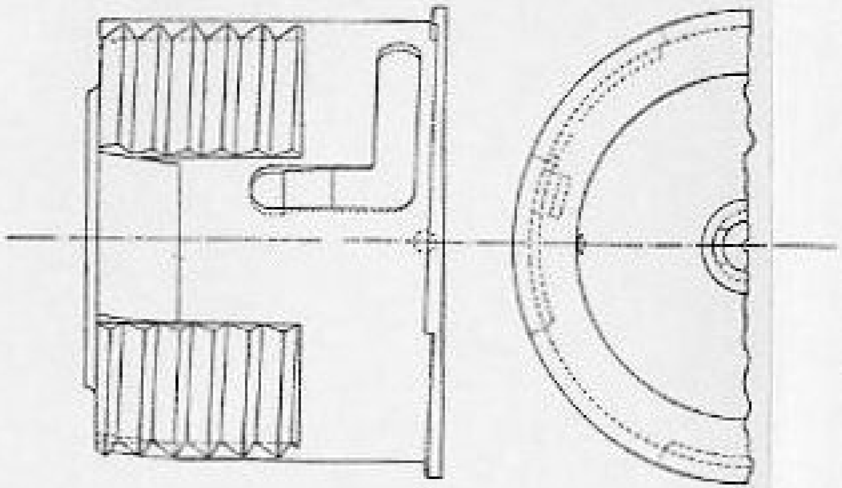


FIG. 2. SLIDING WEDGE.
HOTCHKISS 6-PDR.

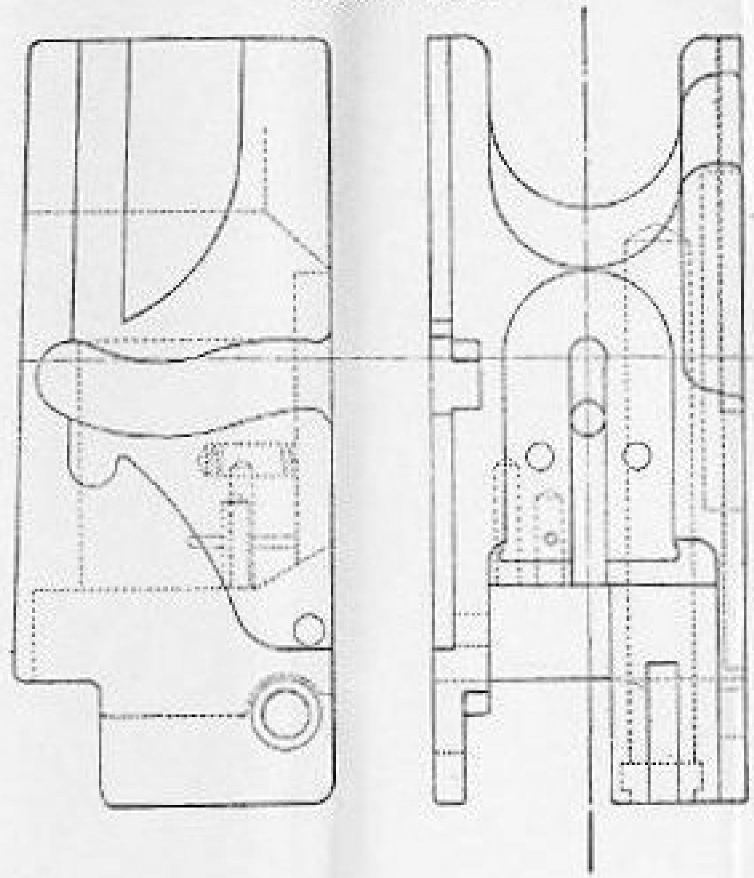


FIG. 3. SLIDING AND ROTARY BLOCK.
DRIGGS-SCHROEDER 6-PDR.

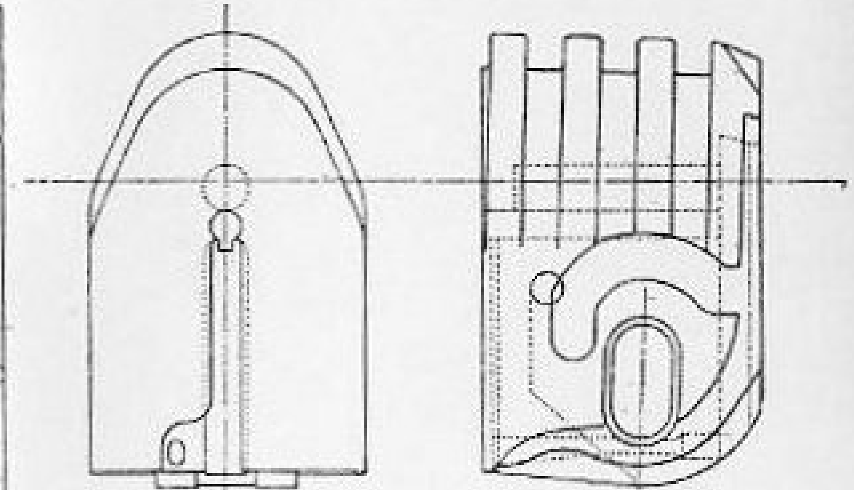
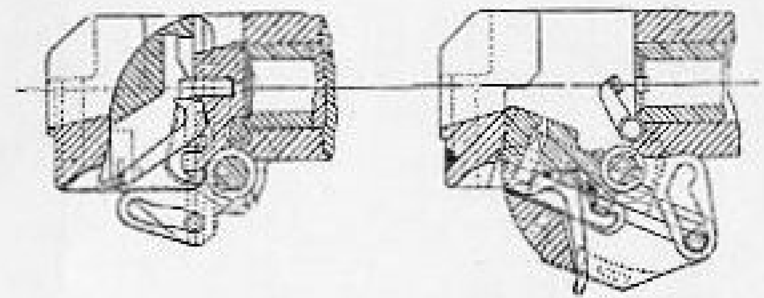
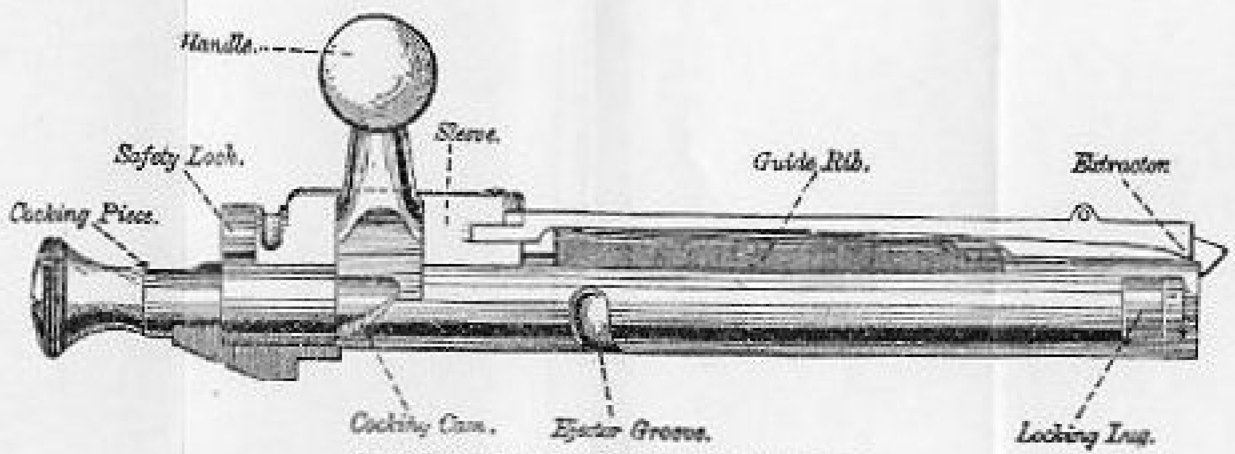


FIG. 4. COMBINED ROTARY AND SLIDING WEDGE.
NORDENFELT 6-PDR.





SYSTEMS OF BREECH-BLOCKS.

FIG. 1 FRENCH INTERRUPTED SCREW.

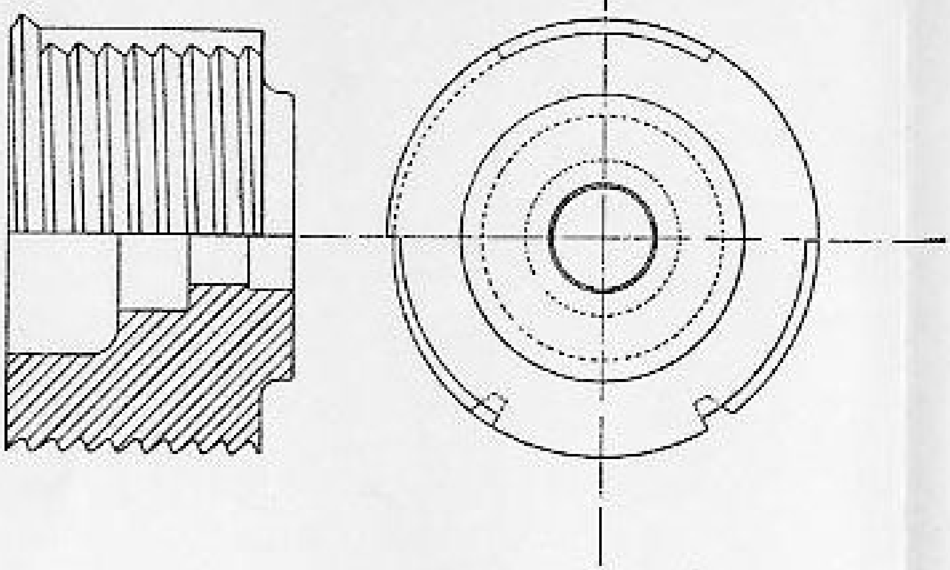


FIG. 2 ELSWICK INTERRUPTED SCREW.

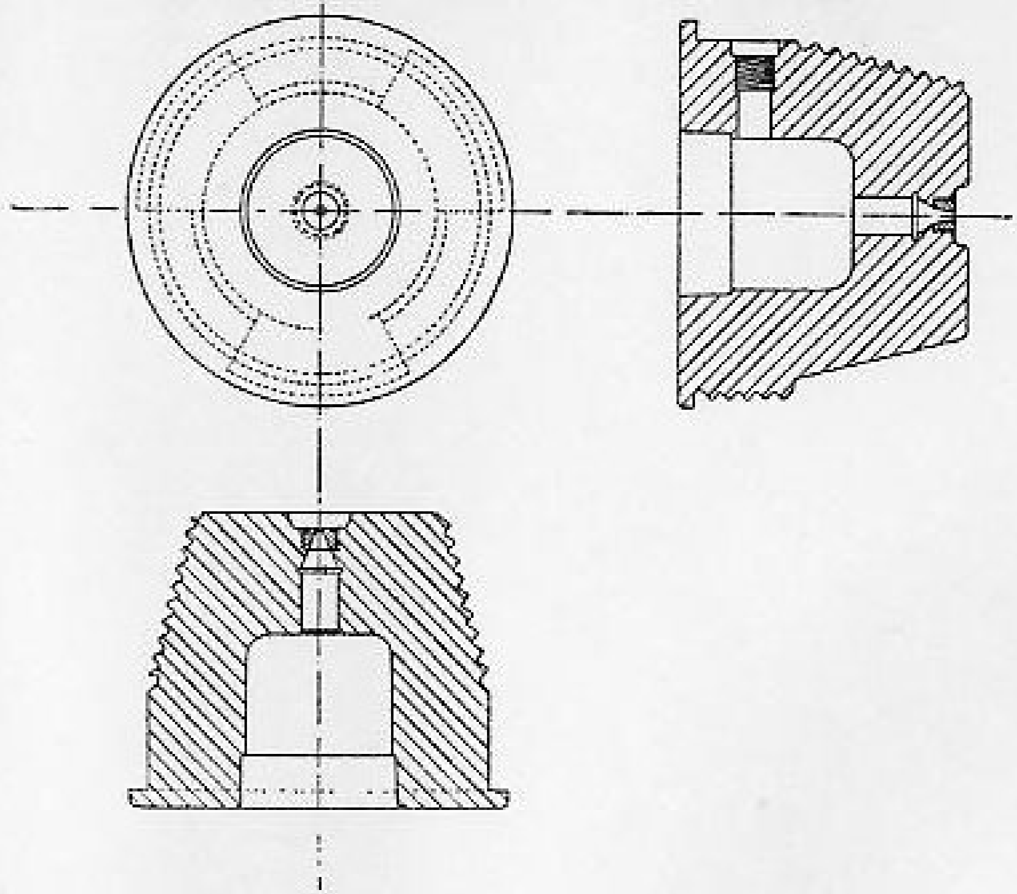
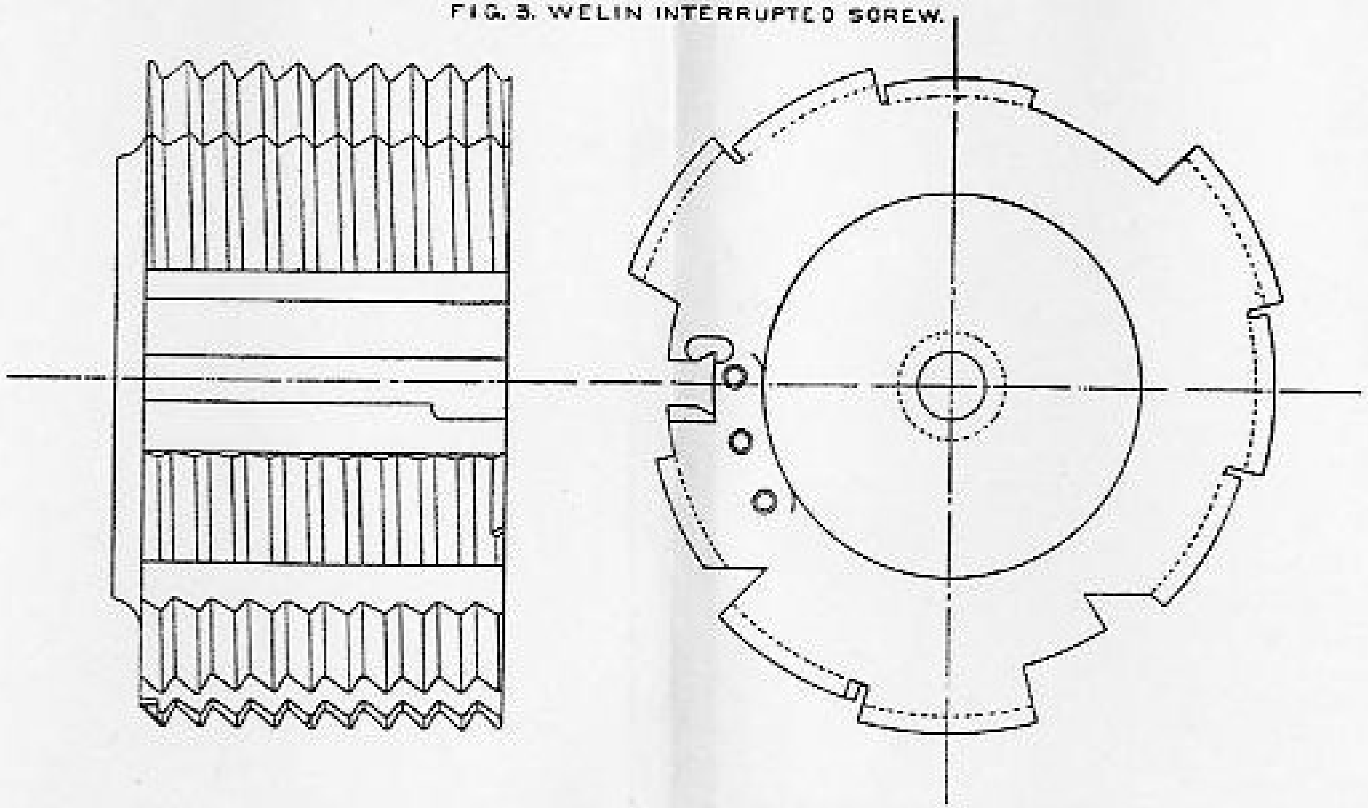


FIG. 3. WELIN INTERRUPTED SCREW.



THREE SYSTEMS OF INTERRUPTED-SCREW THREAD.

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. (Plate I, Fig. 4.)

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 guns. 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 the final movement in closing is upward and to the front, pushing home the cartridge case. The operation is through a cam within the block, moving against curved surfaces in the block's recess; the cam is moved by a transverse axis. (Plate I, Fig. 3.)

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." (Plate I, Fig. 5.)

707. Types of breech mechanism used on intermediate and major caliber guns.—The Smith-Asbury system of operation is employed on breech mechanisms of 4-inch, 5-inch, 6-inch, 14-inch, and 16-inch guns. The 12-inch breech mechanisms now in service (and a few of the original 14-inch breech mechanisms remaining on the *New York* and *Texas*) employ the Farcot operating mechanism for opening and closing the Welin-type plug. In the Farcot system a worm shaft and gearing rotate the plug, translate the plug axially to the rear until it is received upon and latched to the plug tray. Continued rotation of the crank handle on the worm shaft then unlocks the plug tray from the breech and permits the plug tray to swing the plug clear for loading.

The 8-inch breech mechanism installed on the heavy cruisers is of the carrier type operated by a Bureau of Ordnance design. A short continuous swing of the operating lever, by means of a crank and cams, accomplishes the rotation of the plug and withdrawal of the plug from the screw-box liner.

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

A quick-fire breech mechanism is one which can be easily and rapidly operated. It is used on bag guns and hence requires a gas check, gas ejector, and firing lock suitable for bag ammunition.

A rapid-fire breech mechanism is one which can be easily and rapidly operated and which is fitted to case guns. It requires an extractor and special firing mechanism suitable for case ammunition.

There is, in reality, no distinction between the rapid fire and the quick fire, so far as the operating gear is concerned; but the names are given because of the differences in the breech mechanisms and the differences in the loading drill which result from differences in assembly of the ammunition. In loading a rapid-fire gun, no *bore clear* signal is required.

The term "quick fire" is apparently indiscriminately used abroad for guns having a quick-acting mechanism, whether using metallic cartridge case or powder charges in bags. It is well that a distinction should be made, as in the U. S. Navy, by the use of the terms "case guns" and "bag guns."

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.

709. 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.

The following are the **principal characteristics** governing the design of a gas check:

1. It should function at all temperatures that may be encountered in service due to weather conditions, that is, from approximately 5° to 110° F., and also be unaffected by the variations in temperature due to firing the gun. Temperature increases as high as 200° F. have been observed when firing a 3-inch rapid-fire gun.

2. In order that the mechanism will function with ease, the device should not adhere too strongly to its seat.

3. It should be elastic enough to conform to its seat, but also rigid enough so as not to be deformed to such an extent as to prevent successive functioning.

4. It should respond equally as well to the lowest as to the highest pressure developed in the gun.

5. It should exert a pressure on its seat greater than, or at least equal to, the gas pressure.

To meet the above requirements it is necessary to consider, first, the type, and second, the application of the gas check.

710. There are in general two types of gas checks, the *plastic* and the *elastic*.

The first plastic materials used for gas checks were fibrous materials such as cardboard or papier-mâché. Experiments were also made with soap, but the soap liquefied due to the action of the heat. The materials actually in use are composed of about 65 per cent of a mineral fiber such as asbestos, and 35 per cent of tallow. The tallow keeps the gas check plastic and causes the fiber to flow under the action of the heat and pressure.

The advantage of the *plastic gas check* is that it conforms to any irregularities of its seat caused by erosion or accident. The disadvantages are the fact that it is apt to adhere to its seat too strongly, or to be deformed while the block is open with the result that the mechanism will not function with ease. Plastic materials do not retain a definite form, but may easily be deformed and reformed under pressure. The pressure is transmitted equally in all directions, as in a fluid, and to a greater degree than in elastic solids.

Plastic gas checks function satisfactorily when the gun is not fired too rapidly and with proper care a large number of rounds may be fired without changing the pad. They are used on all bag guns in our Navy.

711. Elastic gas check material may be divided into two classes, rigid and flexible, depending upon the resistance they offer to deformation. Steel is the most rigid and rubber compounds are the most flexible materials that have been used. Rubber compounds give a good seal for a few rounds, as they conform easily to their seats, but they are apt to adhere to the gun or block which makes it difficult to operate the breech mechanism. They are sensible to variations in temperature, being too soft at high and too hard at low temperatures. They are also attacked by the powder gas and oil. Elastic gas checks are made of copper, brass or steel.

An elastic gas check conforms to its seat under pressure except when small irregularities exist in the surface of the gas-check seat, hence the sealing depends upon the condition of the surfaces in contact. On the other hand, there is less tendency to adhere to its seat as the device returns to its original form as soon as the pressure is relieved, and it is not so easily deformed when the block is open.

712. Automatic sealing.—Scaling of the breech of the gun against the passage of the flame and gases of combustion is effected in the U. S. Navy by gas checks in which the pressure on the seat is built up automatically by the pressure of the powder gas. There are two methods of automatic sealing (a) by expansion and (b) by compression.

(*a*) *Sealing by expansion* is obtained by the use of a metal cartridge case, Fig. 701. The action of the gas is to expand the cartridge case against the wall of the chamber of the gun. The amount of this expansion being equal to the clearance between the case and chamber, plus the deformation of the gun due to the pressure of the powder gas. The total expansion should not exceed the elastic expansion of

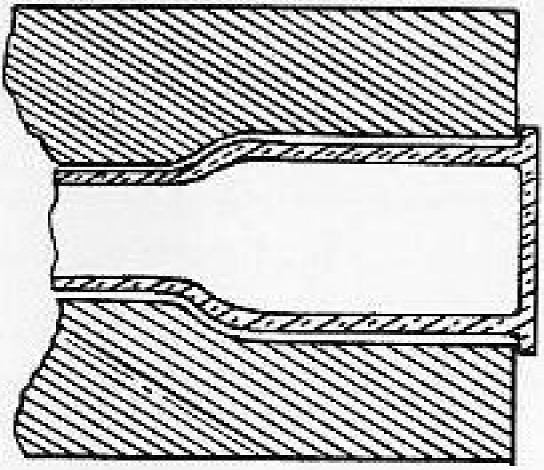


FIG. 701.

the case, as otherwise the case may be permanently deformed or cracked and offer too much resistance to ejection. For this reason the metal should not be too hard or too soft.

When the charge is first ignited a small quantity of gas passes between the case and the wall of the chamber, but due to the small area, and great length of the channel, the resistance to its passage is high and the pressure builds up so rapidly in the case that the sealing takes place very quickly. The surface in contact is so large that small local irregularities do not affect the seal.

The case should be sufficiently thick at the base to prevent the metal from being forced into the joint between the breech block and the gun, but sufficiently thin at the mouth to insure easy expansion.

(*b*) *Sealing by compression* is generally obtained by the use of a plastic gas check as in the De Bange system, Fig. 702. A ring-shaped pad of plastic material, A, contained in an envelope, B, is held between the breech block, C, and the "mushroom," D, by the spindle of the mushroom which passes through the pad and breech block.

The action of the gas pressure is to force the head of the mushroom to the rear, thus building up pressure in the plastic material which is

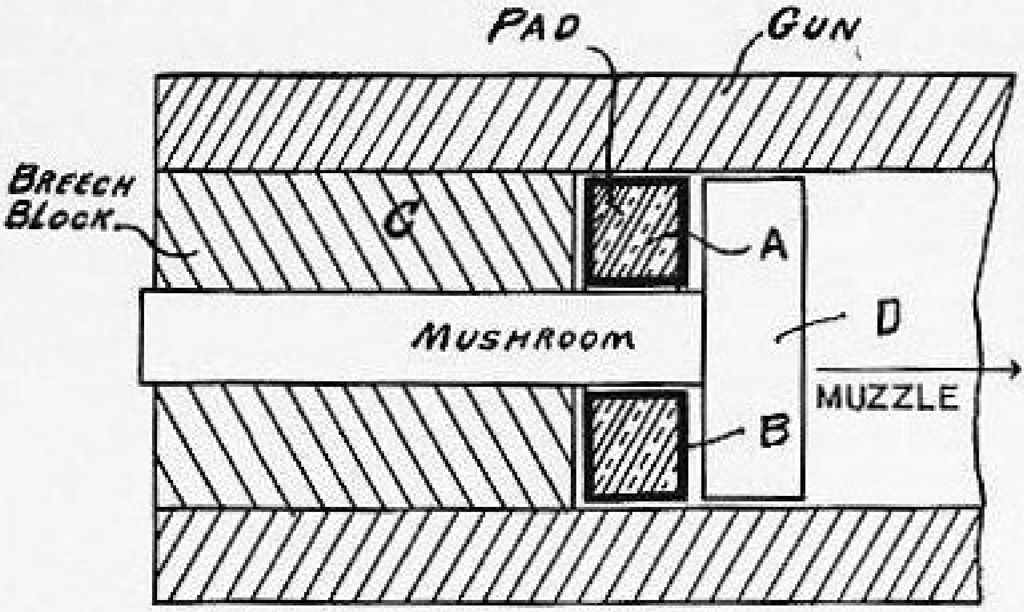


FIG. 702.

transmitted in all directions and presses the envelope against the wall of the gun.

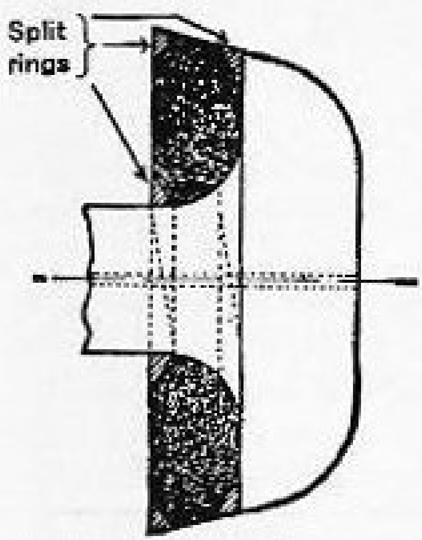


FIG. 703.—THE DE BANGE GAS CHECK—SHOWING SPLIT-RINGS.

713. The De Bange gas check pads used in the Navy, as shown in Figs. 703 and 706, are made of a plastic material with a neat-fitting canvas cover. The edges are protected by split metal rings which expand due to the pressure transmitted by the pad. The chamfered edges where the rings are split, have a tendency to wear or cut the covering of the pad. On guns of 6-inch caliber and above, this is prevented by a thin copper protector formed to the contour of the forward face of the pad. The use of this copper protector will doubtless be extended to all bag guns.

When the pads are to be used in guns where high pressures are developed, the pads are made as above except they are compressed in steel dies under a pressure from 50,000 to 80,000 pounds per square inch. After being subjected to this pressure they are no longer soft but possess a certain amount of elasticity, and may be said to be plastic-elastic. Due to this initial compression the recoil of the mushroom relative to the breech block is very small.

714. A gas check experimented with in Spain is shown in **Fig. 704.** It consists of a mushroom, *A*, which bears against a copper ring, *B*, of triangular cross section. The pressure of the powder gas on the mushroom head causes the copper ring to expand and exert a pressure on its seats. It appears that this system should give good results, but there is none of this type in the U. S. Navy.

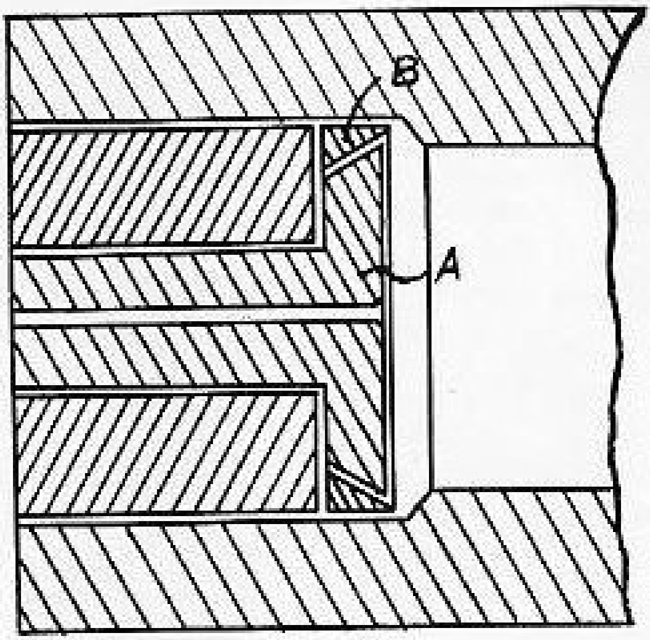


FIG. 704.

715. Mechanism for breaking the seal of gas checks and extracting cartridge cases: When plastic gas checks are used it is necessary that the breech mechanism be designed so as to facilitate the breaking of the seal of the gas checks, which adhere strongly to their seats after the gun has been fired. In the first place it is necessary that the breech block may be rotated independently of the gas check, and secondly, that sufficient force may be exerted to translate the block and gas check to the rear. A thorough description of the action of the breech mechanism and the De Bange gas check pad will be found in the description of the Mark VII—5″ breech mechanism (see **Art. 728**).

When cartridge cases are used it is necessary to provide a mechanism for extracting the case. This mechanism should be designed, first, to loosen the case by extraction, and second to eject the case when the breech is fully open. In general, it consists of a lever which engages the rim on the base of the cartridge case, the other end being pivoted near the hinge pin of the breech-block carrier. This lever remains stationary during the first part of the rotation of the block; the portion which engages the case is then moved slowly to the rear as the outboard end of the extractor lever is forced forward by a cam surface on the breech-block carrier. This exerts sufficient force on the case to start it from its seat. The lever then becomes practically stationary until the breech is fully opened. The final movement of opening gives the outboard end of the lever a very quick motion forward with the result that the inner end of the lever ejects the case clear of the gun. With breech mechanisms of the sliding wedge type, the extraction is accomplished upon the same principle, but details of its application vary slightly.

TYPES OF SALVO LATCHES.

716. When a number of guns are fired in salvo, the gun captain sometimes fails to observe whether or not his own gun recoils and counter-recoils. In other words, after a salvo the gun captain sometimes does not know whether or not his own gun has fired. If the gun captain, thinking his gun has fired, should open the breech while a hangfire was in progress, a disaster would result. To prevent the opening of the breech of a gun after loading, the operating mechanism is locked by a salvo latch until the gun has fired and recoiled.

Breech mechanisms in general cannot be opened by a pressure on the front face of the breech block, but there is a tendency for the breech mechanism to rebound from the breech in closing, and to open due to inertia during recoil or counter-recoil, or due to the shock of firing. In addition to performing its primary function, the salvo latch prevents the rebounding of the plug and premature opening during firing or recoil.

The design of these latches varies with the particular mechanism, but usually the lock feature is incorporated in the operating mechanism. As soon as the breech has been closed, the operating handle is latched in a closed position by the salvo latch which unlatches during the recoil of the gun. The salvo latch prevents the mechanism from being opened after the gun has been loaded except when this is done deliberately with full knowledge that the gun is loaded. Most guns are fitted with salvo latches which are unlocked by *inertia*. Breech mechanisms of the sliding-wedge types lend themselves to the attachment of *positive* type salvo latches which are unlocked by the full recoil of the gun past a fixed attachment on the slide. The recoil produced by the firing of reduced charges is sufficient to accomplish the unlocking of the breech. The latest guns developed in the U. S. Navy, 5-inch 25-caliber and 5-inch 38-caliber guns, are of the sliding-wedge type breech mechanism, and these guns as well as the 3-inch

50-caliber anti-aircraft guns are fitted with positive type salvo latches. The positive type is superior to the inertia type salvo latch. Guns now fitted with inertia type salvo latches will gradually be modified by the installation of positive type salvo latches. New guns of all types will be fitted with positive type salvo latches.

3-INCH SEMI-AUTOMATIC BREECH MECHANISM, MARK V.

(Plate III.)

717. This mechanism is of the vertical sliding-wedge type, which has been sometimes designated as the "Driggs-Seabury semi-automatic mechanism." Several modifications have been made to remedy minor defects in the original design.

718. The operation of this mechanism may be readily understood by following the description below and referring to Plate III. If model breech mechanisms or guns are available, as at the Naval Academy, it is recommended, however, that the mechanisms be inspected in conjunction with a study of these pages.

The crank shaft H (Fig. 2) rests in a cradle projection under the gun and is held in place by means of a lock plate L (Figs. 4 and 5), which is dovetailed to the bottom of the breech housing and secured by the lock plate lock bolt. As the crank shaft is rotated the breech block crank (Fig. 2) moves along a sloping cam surface on the under side of the block, raising or lowering it.

Assume that the thrust cam B (Figs. 7 and 8), which is attached to a bracket secured to the slide, is set for semi-automatic operation. Then, when the gun recoils, the tumbler crank on the left end of the crank shaft H (Fig. 2) strikes and passes over the thrust cam B (Figs. 7 and 8), forcing the latter to rotate through 68° to 74°. After the tumbler crank has passed by the thrust cam, the latter is returned to its original position by the thrust cam spring (Fig. 5), so that on counter recoil the tumbler crank again is brought up against the thrust cam (Fig. 9). This time, however, the thrust cam, being locked, forces the crank shaft to rotate, thus causing the breech block to be dropped.

The rotation of the crank shaft also causes the operating spring to be compressed (Fig. 1), the operating spring arm on the right end of the crank shaft being engaged to the spring piston through the operating chain and spring piston rod.

As the block drops, the extractor lugs C (Fig. 5) follow the extractor grooves in the block, forcing the lugs forward and the upper nibs of the extractors aft, accomplishing extraction. The lugs also, by bearing on shoulders M (Fig. 4) in the block at the top of the extractor grooves, hold the breech block down. The extractors are held in this position

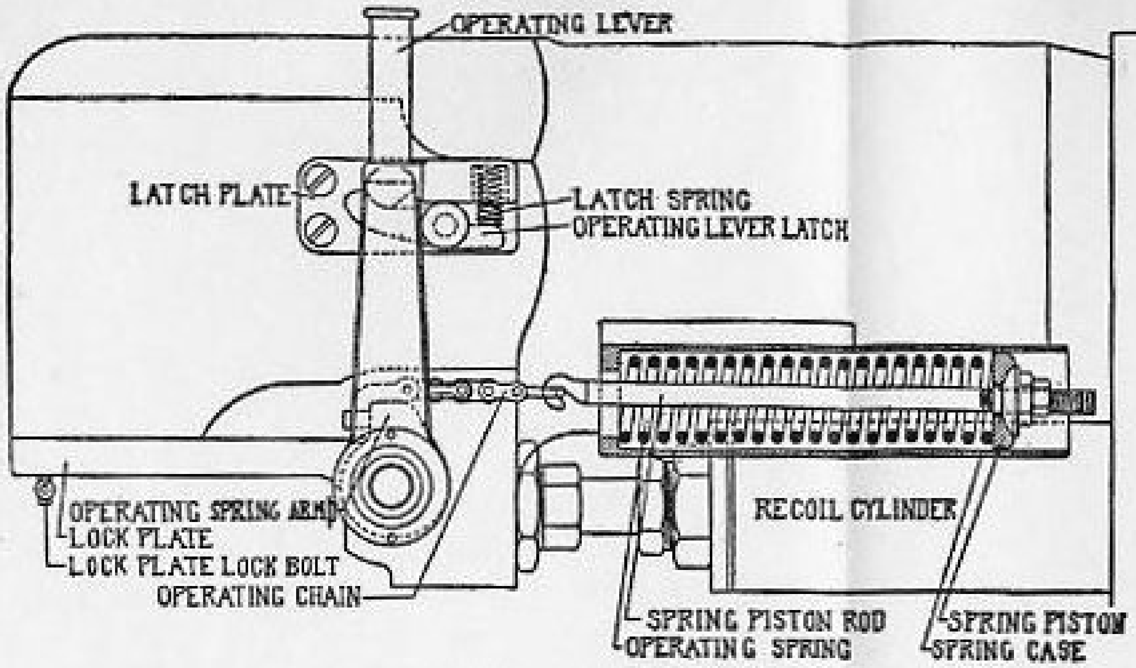


FIG. 1.—Right Side of Gun. (Breech closed.)

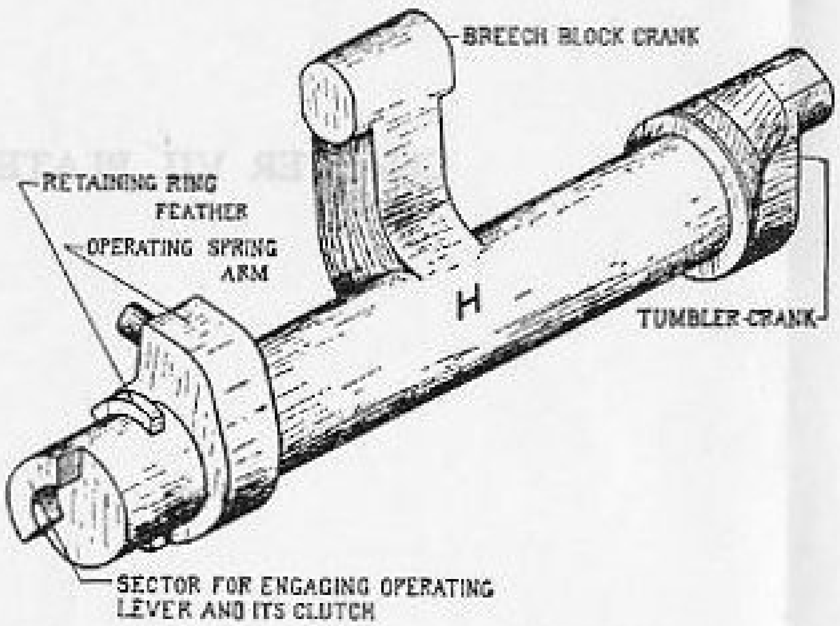


FIG. 2.—Crank-Shaft.

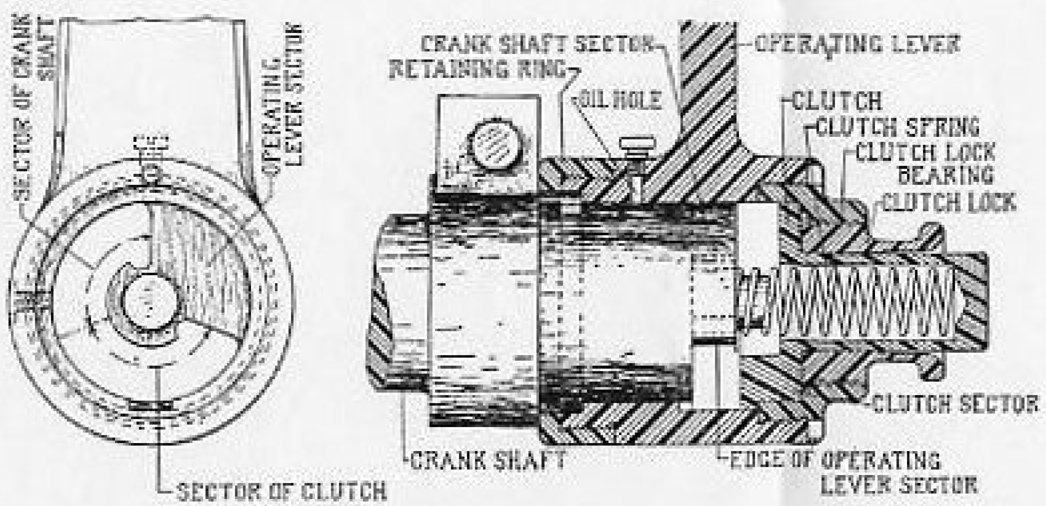


FIG. 3.—Clutch-Mechanism.

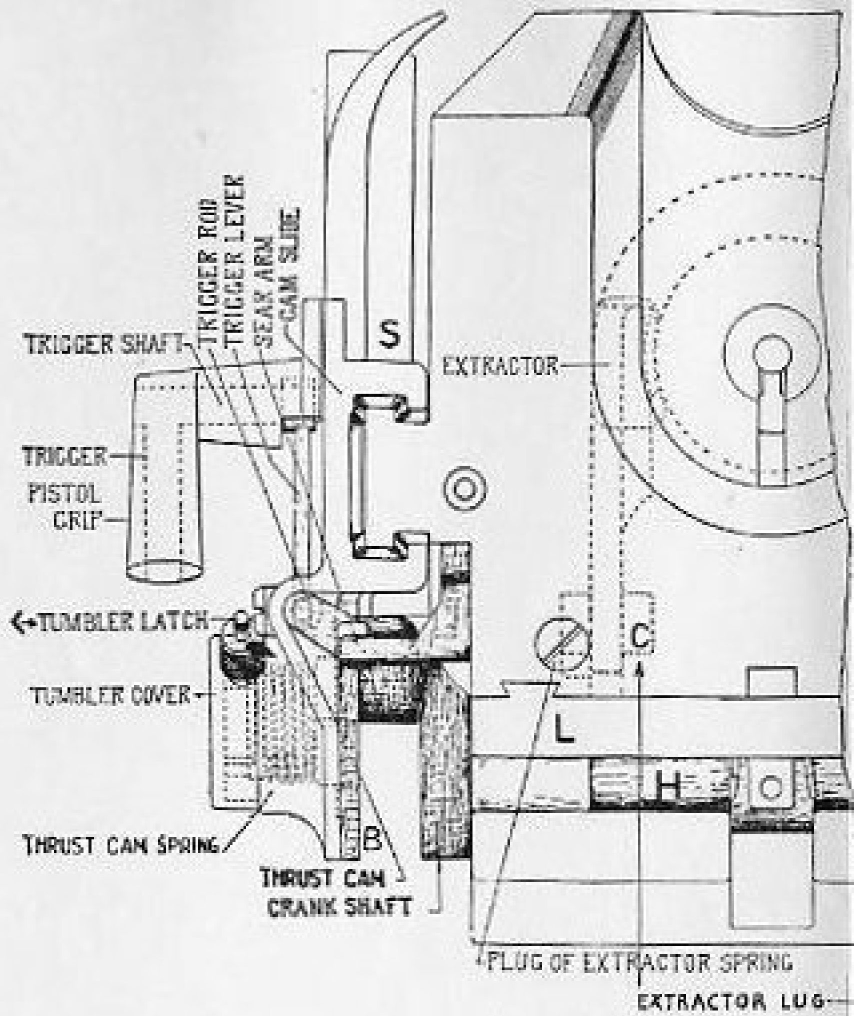


FIG. 5.—Rear View. (Breech closed.)

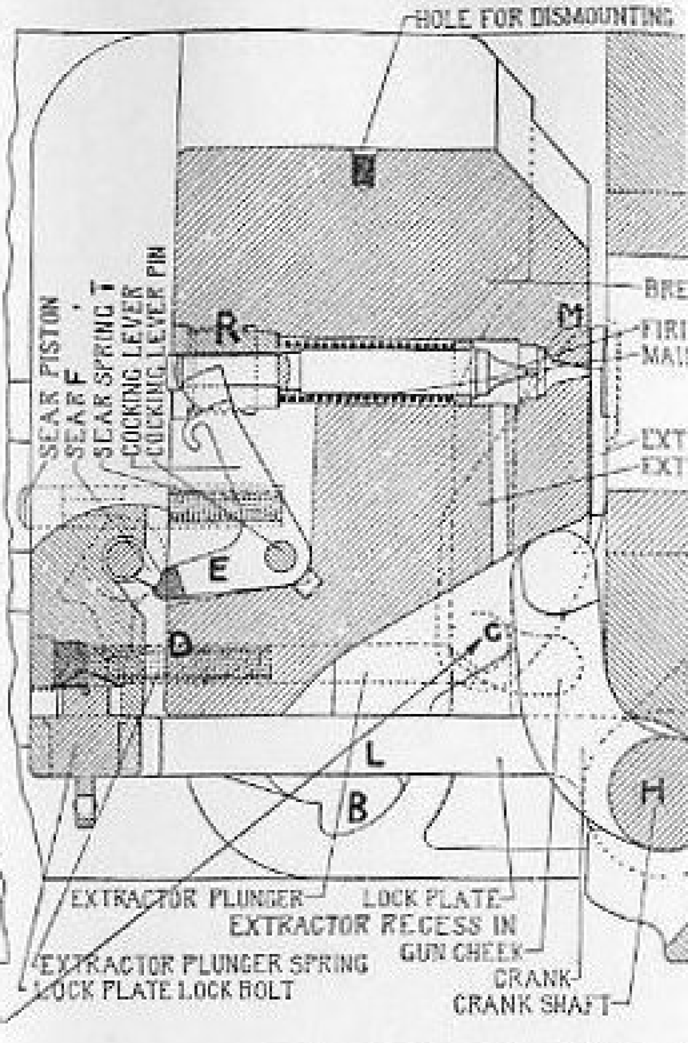


FIG. 4.—Gun Closed. (Breec

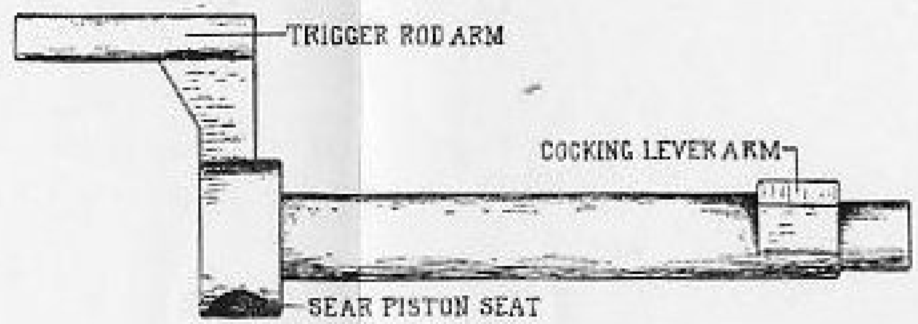


FIG. 6.—Sear.

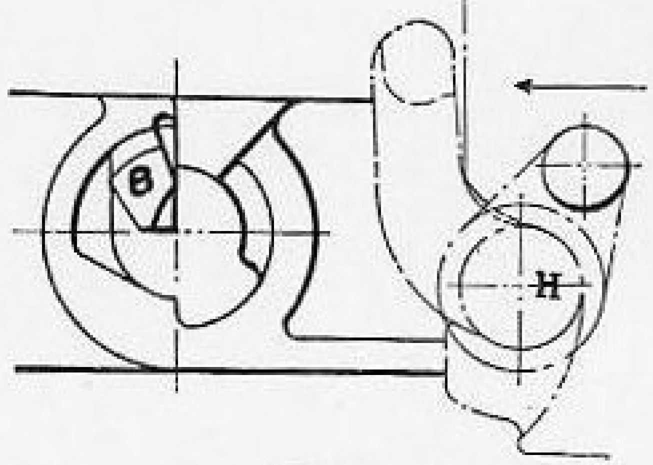


FIG. 7.

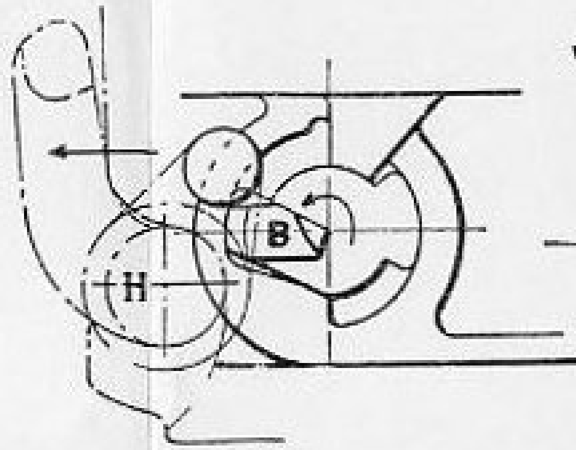
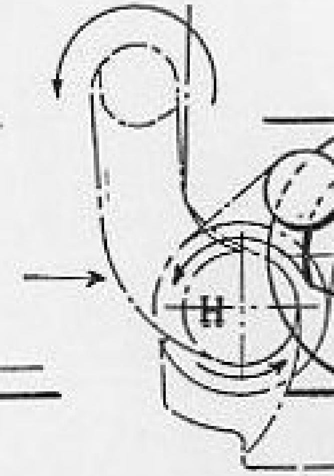


FIG. 8.



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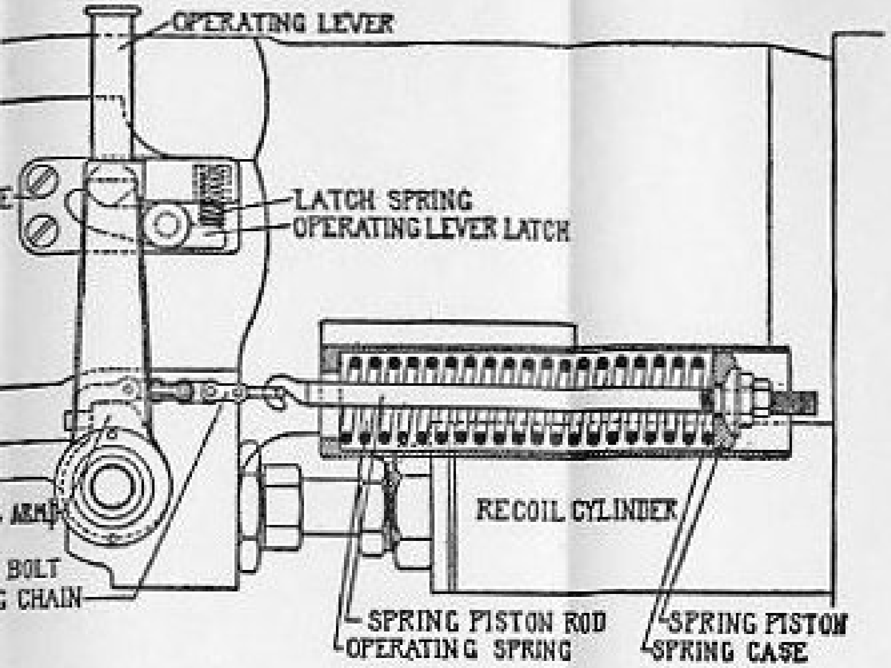


FIG. 1.—Right Side of Gun. (Breech closed.)

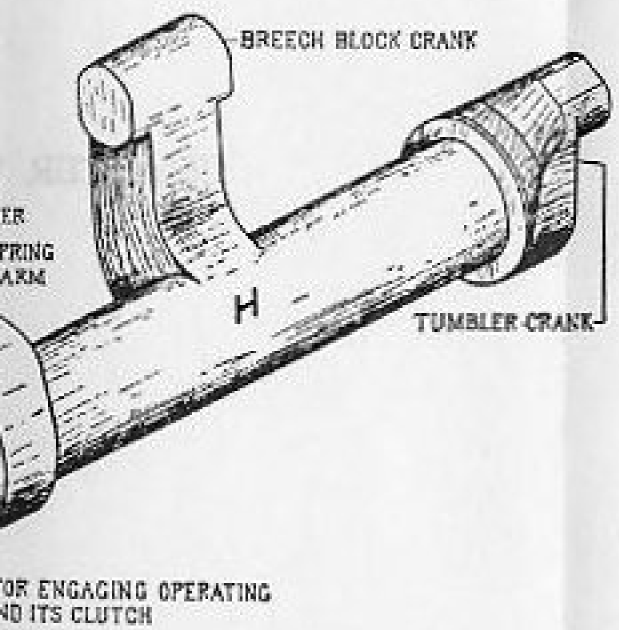


FIG. 2.—Crank-Shaft.

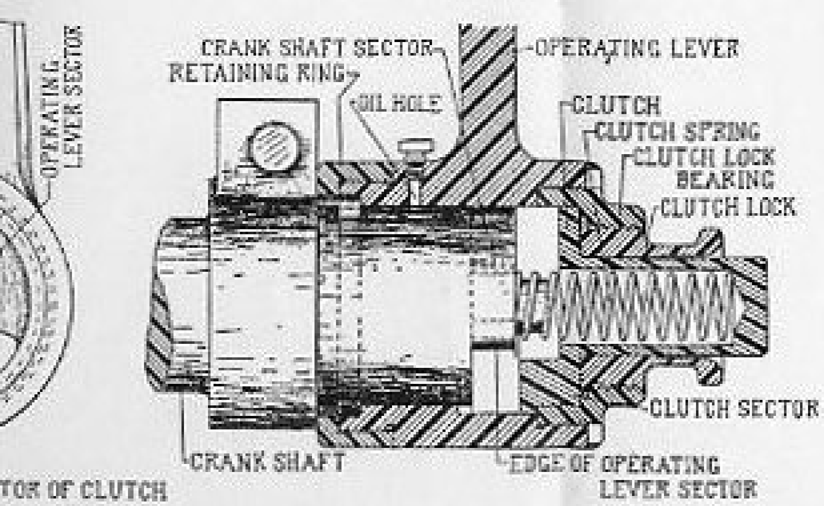


FIG. 3.—Clutch-Mechanism.

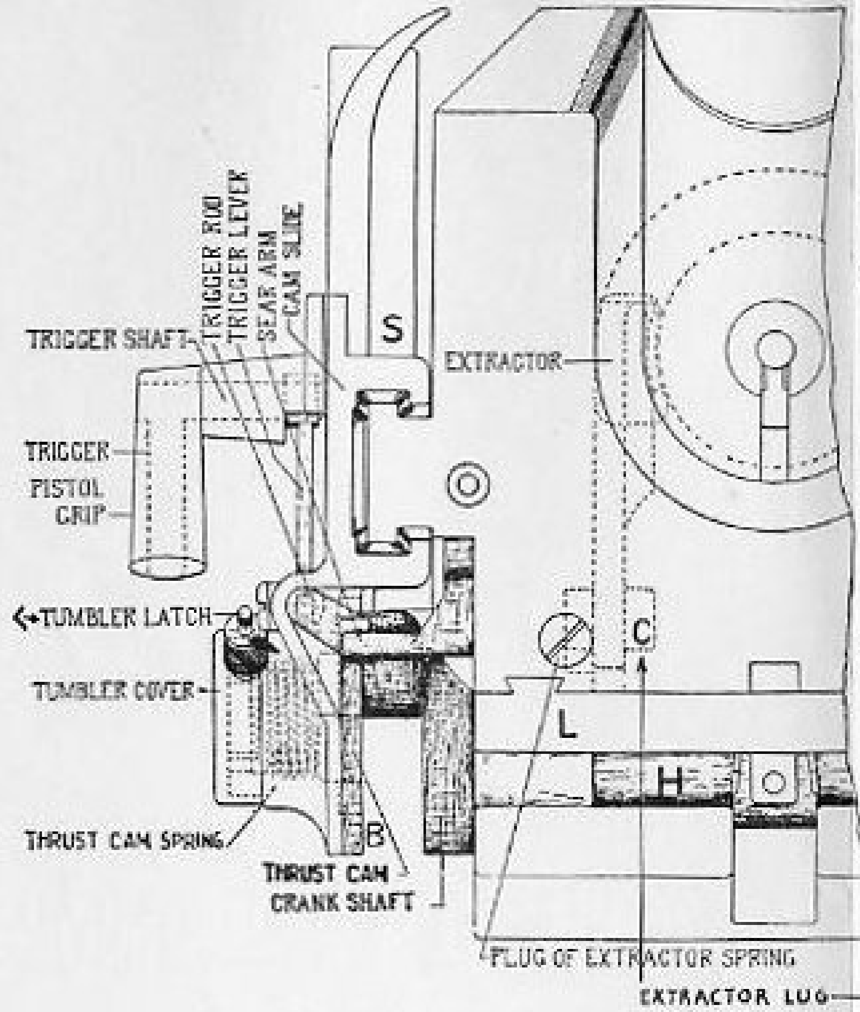


FIG. 5.—Rear View. (Breech closed.)

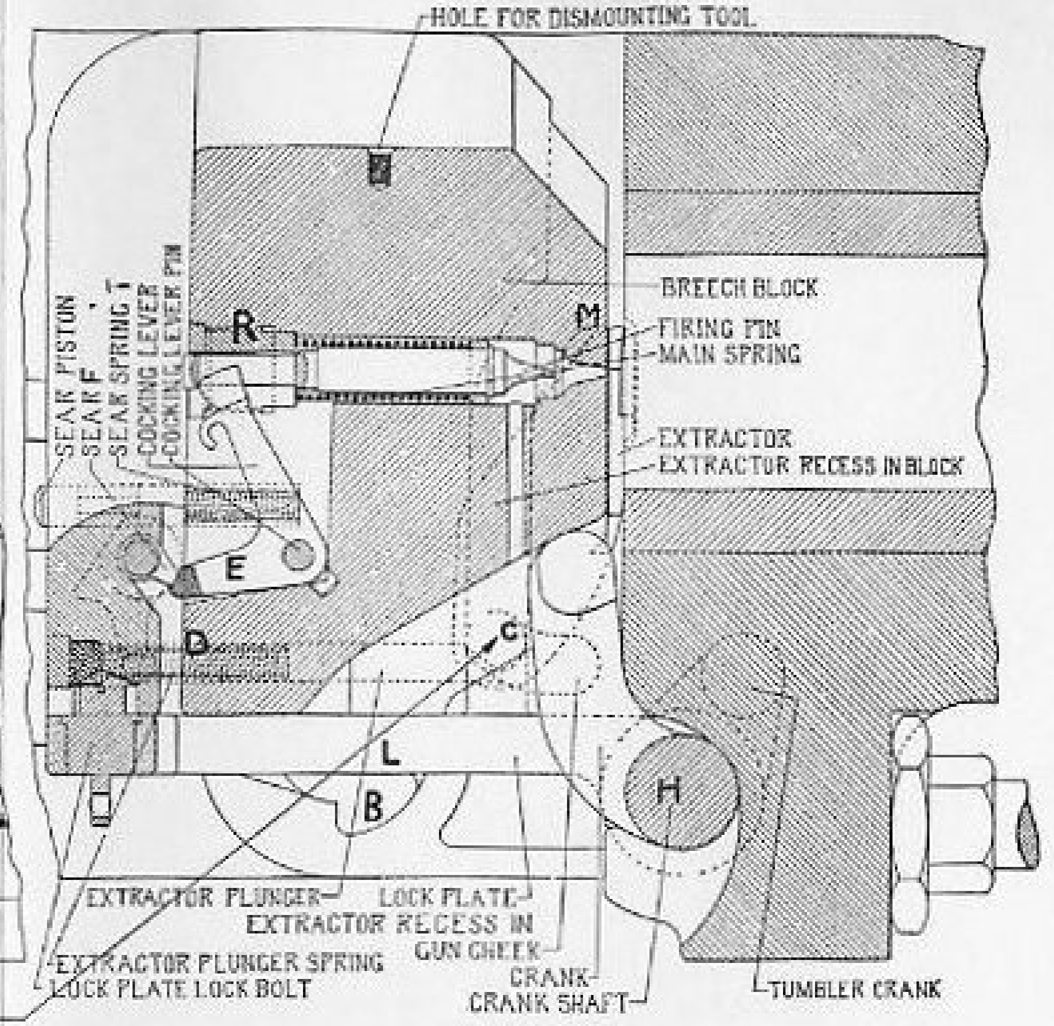


FIG. 4.—Gun Closed. (Breech closed.)

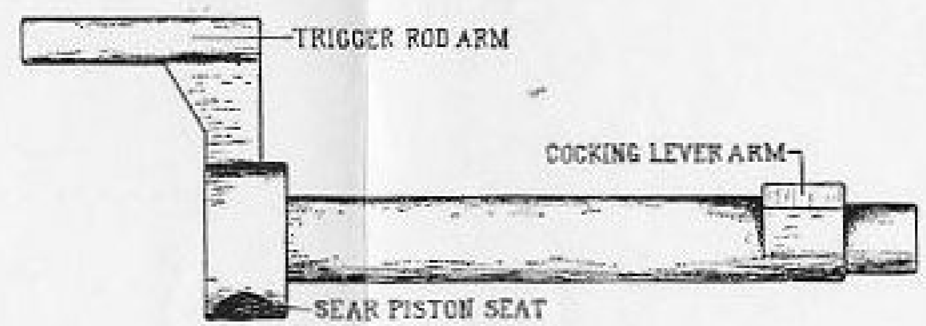


FIG. 6.—Sear.

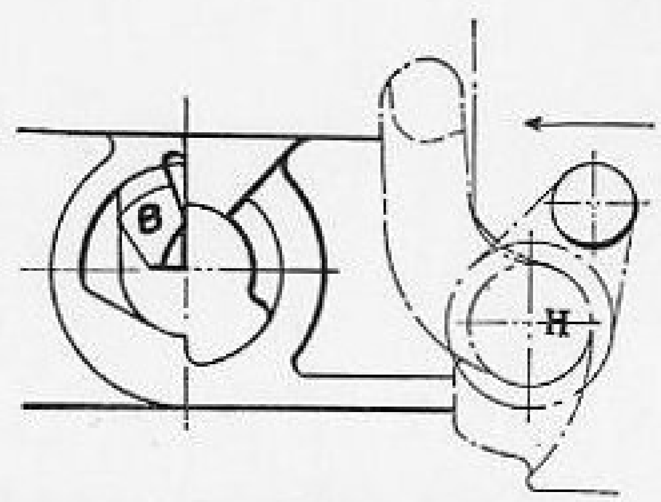


FIG. 7.

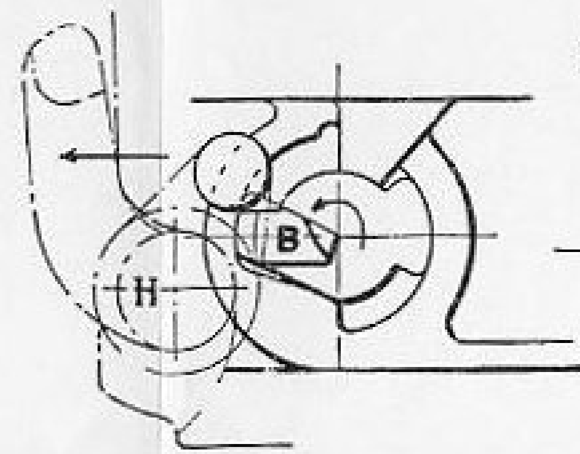


FIG. 8.

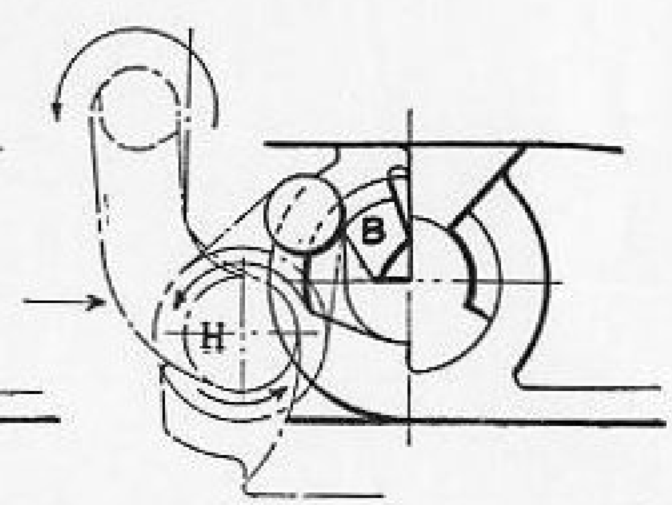


FIG. 9

by the extractor springs D (Fig. 4) and plungers, one to each extractor.

When the cartridge is loaded, the extractor nibs are struck by the flange on the base of the cartridge case and forced forward, and the lugs are disengaged from the shoulders on the block. The operating spring (Fig. 1), which was compressed on counter-recoil, then causes the crank shaft H to rotate, raising the block and closing the breech.

The semi-automatic feature can be eliminated by turning the thrust cam B (Fig. 7) to the rear and down, thus permitting the tumbler crank on the crank shaft to pass above the cam as the gun returns to battery. For this purpose there is a tumbler latch K (Fig. 5) fitted in the tumbler cover which holds the thrust cam down and to the rear.

719. Operating lever clutch mechanism (Fig. 3).—This mechanism is for the purpose of disengaging the operating lever, *i.e.*, preventing its rotation, when the gun is set for semi-automatic operation.

In Figs. 2 and 3 it will be observed that there are three 120° sectors for engaging the operating lever to the crank shaft, one, an integral part of the crank shaft (Fig. 2), one, an integral part of the operating lever (which otherwise is bored out to pass over the crank shaft), and the third, the clutch sector.

When the breech block is closed and the operating lever is in the vertical position, the upper face of the crank shaft sector is also vertical as in Fig. 2, and abuts against a corresponding face of the operating lever sector. If the clutch lock and sector are screwed out, there will be left a blank sector of 120°. Consequently, for semi-automatic operation it is evident that rotation of the shaft will not rotate the operating lever as the shaft sector will move in a blank sector. On the other hand, if necessary, rotation of the operating lever will rotate the crank shaft.

When the gun is not set for semi-automatic operation, the clutch lock is screwed inward, carrying the clutch sector in against the compression of its spring and filling the former blank space. The shaft and operating lever are thus securely locked together.

720. The firing mechanism (see Art. 750) functions as follows (Fig. 4):

When the breech block rises the cocking lever toe E strikes the nib of the sear F, thus drawing back the firing pin and compressing its spring. The sear F fits into the left of the breech housing and is held in position by a plunger and spring. The sear is rotated by the action of pull on the trigger, acting through the trigger lever, trigger rod, and sear arm. When the trigger is pulled the sear is rotated against the force of the sear spring, the cocking lever is released by the sear nib, and the firing pin flies forward. If the trigger were lashed in the closed position, firing would result automatically as soon as the breech is closed. Firing may also be accomplished by an electrical firing circuit, which includes a pointer's firing key and a solenoid. The plunger of the latter strikes the sear arm, tripping the sear.

721. The salvo latch, of the positive type, engages the left end of the plug-operating shaft. This latch unlocks when the gun has recoiled approximately half the amount of its normal recoil. As the plug, when operated automatically, does not start to open until after the beginning of counter-recoil and, if operated by hand, is not opened until after the completion of counter-recoil, it is apparent that the salvo latch unlocks sufficiently in advance to prevent interference with the normal operation of the plug. With the plug closed and locked, the salvo latch may be unlocked by hand.

5-INCH 25-CALIBER ANTI-AIRCRAFT BREECH MECHANISM.

722. The 5-inch 25-caliber breech mechanism is of the semi-automatic sliding-wedge type and is essentially the same as that of the 3-inch, 50-caliber anti-aircraft gun. It may be hand operated by a lever on the right side of the slide. The salvo latch, of the positive type, engages the left end of the plug-operating shaft. The latch unlocks when the gun has recoiled approximately half the amount of its normal recoil. As the plug, when operated automatically, does not start to open until after the beginning of counter-recoil and, if operated by hand, is not opened until after the completion of counter-recoil, it is apparent that the salvo latch unlocks sufficiently in advance to prevent interference with the normal operation of the plug. With the plug closed and locked, the salvo latch may be unlocked by hand.

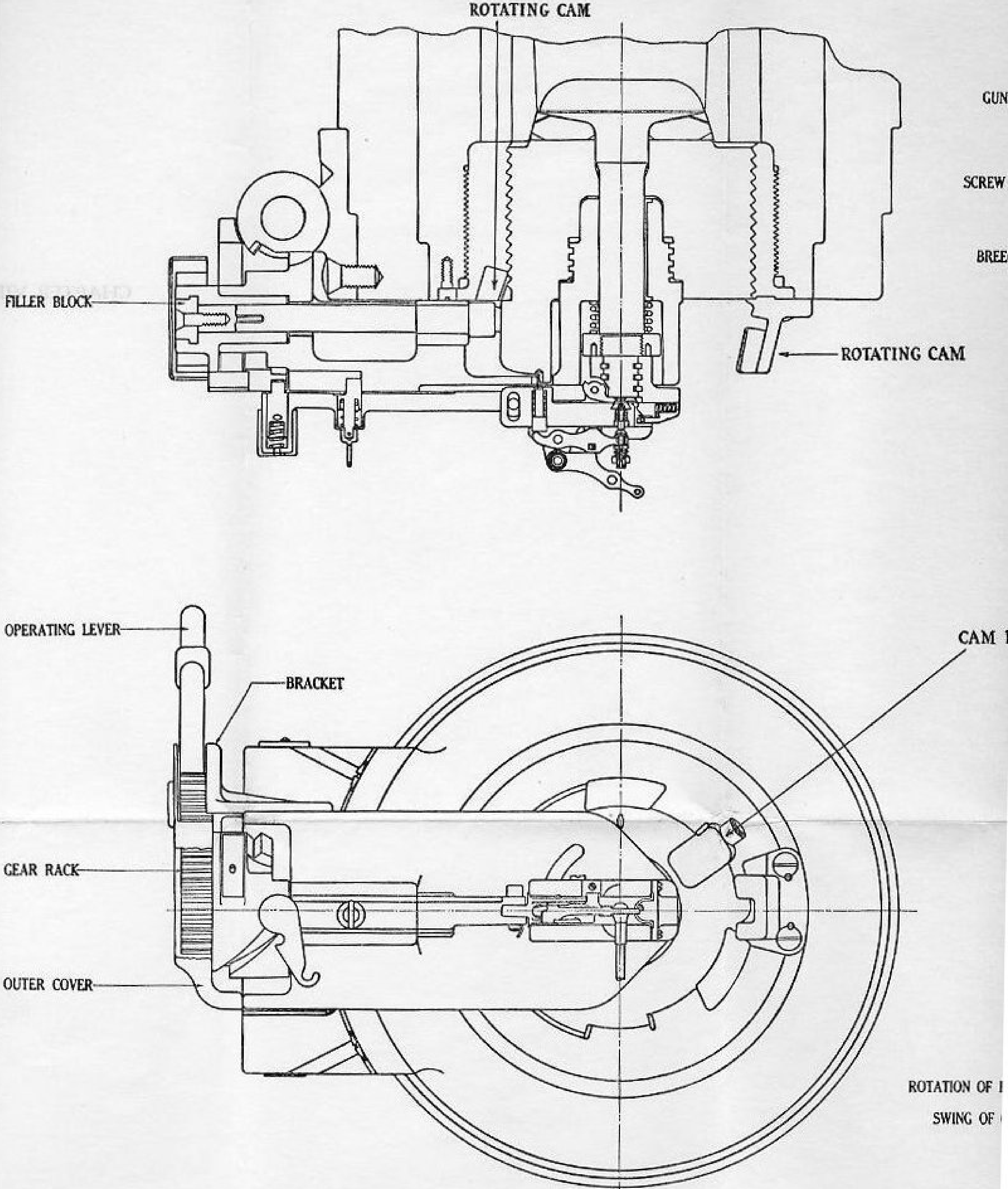
5-INCH BREECH MECHANISM, MARK VII.

(Plates IV and V, Figs. 705 and 706.)

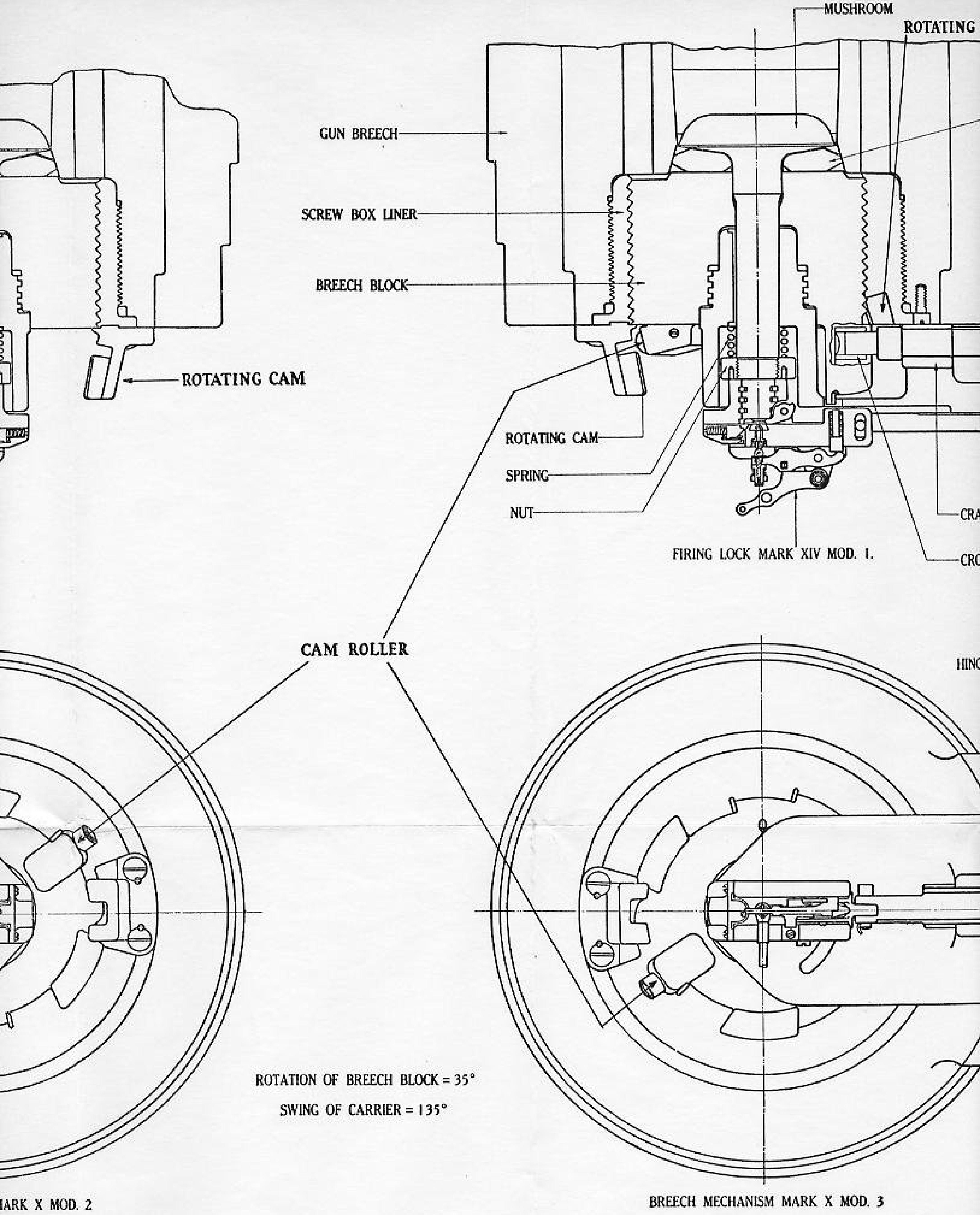
723. Introductory.—The description in detail of the 5-inch Mark VII breech mechanism follows. Except for minor details, this description covers also the 6-inch Mark X, 12-inch Mark IX, 14-inch Marks II, III, and IV, and 16-inch Mark I breech mechanisms.

724. General design.—This breech mechanism is designed to fit the 5-inch bag gun. The breech mechanism is of the carrier type, with the Welin breech plug, De Bange gas check system, and the Smith-Asbury type of operating mechanism.

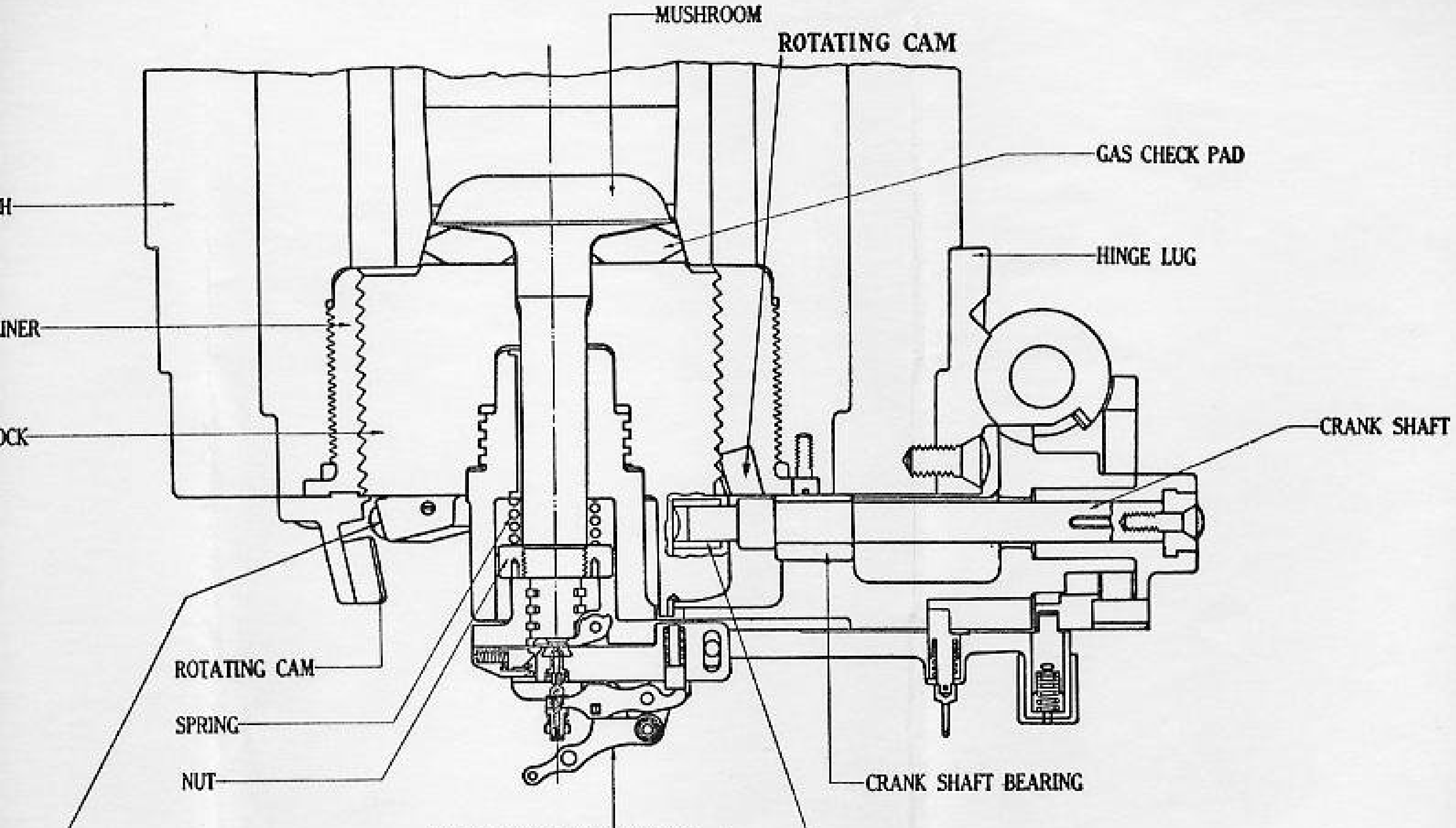
725. The carrier (see Plates IV, V, and Figs. 705, 706) is journaled on a vertical hinge pin on the right-hand side of the gun. The carrier extends across the breech face of the gun and has a forward projecting hub on which the breech plug is journaled. The operating lever is



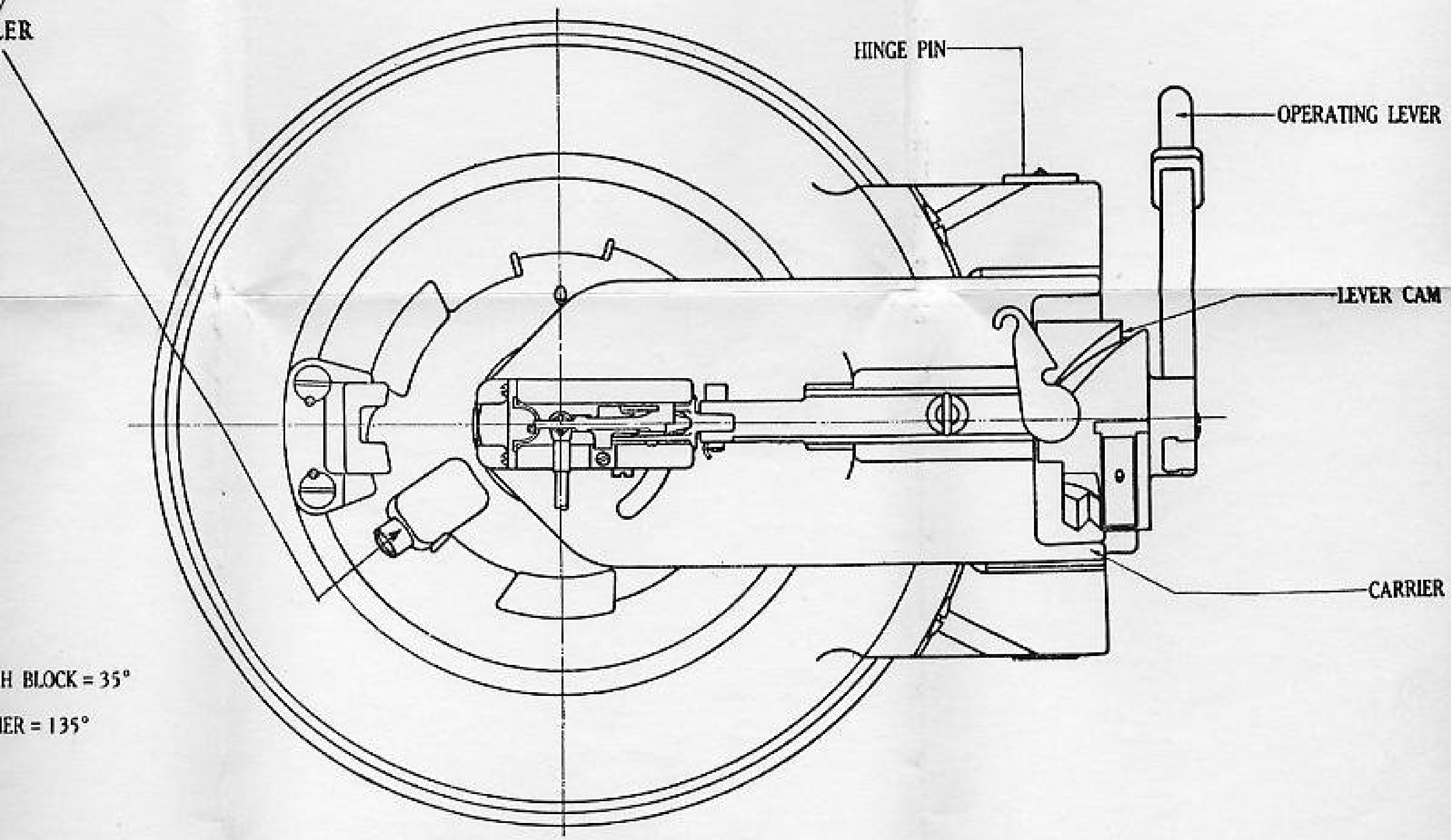
BREECH MECHANISM MARK X MOD. 2



Breech Mechanism, Mark X Mods. 2 and 3



FIRING LOCK MARK XIV MOD. 1.



H BLOCK = 35°

IER = 135°

BREECH MECHANISM MARK X MOD. 3

k X Mods. 2 and 3

attached to a shaft journaled in the carrier. The other end of this shaft carries an overhung crank, the pin of which engages a crosshead which works in a crosshead bearing set into the rear face of the breech plug.

726. 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 crank and crosshead, rotates and unlocks the plug. The operating

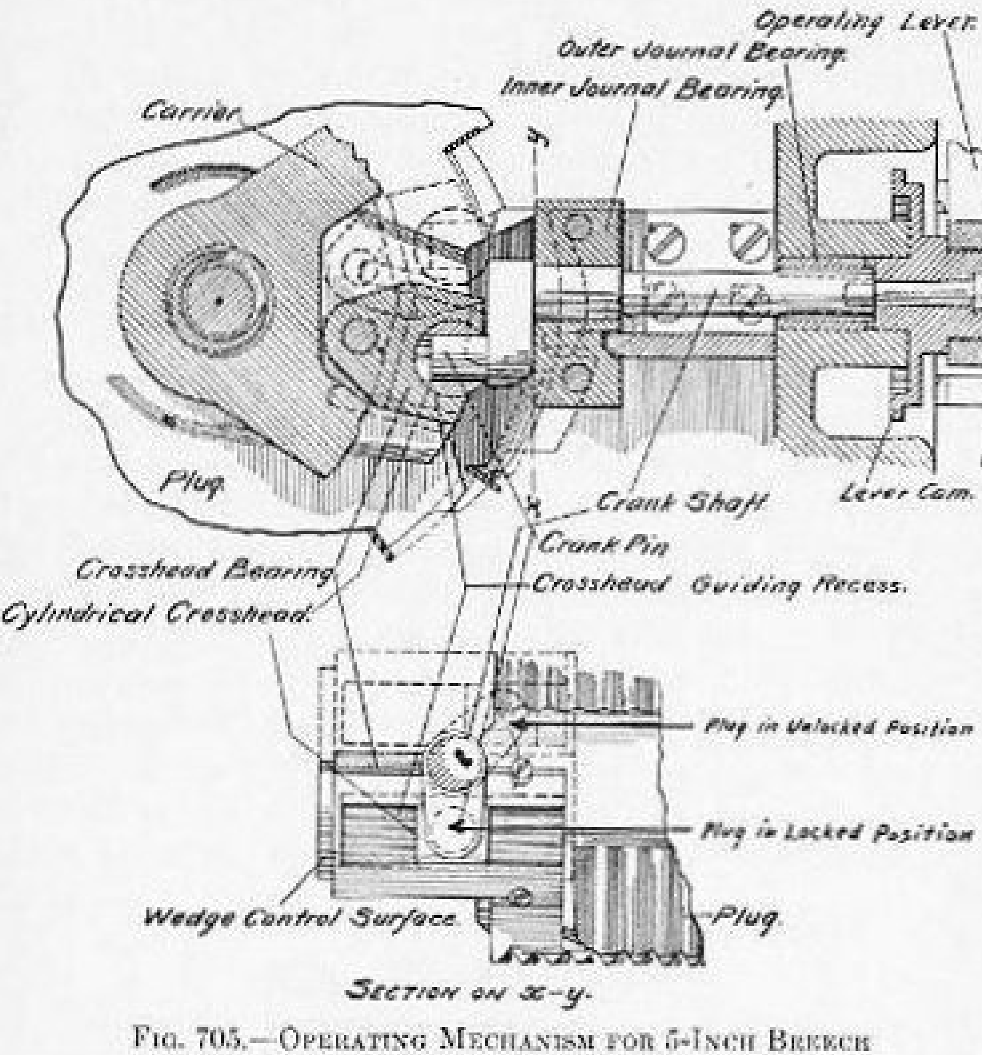


FIG. 705.—OPERATING MECHANISM FOR 5-INCH BREECH MECHANISM, MARK VII.

lever is then swung to the side in a horizontal plane, which swings the carrier and plug about the vertical hinge pin and 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.

727. 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 by the rotation of the breech plug in opening the breech. Air from the valve passes to one or more annular channels turned on the outside of the screw-box liner, and thence through tangential 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 sectors, 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.

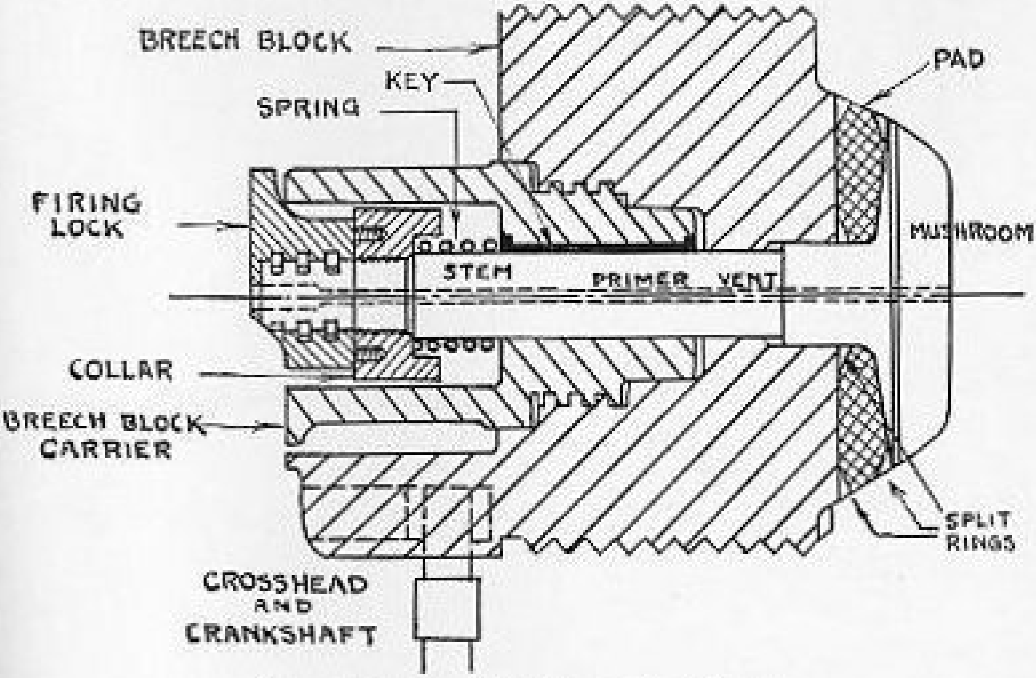


FIG. 706.—THE DE BANGE GAS CHECK.

728. The De Bange gas check system (Fig. 706).—The breech-block carrier has an axial hole through it, through which passes the mushroom stem. The firing lock is secured to the after end of the stem. Just forward of the firing lock is screwed a collar, and between this collar and the carrier is a spiral spring, the compression of which tends at all times to keep the mushroom and gas-check pad pulled aft against the breech block. The mushroom stem is keyed to the carrier so that the mushroom cannot rotate but has free movement in the fore-and-aft direction. The breech block necessarily has to rotate a small amount, but the mushroom cannot rotate and the gas-check pad normally never rotates as it adheres to the mushroom instead of to the breech block. The breech block is screwed on to the forward hub of the carrier, this screw having the same pitch as the screw of the breech block and screw-box liner, thus the carrier is not translated during the rotation to the breech block while opening or closing the breech.

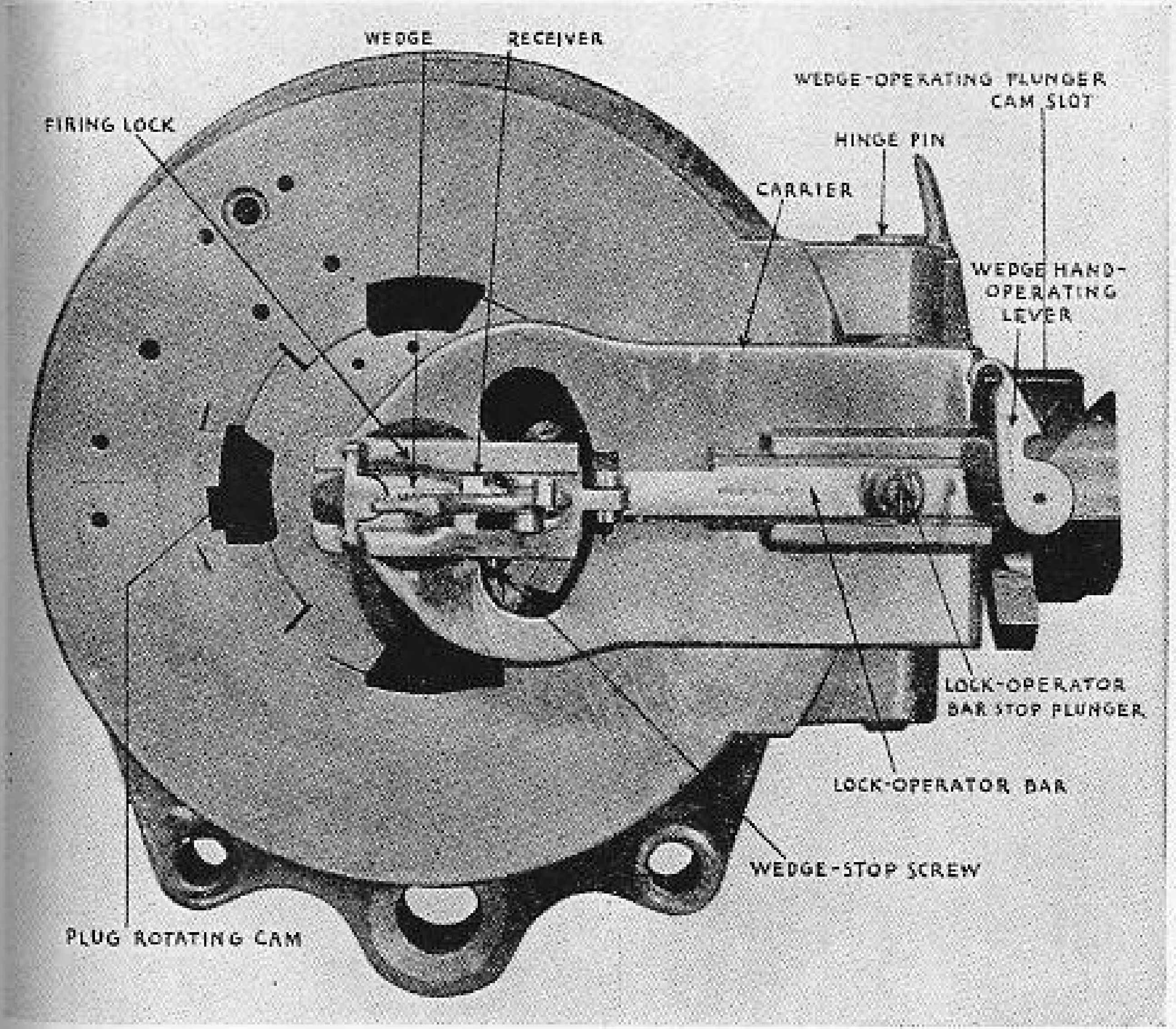
On opening the breech, the action of the mechanism and the gas-check pad is as follows: (a) The breech block is rotated to unlock it. During this rotation the carrier does not move, but the breech block moves aft a small amount due to the pitch of the screw in the screw box and the pitch of the screw on the carrier. When the breech block moves aft this small amount, the spiral spring around the mushroom stem, being under compression, tends to draw the mushroom and gas-check pad aft against the breech block. In some cases this will serve to break the seal and in others it will not accomplish the breaking of the seal. (b) The plug being unlocked, the carrier with the plug is next swung back, opening the breech. If the seal is not broken at the beginning of this movement, the rotation of the carrier through a small arc will put the spiral spring under high compression and thus exert a strong pull on the mushroom stem. In case this fails to break the seal, a slight additional swing of the carrier will compress the spiral spring to its solid length or will bring the collar on the mushroom stem up against the carrier, in which case it is evident that any further movement of the carrier will necessarily break the seal and that the pressure exerted by the spiral spring will force the pad and mushroom back against the breech block.

729. Operating mechanism (Fig. 705).—The 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.

The outboard bearing 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 wedge-operating 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.

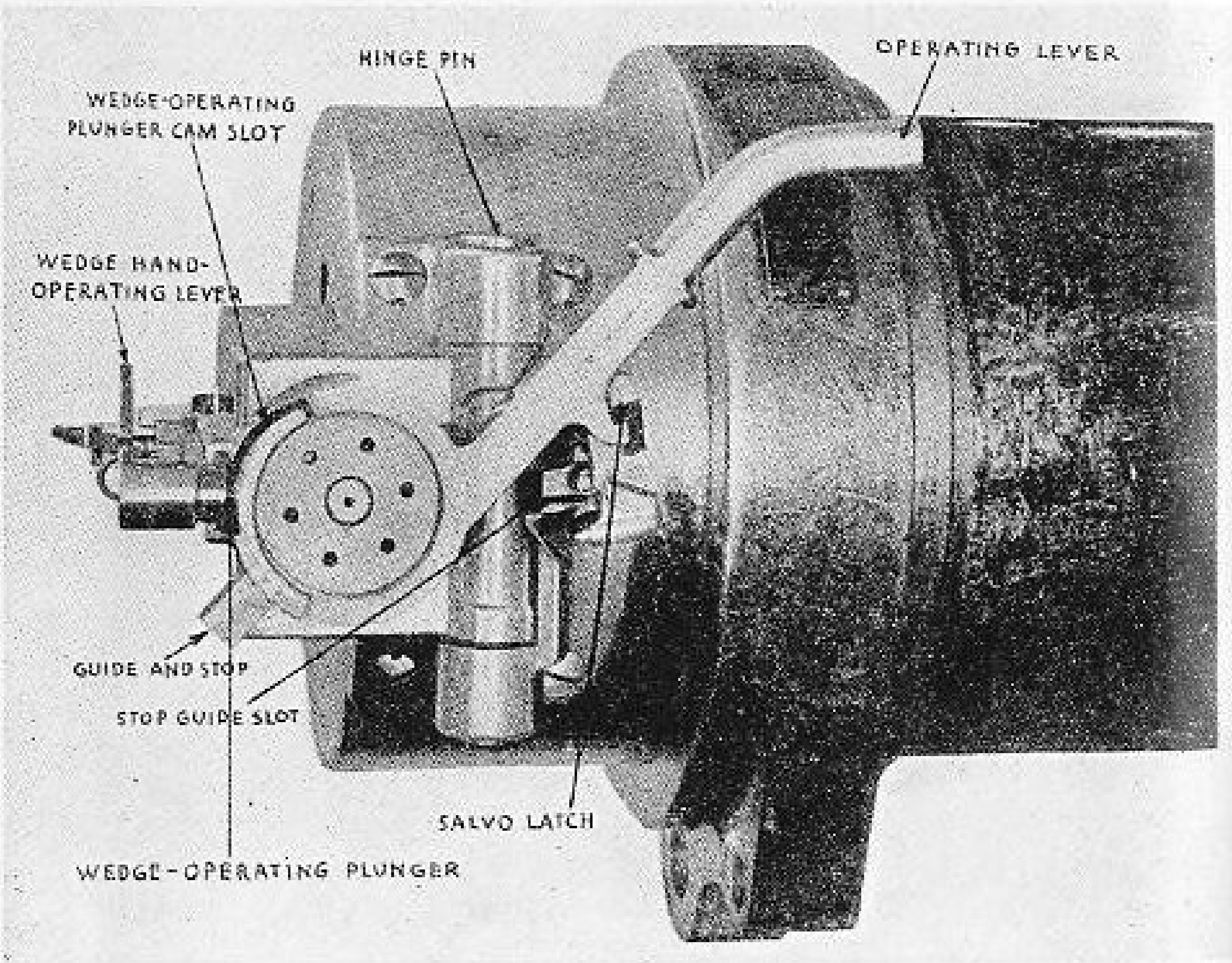
In the rear face of the plug, and located near the right-hand edge, at an angular distance above the horizontal center line (unlocked position) equal to half the angle of rotation, is a counterbore into which is rigidly fitted a hollow, cylindrical crosshead bearing. The crosshead, which is housed in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

CHAPTER VII, PLATE IV.



5-Inch Breech Mechanism—Rear View.

CHAPTER VII, PLATE V.



5-INCH BREECH MECHANISM—SIDE VIEW.

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 crosshead and bearing are below the horizontal center line at an angular distance of 16° 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.

730. 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 crosshead within its bearings into 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.

731. Plug-rotating cam.—The total angular movement of the plug produced by the rotation of the crank shaft is 33° 25′, of which movement but 26° 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. The 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. In all except the largest guns, it also does away with the necessity for closing buffers.

Inefficient forms of power transmission, such as gears, racks, and worms, have been eliminated, and bearings with large surfaces have been introduced instead. In major caliber guns fitted with breech mechanisms of this type, ball bearings or roller bearings on the hinge lug carry the dead weight of all swinging parts. The number of pieces has been greatly reduced.

732. Operating-lever guide and stop (see Plate V).—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 and stop, 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 the guide slot fairly, 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 which is provided with a stud projecting inwardly to engage a slot milled in the outboard end of the carrier (not shown).

733. Features of the operating-lever mechanism.—The 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 eliminates the use of a carrier latch or a plug latch.

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

(3) When the plug is closed, the lever is in such position as to allow the plugman 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.

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

734. Operating-lever latch (salvo latch) (Plate IV).—The lever latch consists of a latch member journaled on a screw bolt attached to the forward 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 causes 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 bottom 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 hangfires 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.

6-INCH 53-CALIBER GUN BREECH MECHANISM.

735. Breech mechanism Mark X, Mods. 2 and 3.—This breech mechanism is essentially the same as the 5-inch Mark VII just described, except that each breech mechanism is fitted with two cam rollers diametrically opposite each other to reduce the shock of closing and to assist in changing the motion of translation to one of rotation. These cam rollers perform the same function as the follower pin on the plug of the 5-inch Mark VII breech mechanism. The right-hand mechanism is the standard for the type as far as the operating lever is concerned, but it was found that when the gun and breech mechanism were rotated 180° for the left-hand gun for a 6-inch twin mount the operation of the lever was not convenient, so a modification of the lever was developed for the left-hand gun consisting of two gear segments and an additional bearing bracket, so as to permit the operating lever to be mounted on the upper part of the carrier and to swing in a manner similar to the right-hand breech mechanism (see Plate VI).

14-INCH BREECH MECHANISMS.

736. Some 14-inch two-gun turrets have Mark II breech mechanisms which are practically identical with the 5-inch Mark VII breech mechanism previously described, except that the carrier trunnions are provided with roller bearings in the hinge lugs because of the greater weights involved.

The 14-inch breech mechanism, Mark III and its modifications is essentially similar to the breech mechanism, 5-inch, Mark VII, and 14-inch, Mark II, except that it has been rotated through 90° to permit the breech plug to swing in the vertical plane in opening and closing. This mechanism is used on the 14-inch 45-caliber guns, mounted in three-gun turrets.

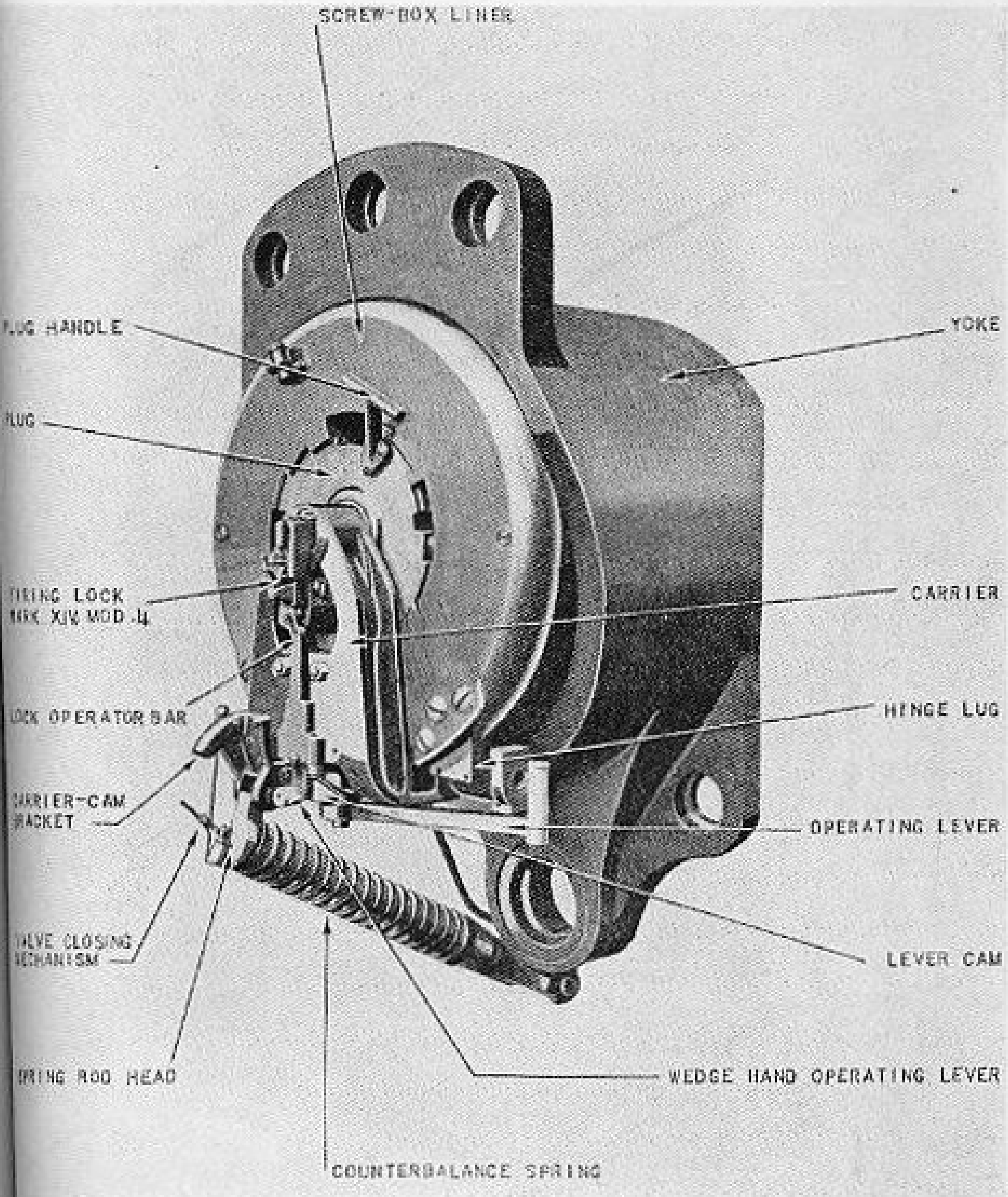
The Mark IV breech mechanism is used on the 14-inch 50-caliber guns, mounted in three-gun turrets. This Mark IV breech mechanism is essentially the same as the Mark III (described below) except that the breech plugs of the right-hand and center guns swing downward at an angle of 16° from the vertical axis, to the right, while the left-hand gun plug swings downward at an angle of 16° to the left of the vertical axis. This arrangement permits more space between the plug and the spanner tray and for handling ammunition.

737. General description of the 14-inch Mark III breech mechanism.—In this description of the 14-inch Mark III breech mechanism and its modifications, the mechanisms and operations which are identical in principle with those of the 5-inch Mark VII are omitted. The breech mechanisms, similar to those of the 5-inch Mark VII, are of the carrier type with the Welin breech plug, De Bange gas-check system, and the Smith-Asbury type of operating mechanism. The operation of opening and closing the breech mechanism is facilitated by using a counterbalance spring and a closing cylinder operated by compressed air (see Plate IX). To reduce friction the two trunnions of the carrier are provided with roller bearings.

738. Breech plug and screw-box liner.—The screw-box liner and the breech plug are slotted to form 16 sections, 4 blanks and 12 threaded steps, in four groups.

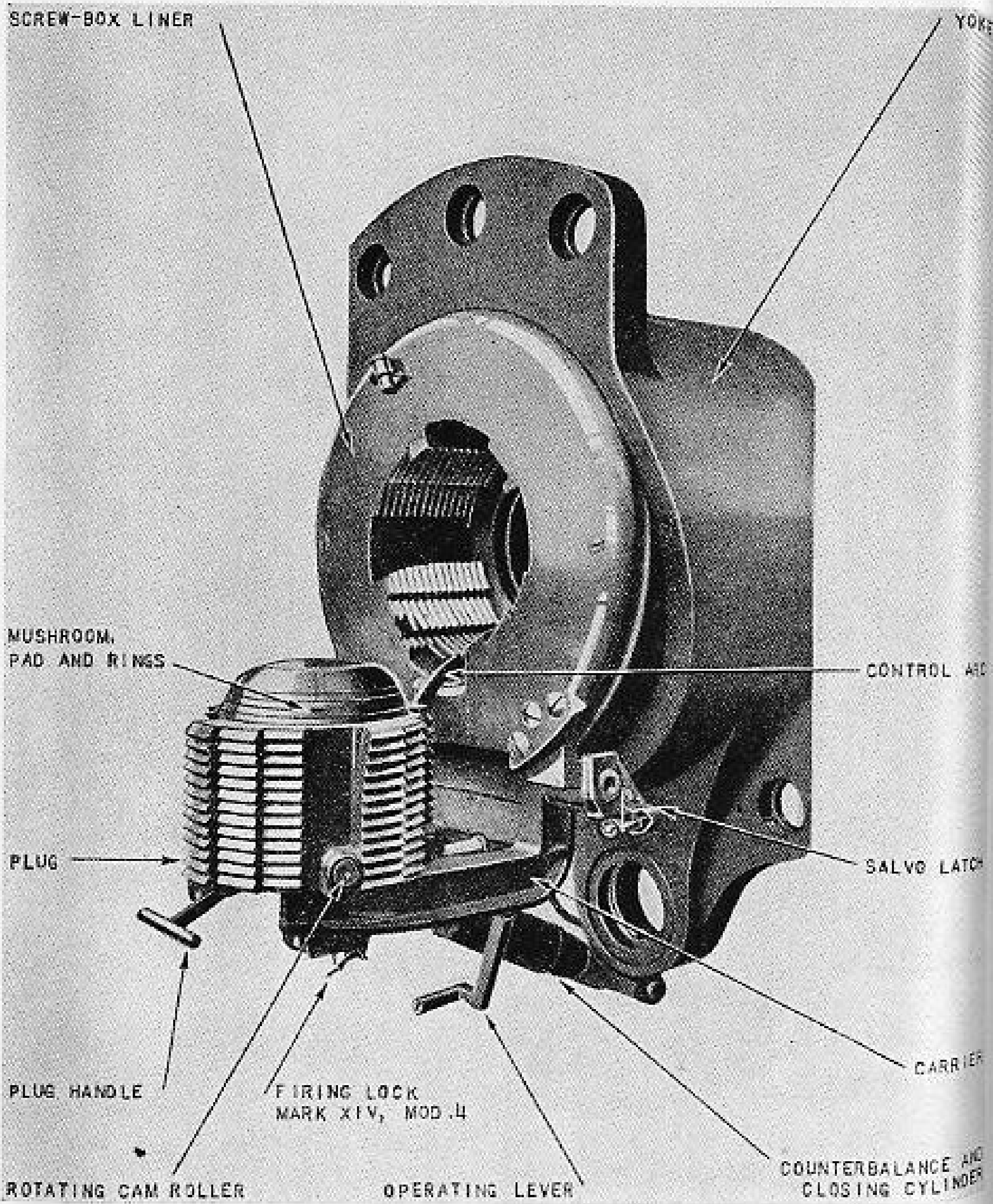
739. Opening the breech.—To open the breech, the operating lever is swung rearward through an angle of 135°. The crank turns through

CHAPTER VII, PLATE VII.



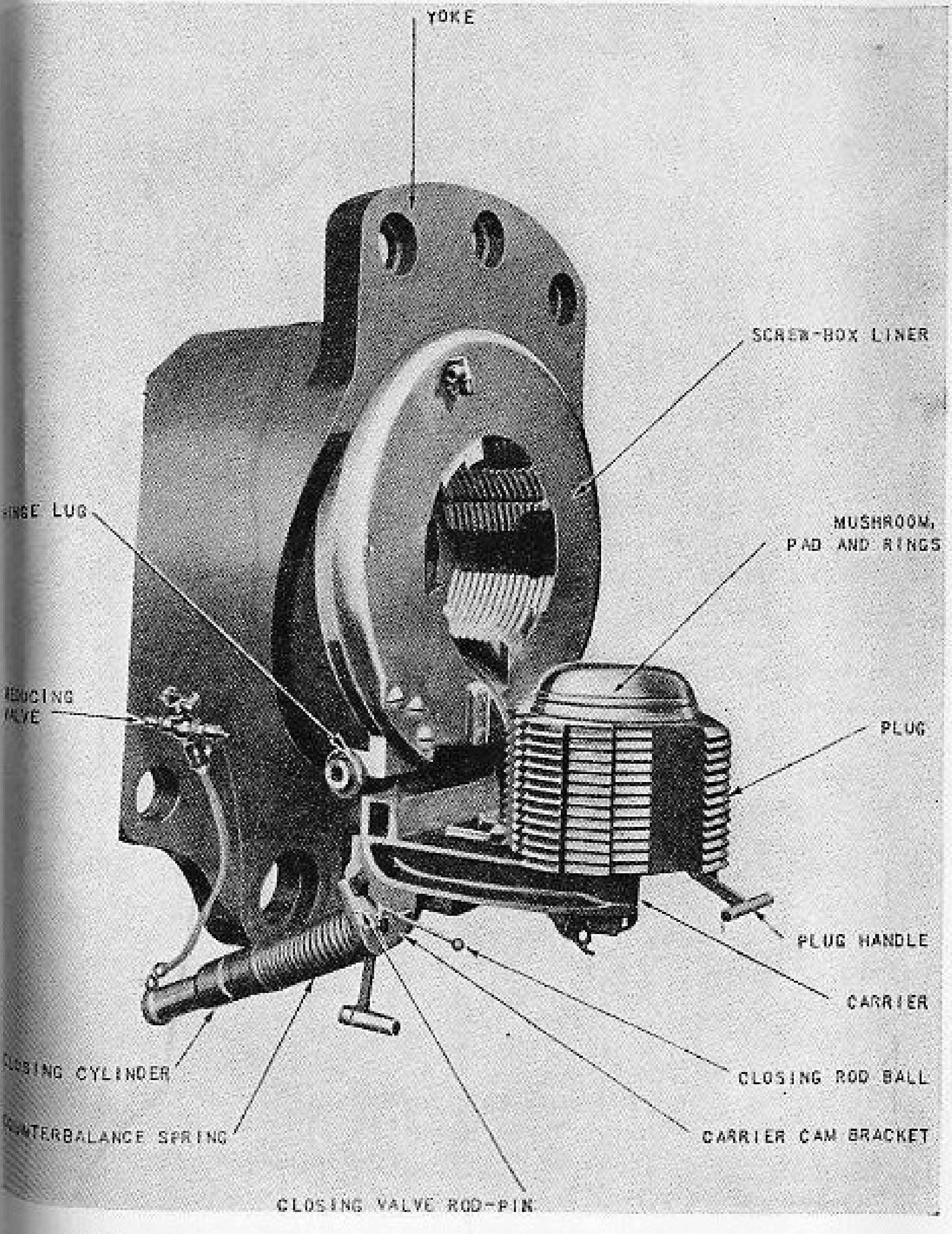
14-INCH BREECH MECHANISM, MARK III, MOD. 1, PLUG CLOSED.

CHAPTER VII, PLATE VIII.



14-INCH BREECH MECHANISM, MARK III, MOD. 1, PLUG OPEN, RIGHT SIDE.

CHAPTER VII, PLATE IX.



14-INCH BREECH MECHANISM, MARK III, MOD. 1, PLUG OPEN, LEFT SIDE.

the same angle. The total angular movement of the plug produced by the rotation of the crank shaft is 27° 30′, 22° 30′ of which is required to disengage the threads. During the remainder of the rotation, a rearward motion is given the plug by means of a rotating cam roller. The rearward swing of the carrier about the hinge pins is continued by means of the plug handle until the plug has swung downward through an angle of 90°, when the energy acquired by the heavy plug and carrier in swinging down is absorbed and checked by the counterbalance spring which also supports the mechanism in the open position.

The Mark III type of breech mechanism should never be opened when the counterbalance spring is not in place, as the plug will drop down, wrecking the carrier and hinge lugs.

740. Control arc.—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 segment concentric with the hinge and is bolted to the screw-box liner between the hinge lugs.

741. Counterbalance and closing cylinder for 14-inch breech mechanism (Plate X).—This device consists of a pneumatic closing cylinder with its bracket bushing and pin, a counterbalance spring with adjusting nut, a spring rod, a spring-rod piston with packings rings, a 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 a bracket pivoted in a journal under the recoil-cylinder lug of the yoke. The spring-rod piston at one end of the spring rod works in the closing cylinder. At its upper end the spring rod terminates in a head with an offset hook which bears on a pin in the carrier-cam bracket. The spring surrounds the spring rod and extends from under the spring-rod head to the adjusting nut which is threaded on the outside of the closing cylinder. The body of the valve for admitting compressed air to the closing cylinder serves as the cylinder head. Compressed air is led to the valve by means of a flexible metallic hose from the reducing valve.

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

To close the breech mechanism, care being taken to stand clear of the moving parts, compressed air is admitted to the closing cylinder by operating the closing valve by hand. The air pressure on the piston is transmitted through the spring rod to the carrier-cam bracket and the carrier and plug are forced upward. When the mechanism is nearly closed, the ball on the closing rod takes up against the valve-closing rod pin, automatically revolving the valve shaft, closing the valve, and at the same time opening a by-pass from the closing cylinder to the atmosphere (see Plate X).

In case of failure of the air pressure, the mechanism can be closed by means of the plug handle bolted to the plug. In closing by hand, care must be taken to stand clear of the path of the operating lever. It is possible for one man to close the plug with the gun elevated to an angle of 20°.

Reducing valve.—The reducing valve is inserted in the air line at the end of rigid piping and fastened to the gun yoke by two pipe clips. It is set to deliver a constant pressure to the inlet valve of the closing cylinder instead of the varying pressure in the air supply lines.

742. Salvo latch.—As the salvo latch is disengaged automatically upon the recoil of the gun, it gives warning of misfires or hangfires which might pass unnoticed when a number of guns are fired in salvo. The salvo-latch bracket and operating-lever buffer are combined in one casting fastened to the hinge lug, so that the catch in the end of the operating lever engages the operating-lever latch when the breech plug is closed (see Plate XI).

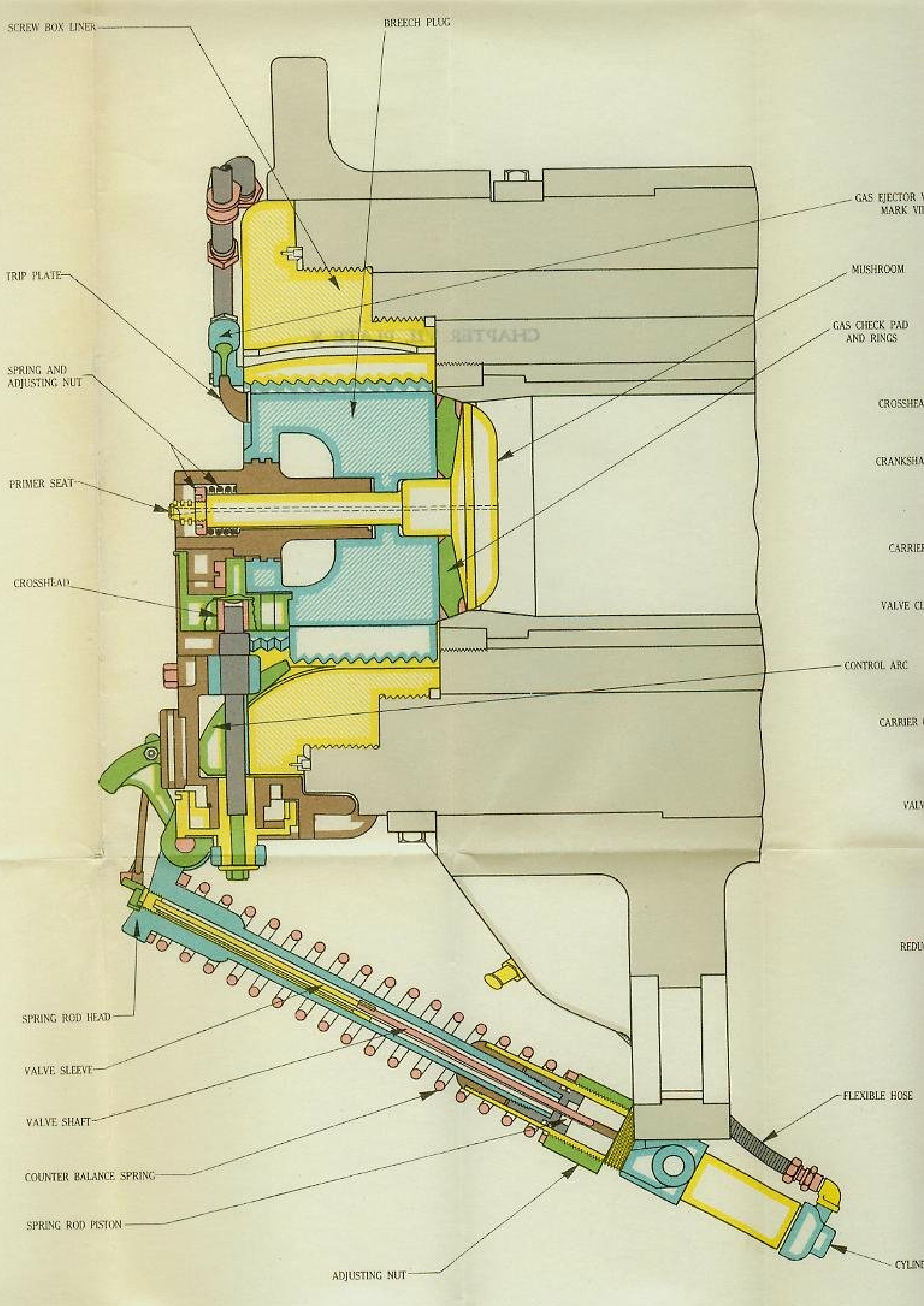
During recoil the inertia forces the salvo latch forward against its spring and the salvo-latch catch is released, thus holding the salvo latch out of the way of the lever latch, which may now be pushed back by the operating-lever catch when opening the mechanism. As the operating-lever latch and catch are no longer engaged, it is possible to swing the operating lever and open the mechanism. For drill purposes the salvo latch is held in its forward position by screwing in a locking pin not shown.

The hydraulic buffer prevents the operating lever from rebounding, thereby permitting the lever latch to engage the lever catch. A rawhide buffer is also inserted in the salvo-latch bracket to cushion the blow of the operating lever when it swings home.

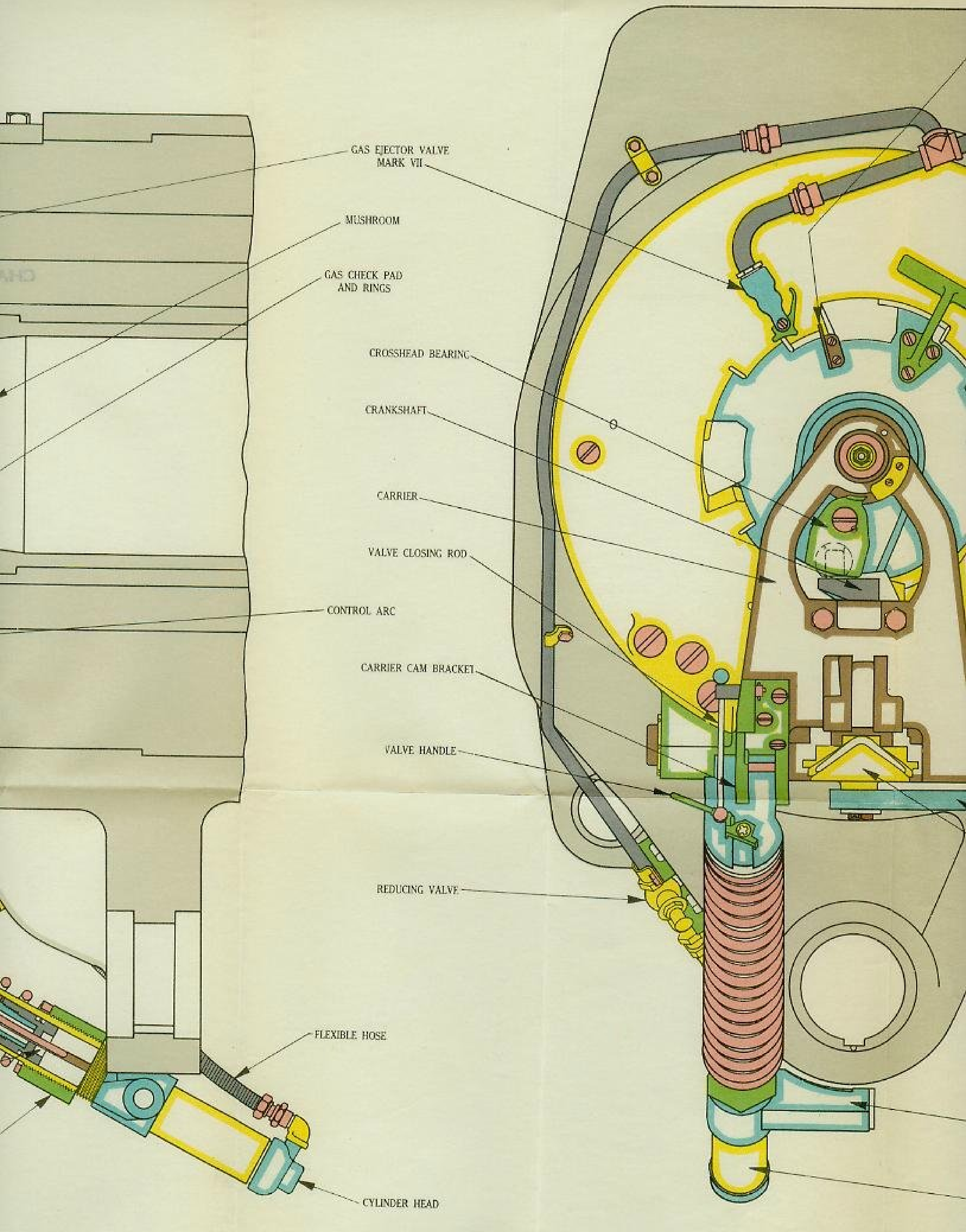
16-INCH BREECH MECHANISMS, MARK I AND MARK I, MOD. 1.

(Plates XII–XX.)

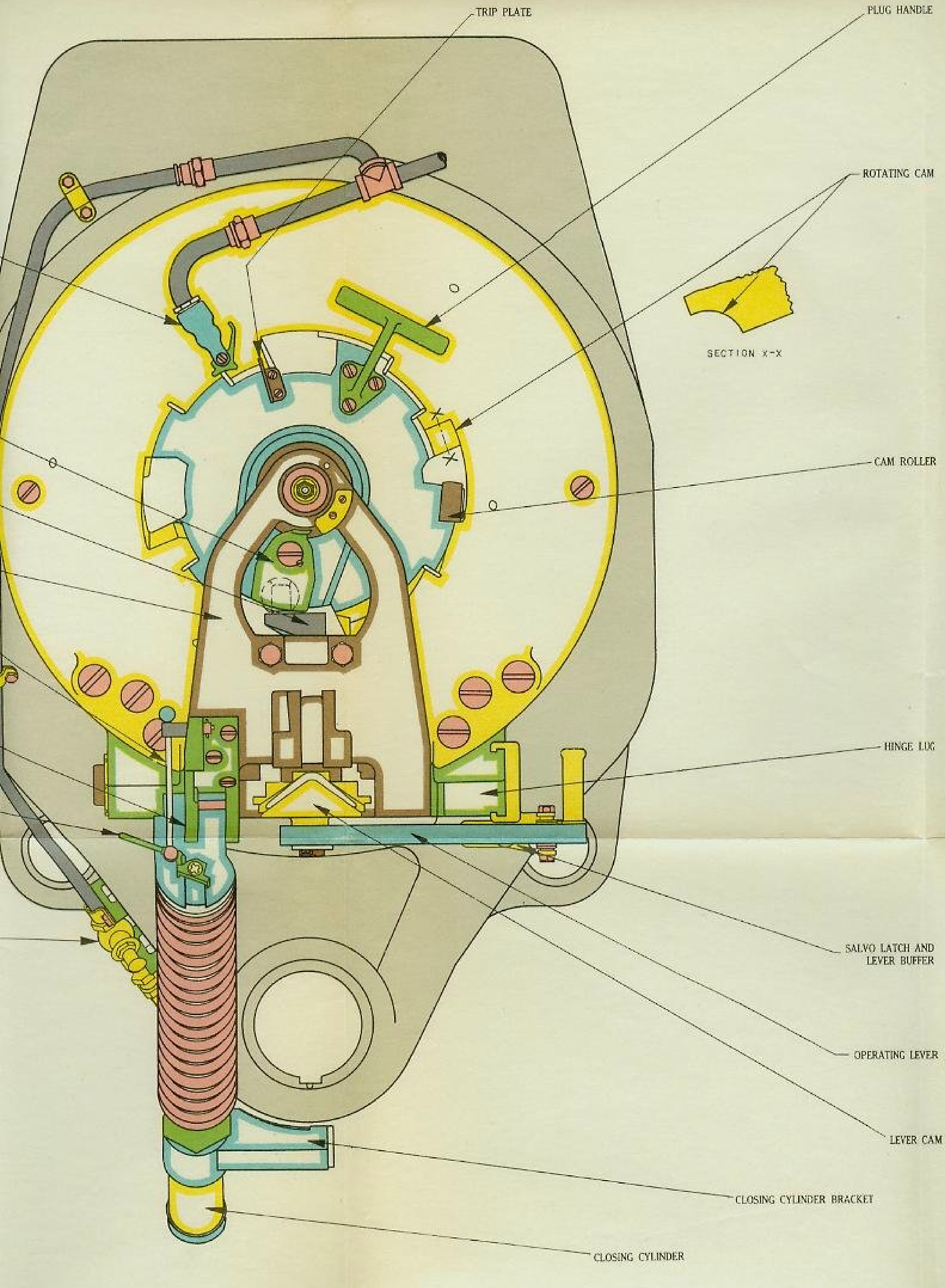
743. The 16-inch Mark I and Mark I, Mod. 1, breech mechanisms were designed for the 16-inch Mark I (45-caliber) and 16-inch Mark II (50-caliber) guns, respectively. These mechanisms are essentially similar to the 5-inch Mark VII and the 14-inch breech mechanisms



14-Inch Breech Mec



14-Inch Breech Mechanism, Mark III, Mod, 3, General Arrangement



3, General Arrangement

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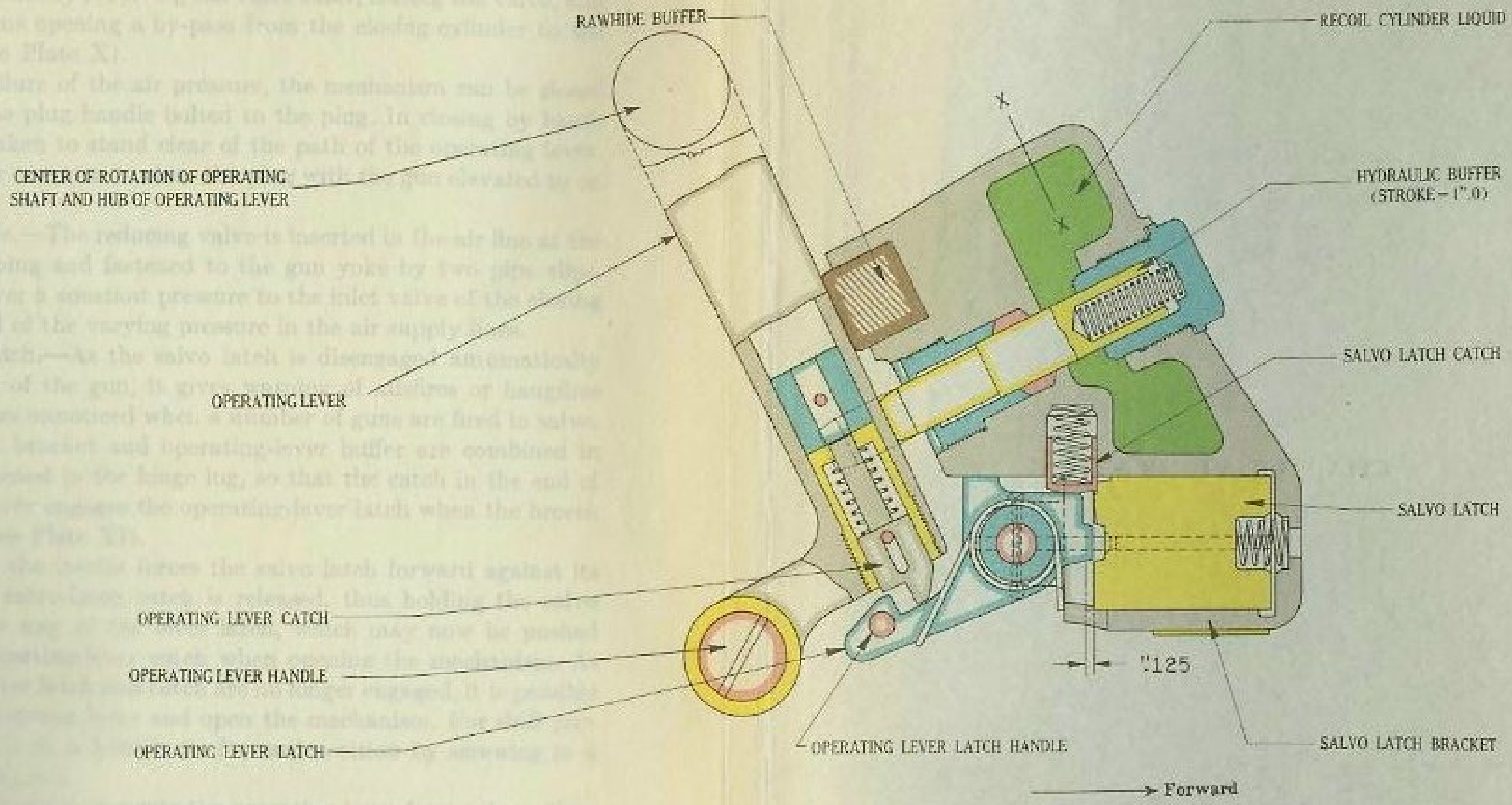
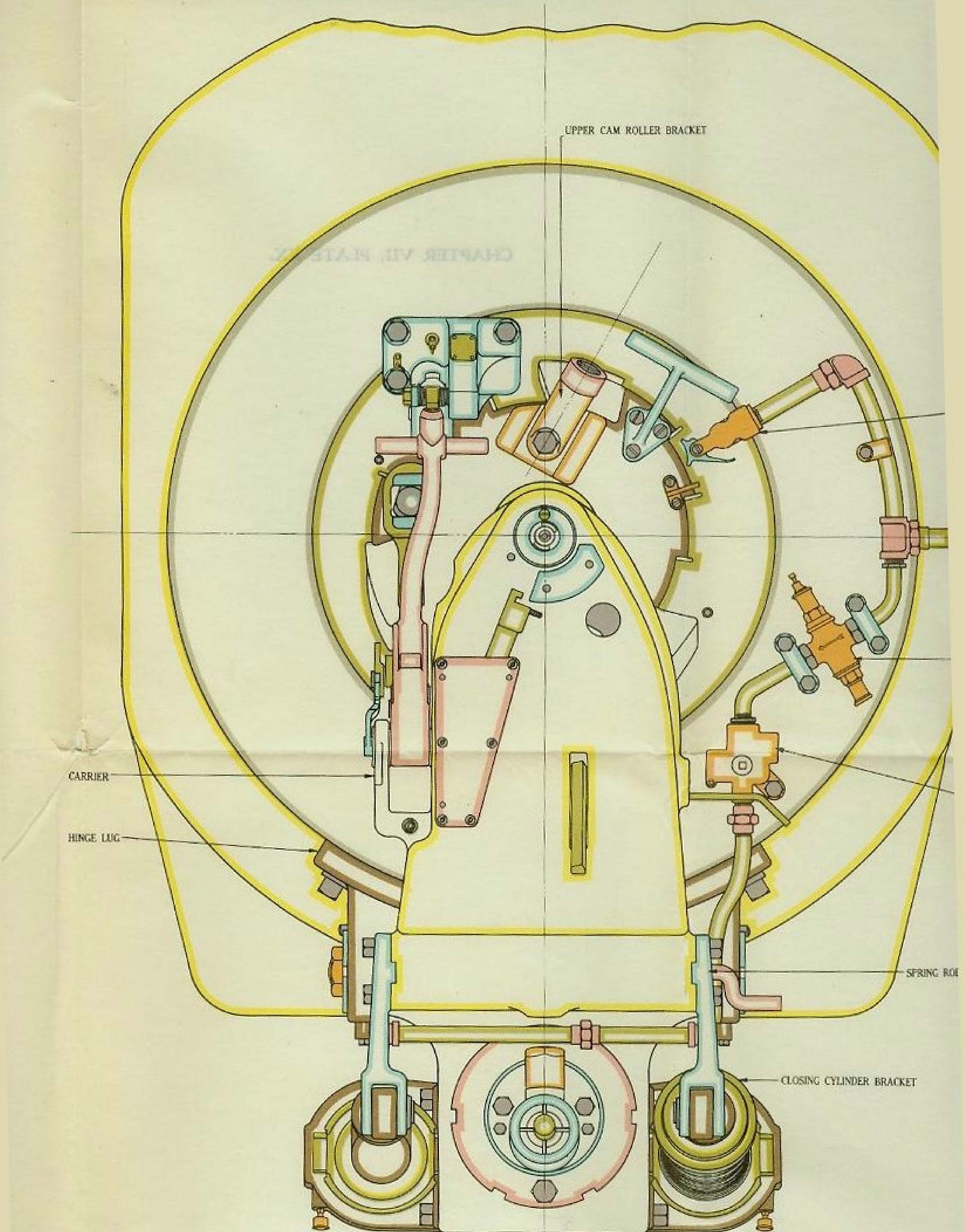
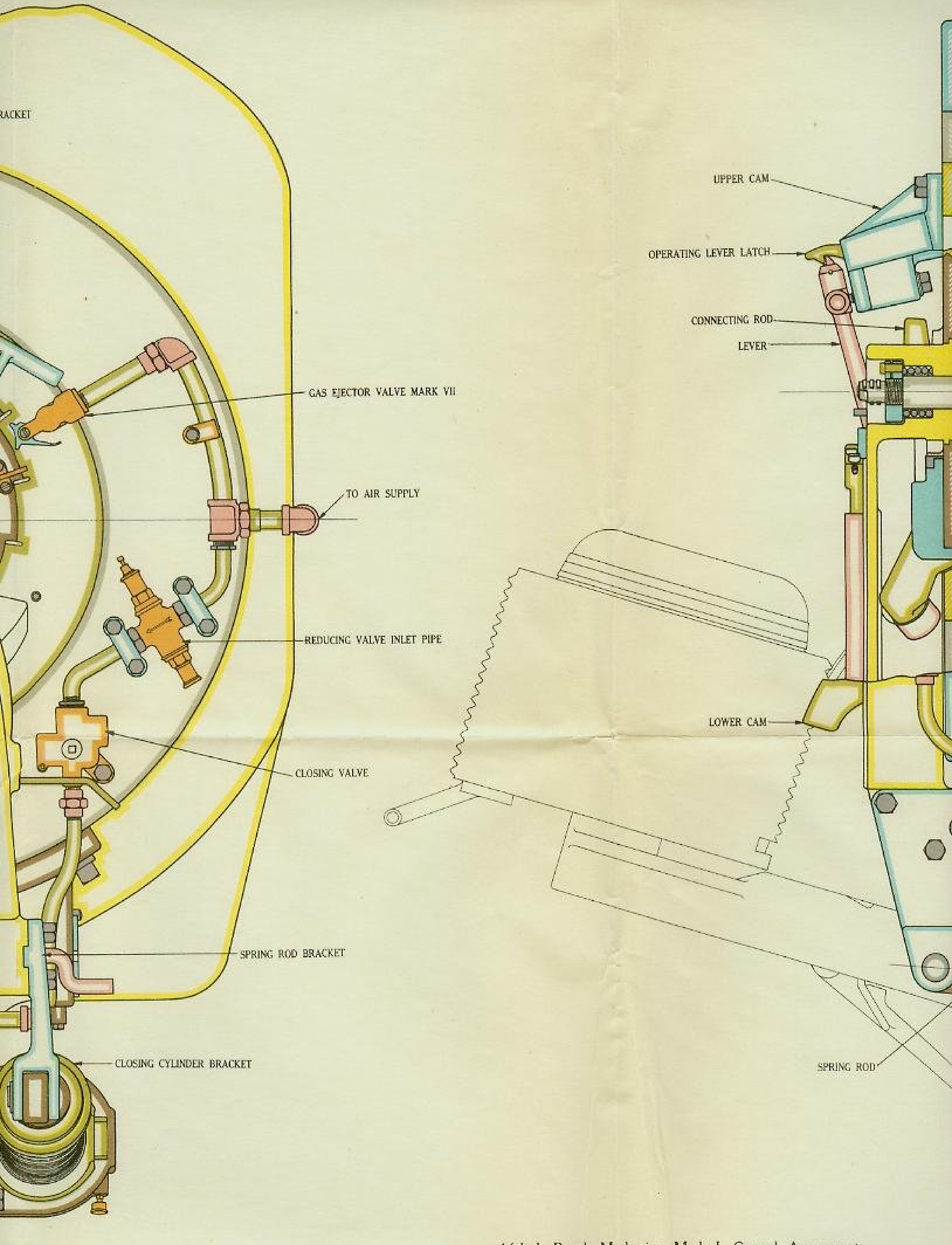


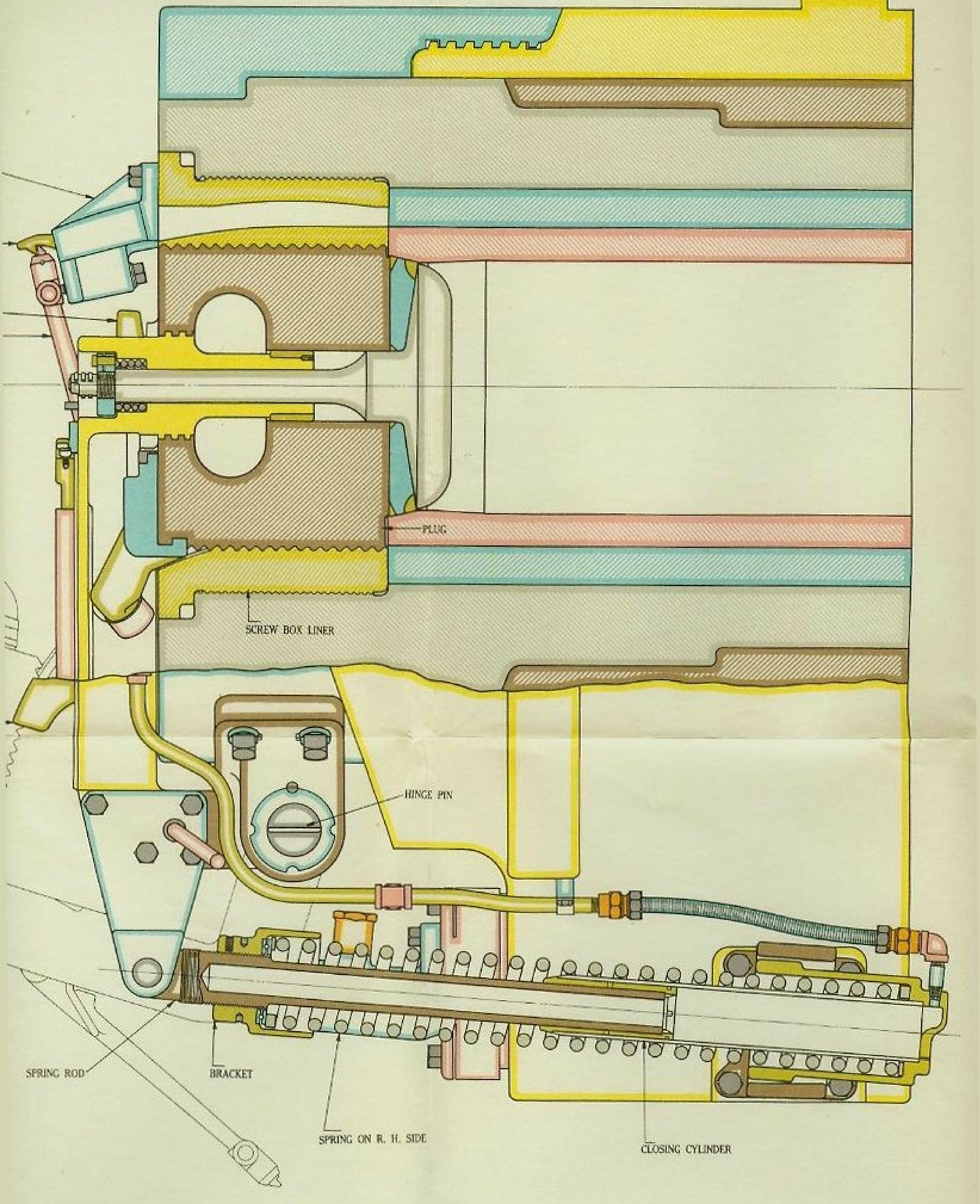
Plan View in Section, Salvo Latch in Recoiled Position.
(14-Inch Breech Mechanism, Mark III and Mods.)

Litho. A. Hoen & Co., Inc.

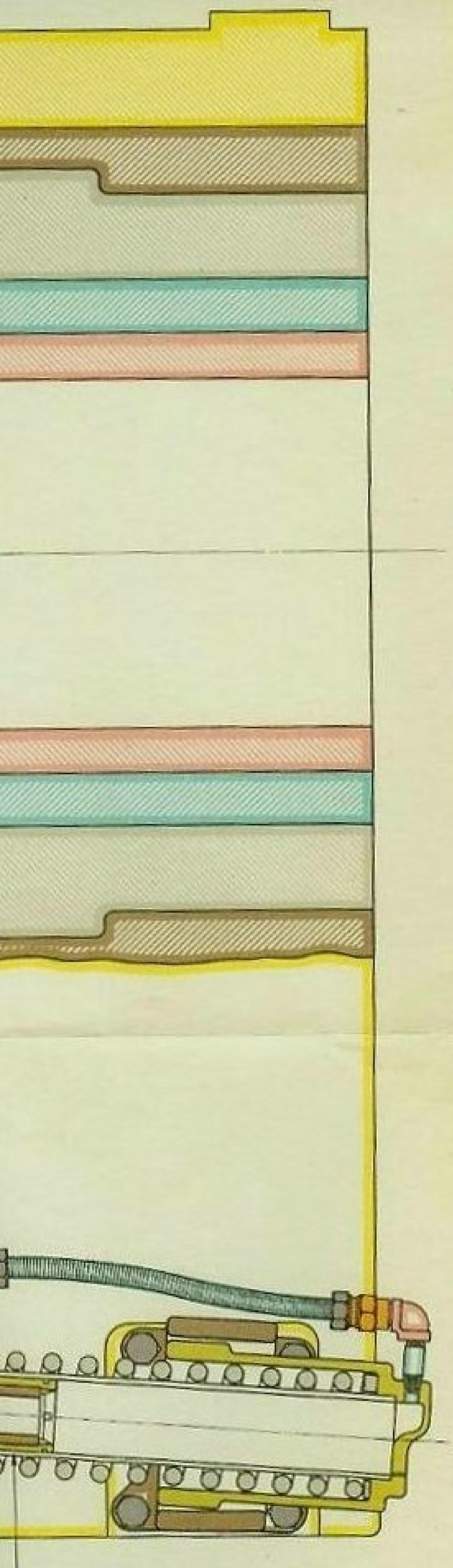

UPPER CAM ROLLER BRACKET
CARRIER
HINGE LUG
SPRING RO
CLOSING CYLINDER BRACKET



16-Inch Breech Mechanism, Mark I, General Arrangement


PLUG
SCREW BOX LINER
HINGE PIN
SPRING ROD
BRACKET
SPRING ON R. H. SIDE
CLOSING CYLINDER

.rrangement



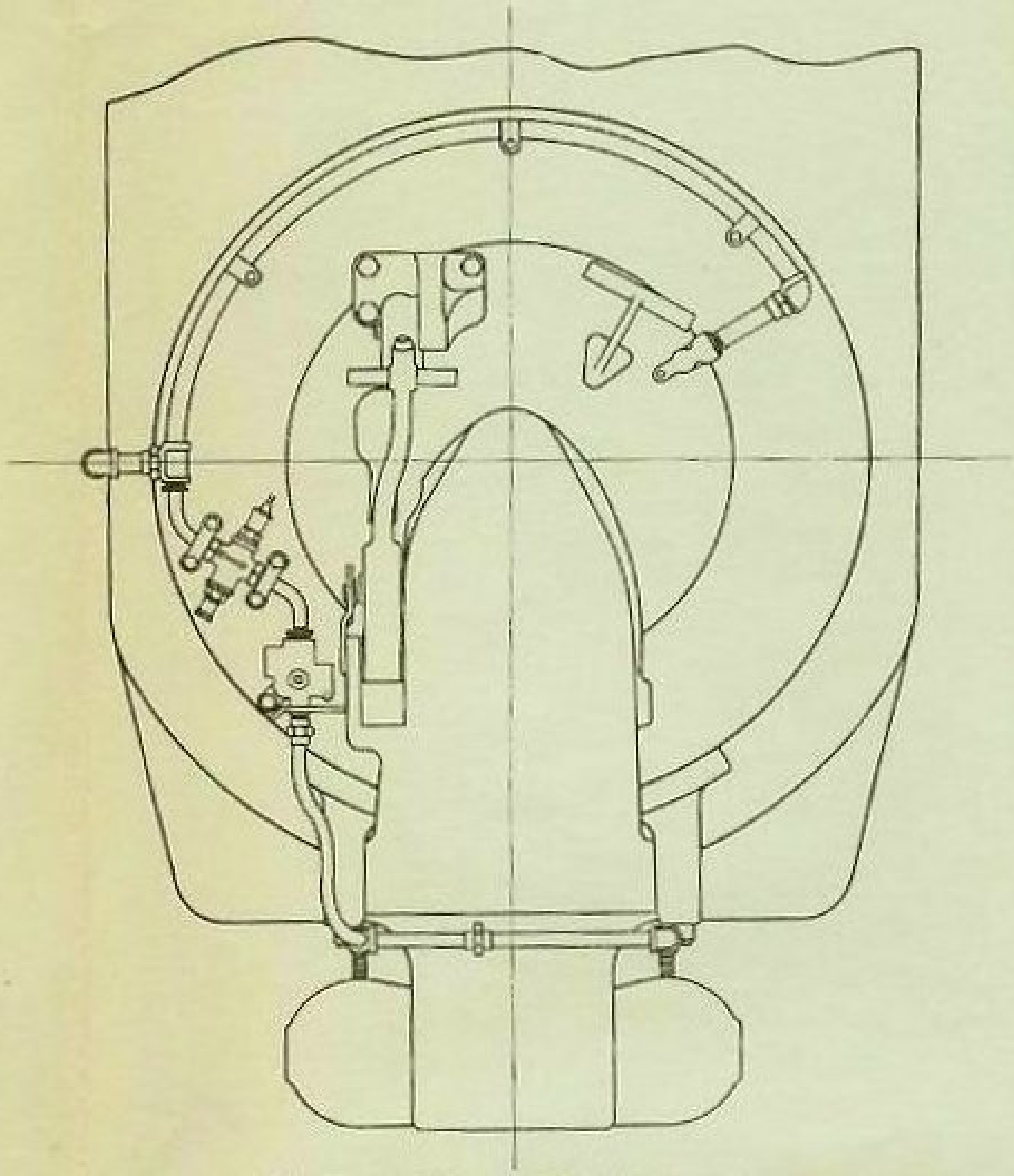
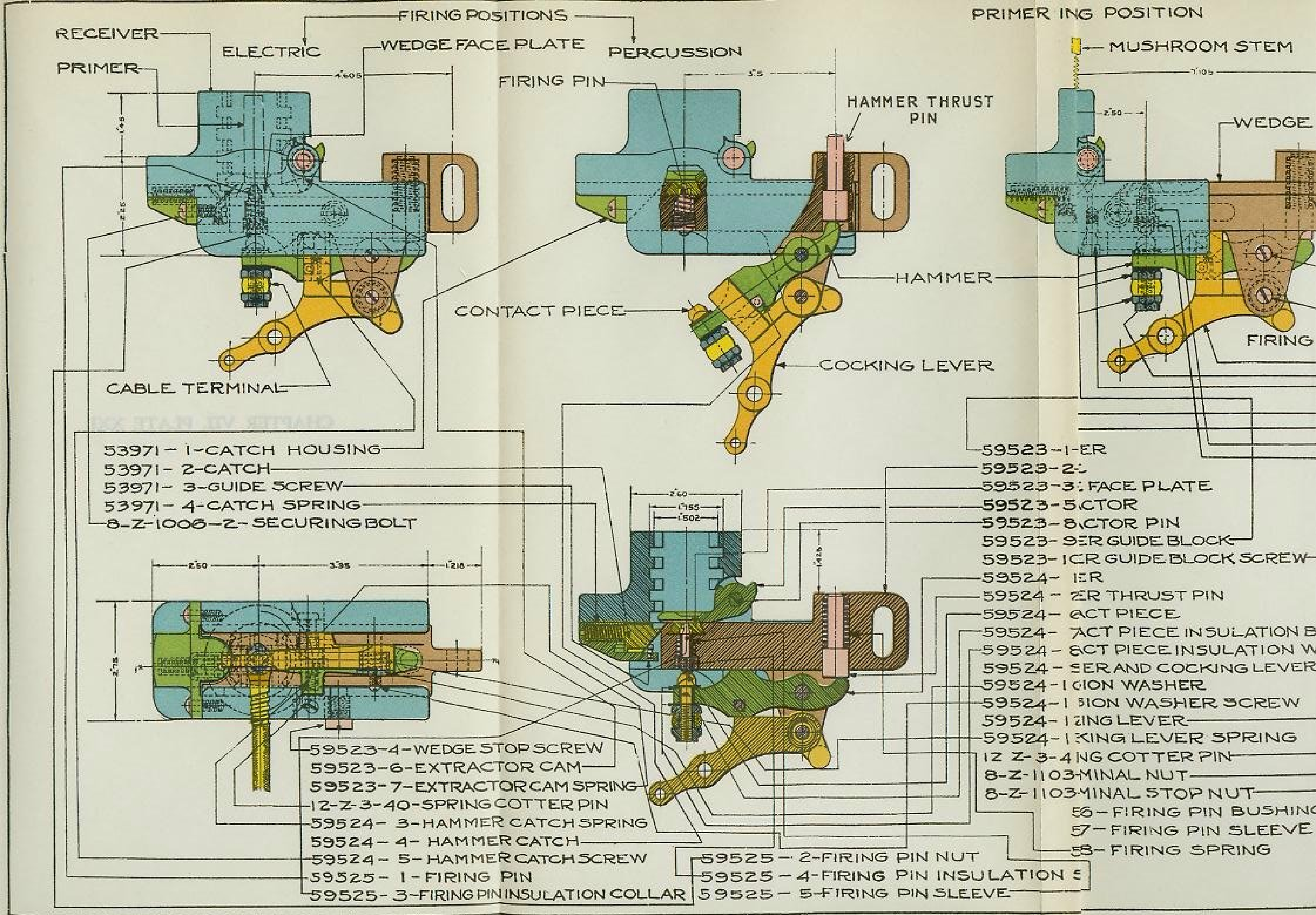
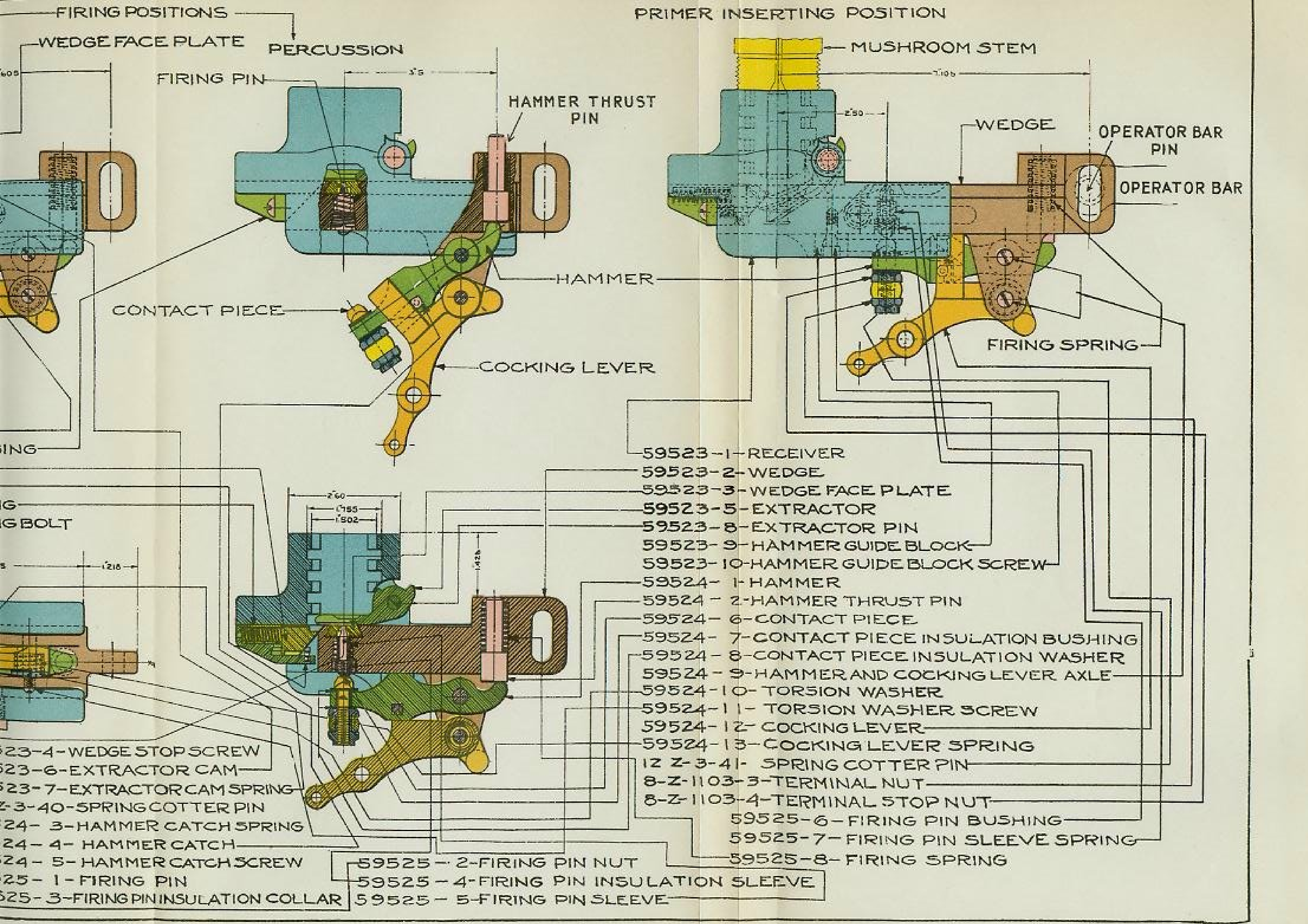


FIGURE 1. LEFT HAND BREECH MECHANISM SHOWING LOCATION OF REDUCING AND CLOSING VALVES



FIRING LOCK, MARK XIV, MOD. I, NOMENCLATURE SHEET.



FIRING LOCK, MARK XIV, MOD. I, NOMENCLATURE SHEET.

previously described. There are, however, some minor variations which will be mentioned.

744. The screw-box liner and breech plug are slotted to form 15 sections, consisting of 3 blanks and 12 threaded.

745. Similarly to the 14-inch, these breech mechanisms are of the down-swing type but with a vertical lever-operating mechanism. The operating lever is on the left of the center line of the carrier and is journaled at its lower end in the carrier. It is offset so as to form a journal for the lower end of the connecting rod (Plate XV), slightly above and to the rear of its own bearing. On the upper end of the connecting rod is provided a universal ball joint, which is set in the rear face of the breech plug and serves to rotate the plug as the operating lever is pulled back.

746. The carrier trunnions are provided with roller bearings mounted in *adjustable eccentric* bushings.

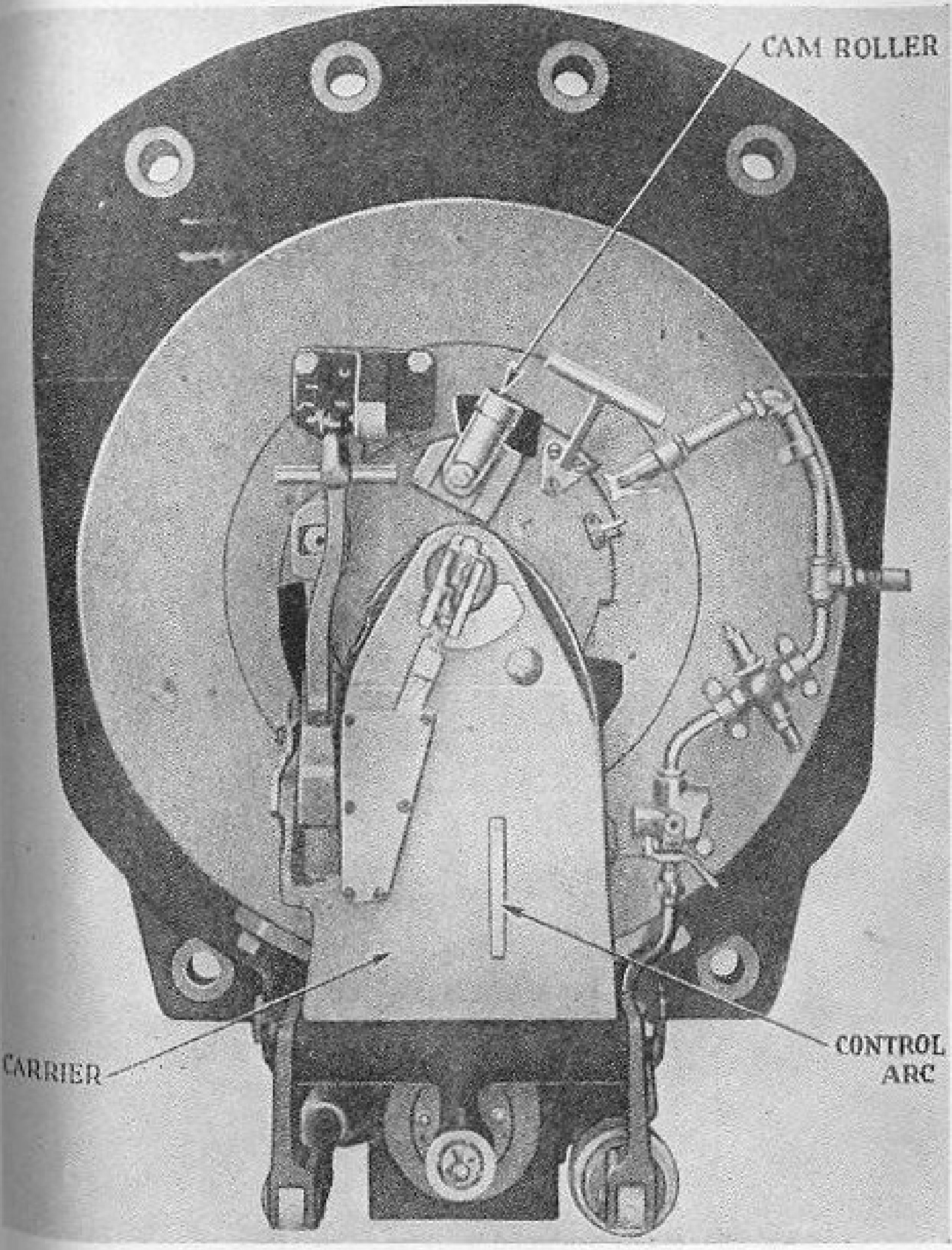
747. Two rotating cams are bolted to the breech end of the gun. They make contact with cam rollers supported in brackets bolted to the plug. These cams are so cut that the upper and lower rollers work in synchronism.

748. Tripping device.—A safety mechanism, known as the holding-down latch, is located in the carrier below the plug. This consists of toggle levers which, when the breech mechanism is open, prevent its being closed without first operating the tripping handle. This mechanism is clearly shown on Plate XVII.

749. Closing mechanism.—The closing mechanism consists chiefly of two pneumatic cylinders fitted with pistons and one counterbalance spring. The pneumatic closing cylinders are secured in the oscillating bearings, which are pivoted in the closing-cylinder brackets. These brackets in turn are bolted to the lower part of the gun yoke. The pistons are secured to the forward ends of the spring rods. The rear ends of these rods are pivoted to the spring-rod brackets, which are bolted to the carrier. Air is led from the reducing valve through the closing valve by means of copper pipe and flexible metallic hose to the forward ends of the closing cylinders. When the closing valve is opened, air is admitted against the spring-rod pistons, forcing them to the rear and thus causing the carrier and plug to swing upward to the closed position. A counterbalance spring surrounds one of the spring rods between the spring-adjusting nut and the oscillating bearing. This spring, which is under its maximum compression while the mechanism is open, assists the spring rods in closing the mechanism and absorbs the energy acquired by the plug and carrier when swinging open.

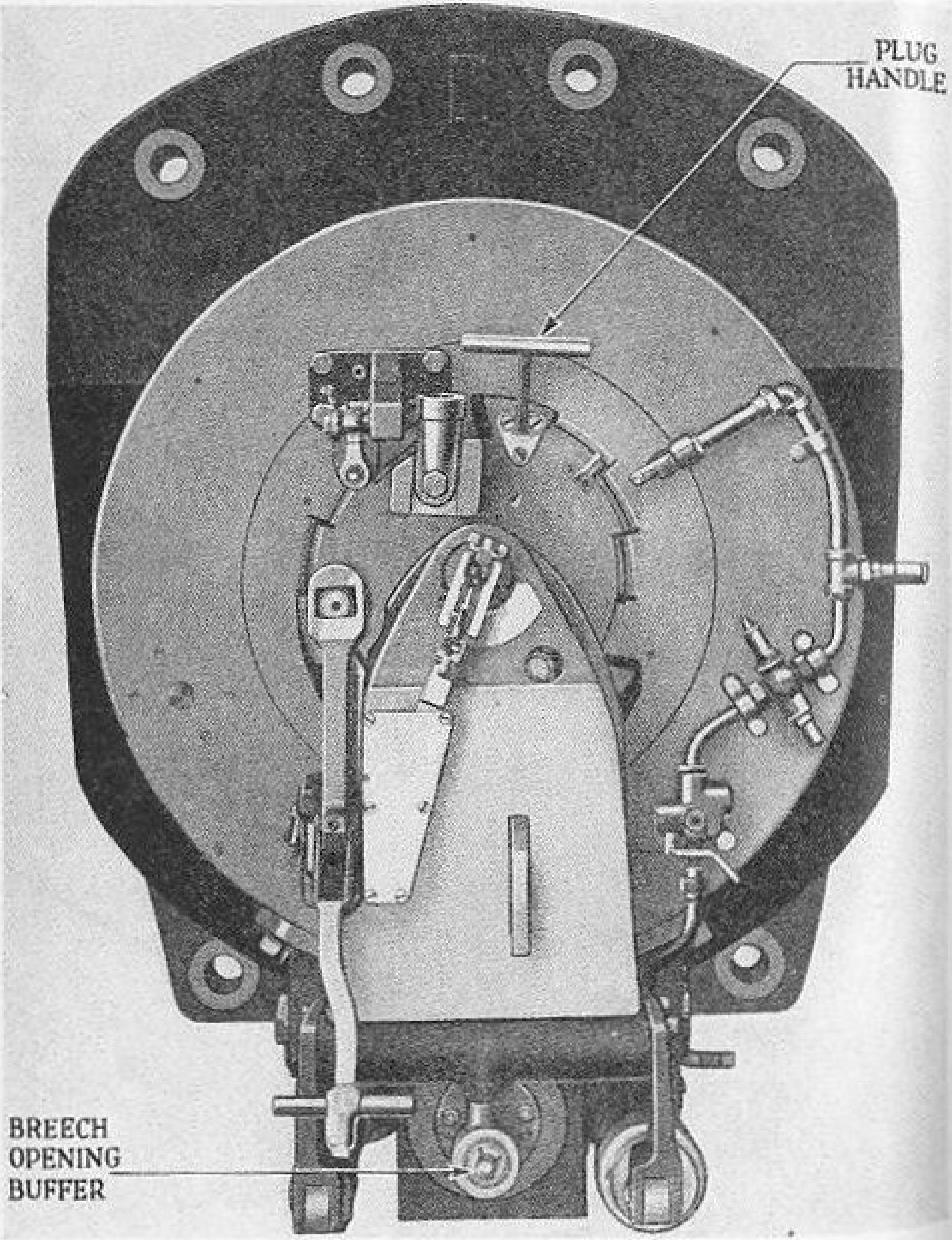
As the carrier reaches the vertical position in swinging home, it

CHAPTER VII, PLATE XII.



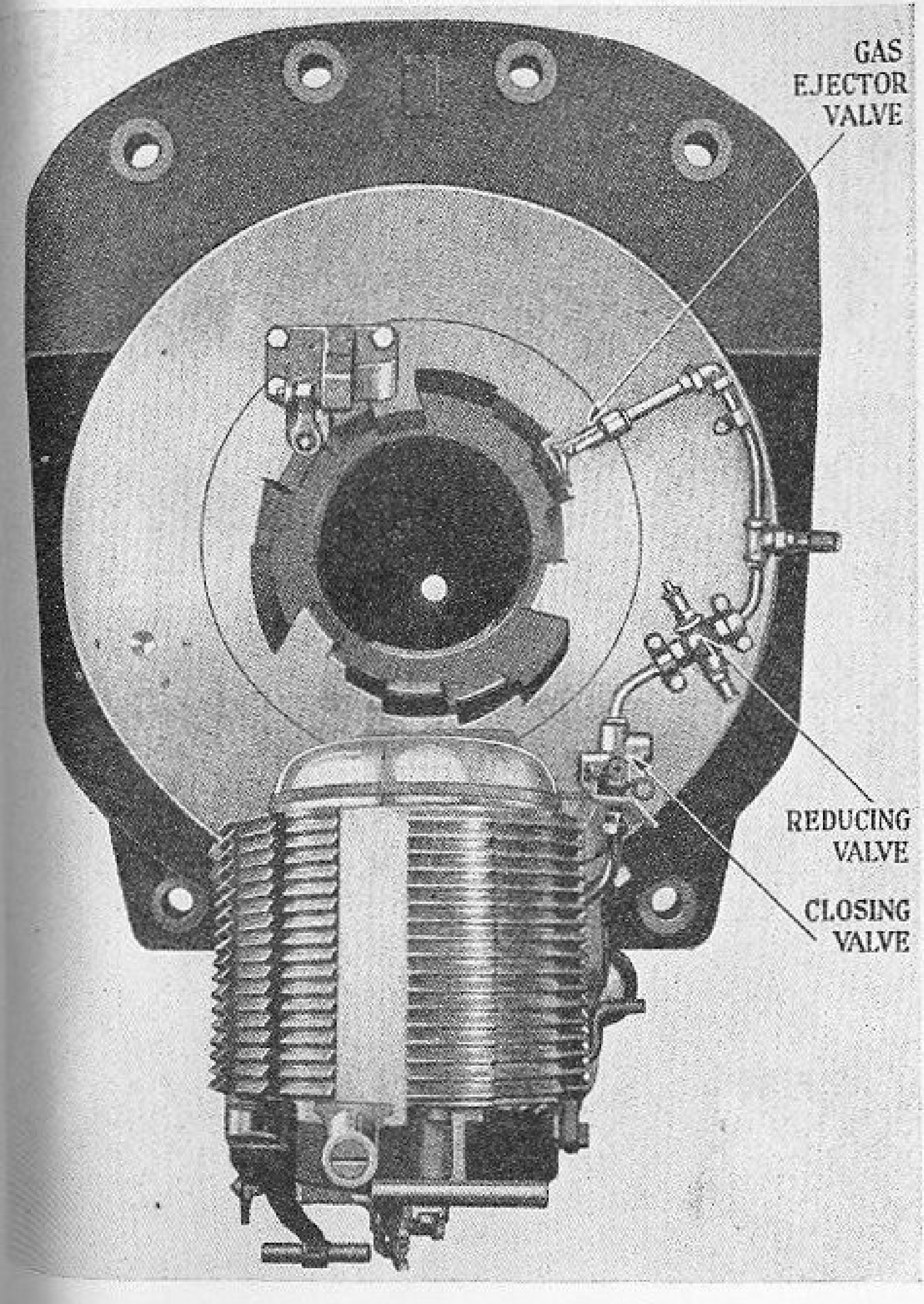
16-INCH BREECH MECHANISM, REAR VIEW, CLOSED.

CHAPTER VII. PLATE XIII.



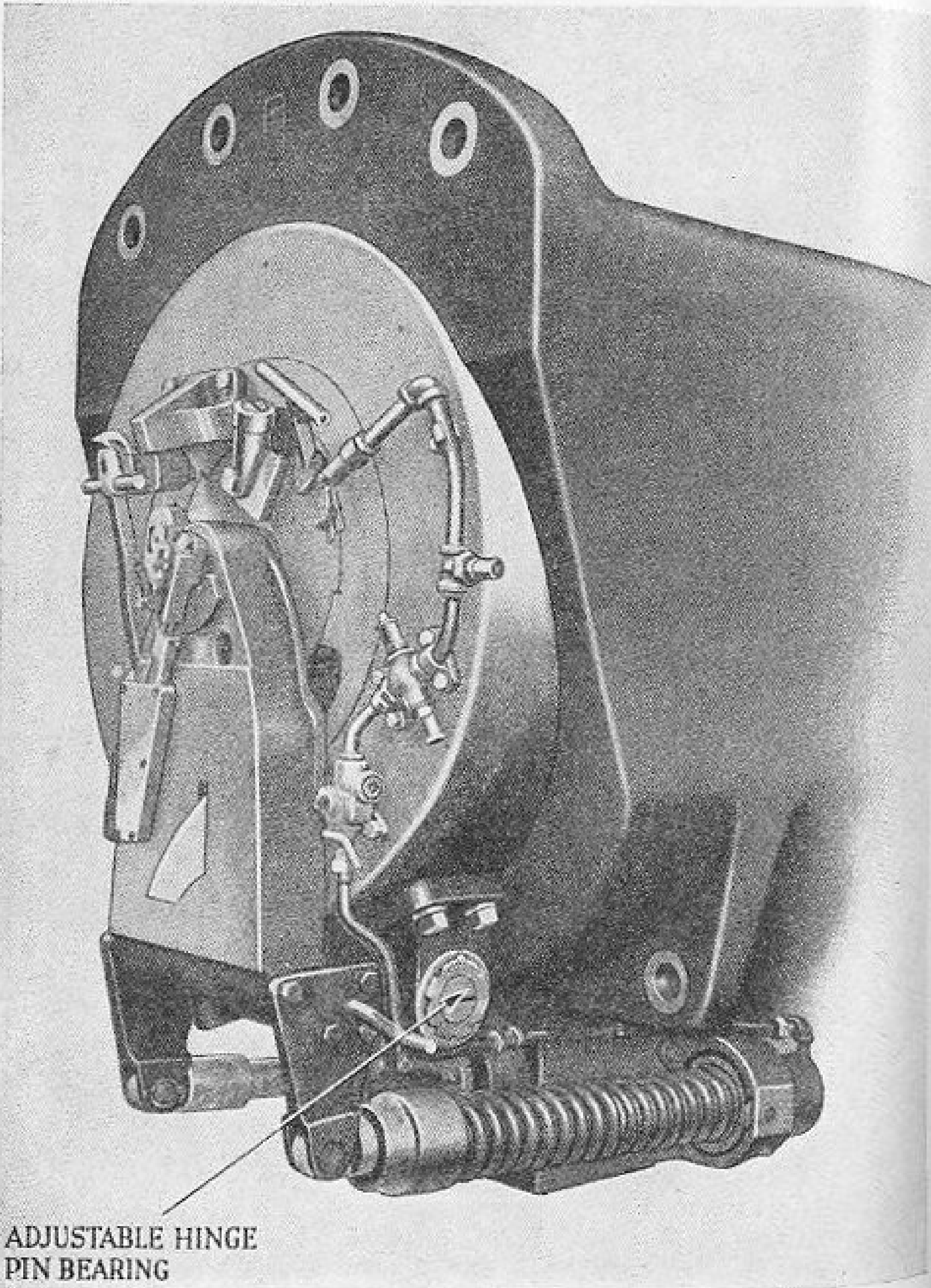
16-INCH BREECH MECHANISM, REAR VIEW, BLOCK ROTATED.

CHAPTER VII, PLATE XIV.



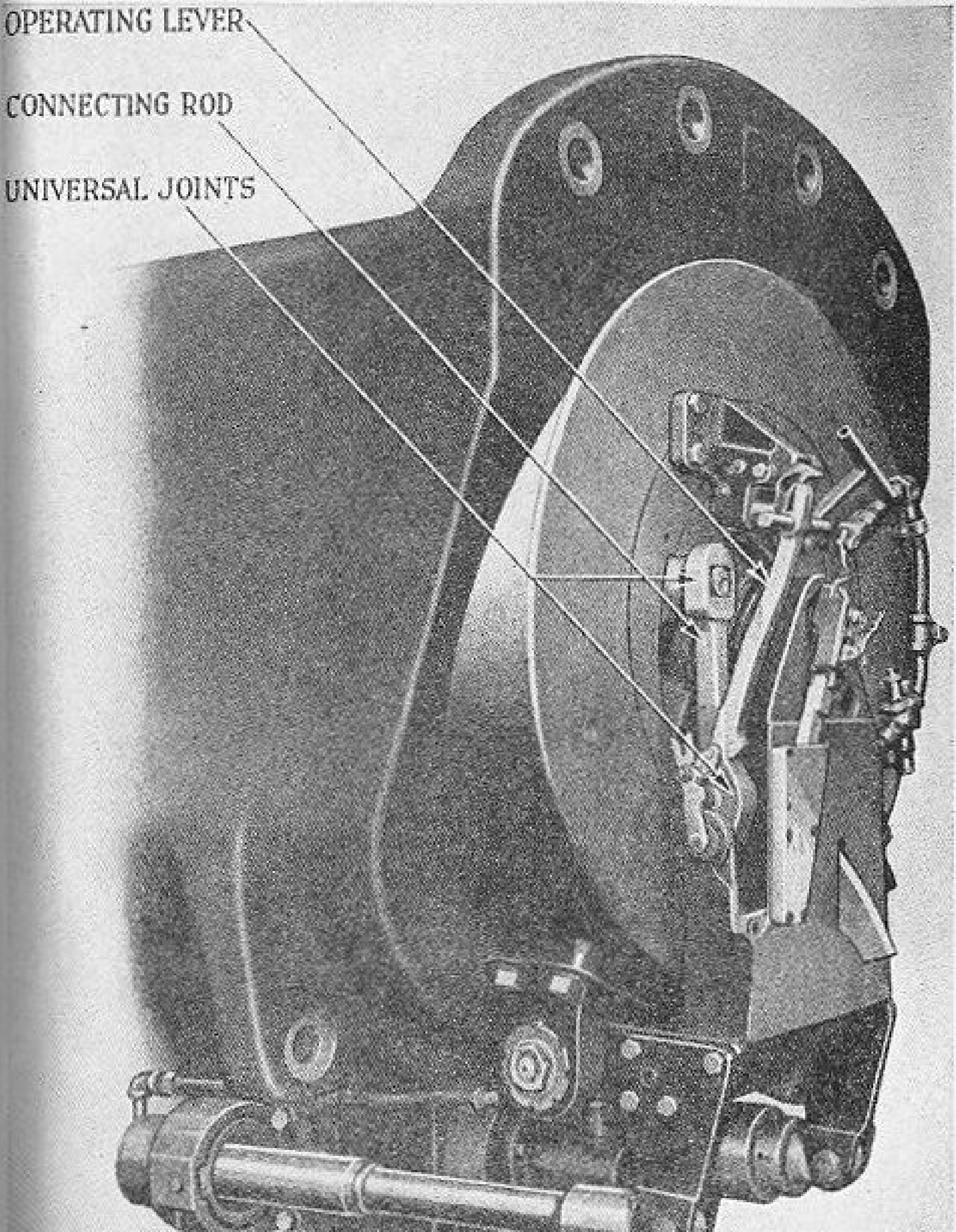
16-INCH BREECH MECHANISM, REAR VIEW, OPEN.

CHAPTER VII, PLATE XV.



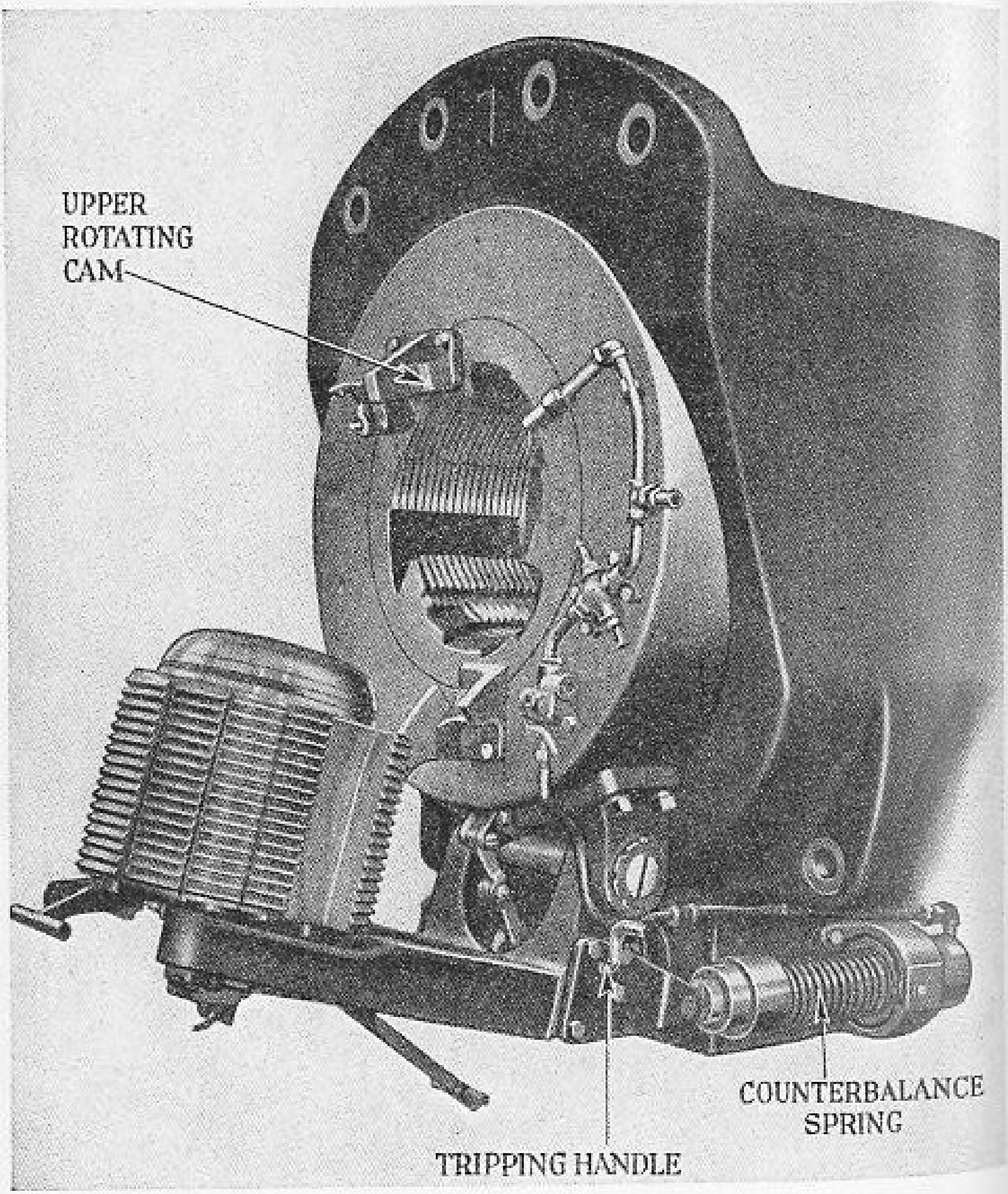
16-INCH BREECH MECHANISM, RIGHT SIDE, REAR VIEW, CLOSED.

CHAPTER VII, PLATE XVI.



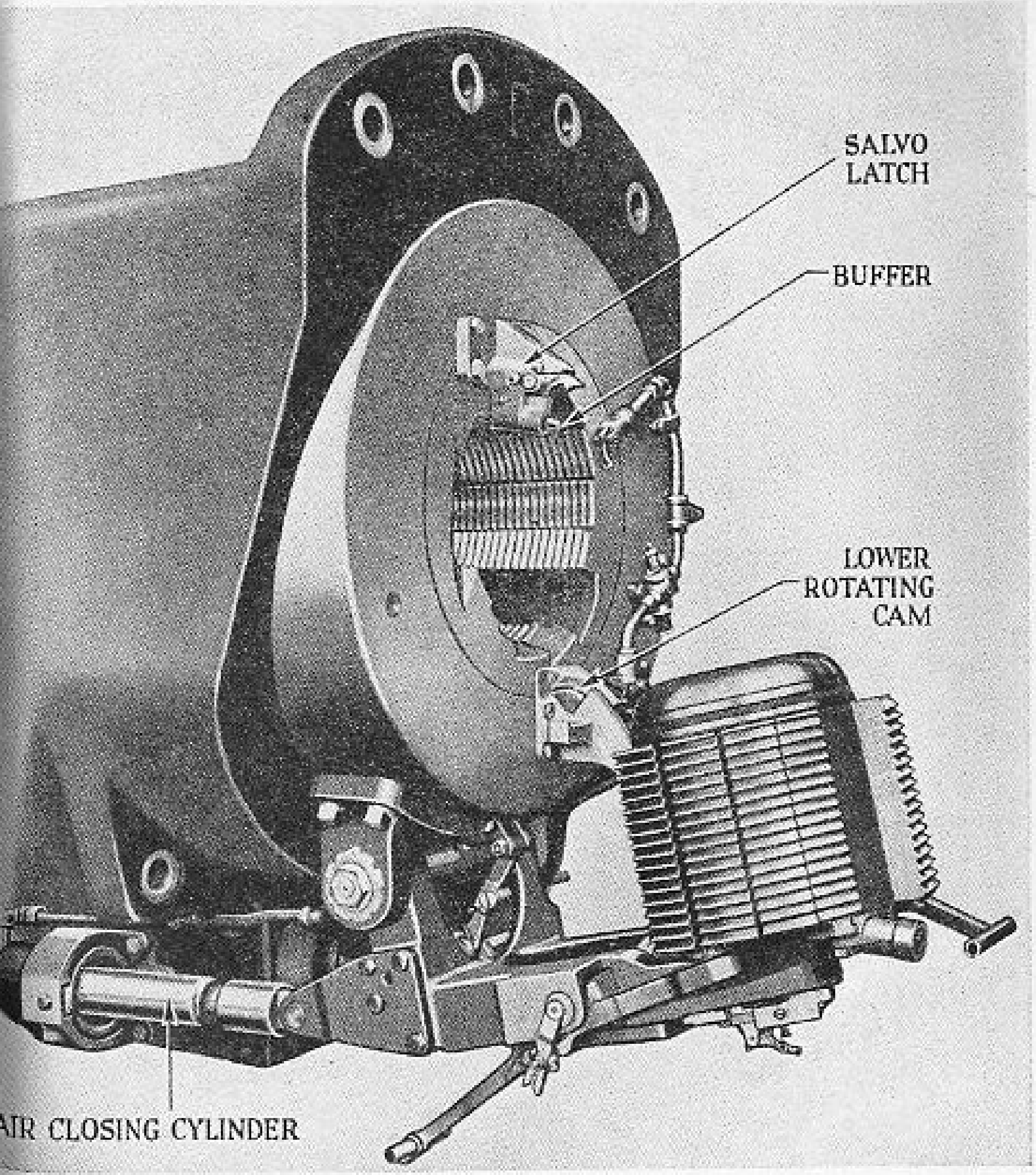
16-INCH BREECH MECHANISM, LEFT SIDE, REAR VIEW, CLOSED.

CHAPTER VII, PLATE XVII.



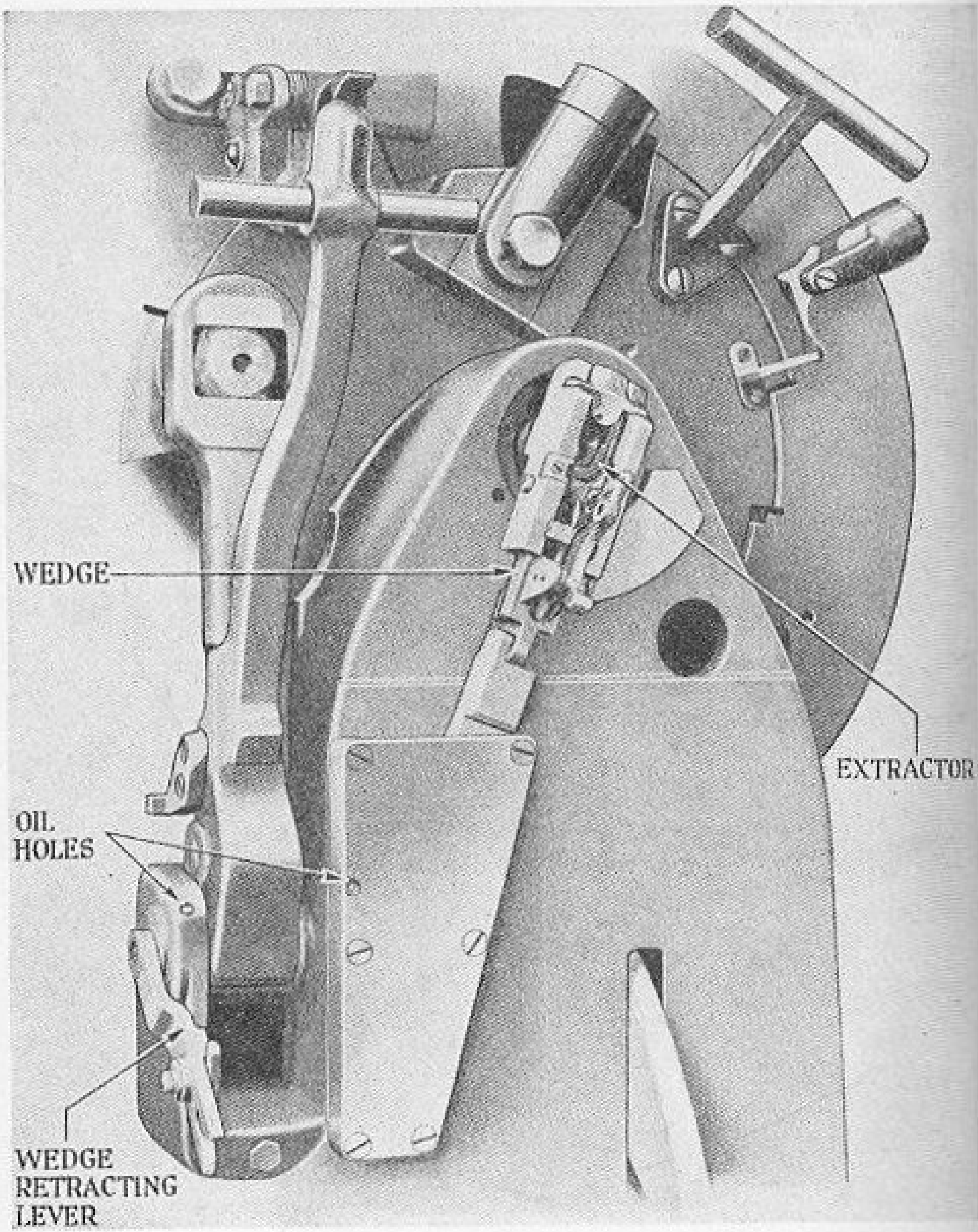
16-INCH BREECH MECHANISM, RIGHT SIDE, REAR VIEW, OPEN.

CHAPTER VII, PLATE XVIII.



16-Inch Breech Mechanism, Left Side, Rear View, Open.

CHAPTER VII, PLATE XIX.



REAR VIEW, 16-INCH FIRING MECHANISM, POSITIONED FOR RE-PRIMING.

comes in contact with the closing valve handle and closes the valve. This cuts off the air pressure, which is released by check-valve vents and allows the air pressure to decrease until the valve spring has sufficient force to lift the valve from its seat.

When the plug is unlocked, it falls in a downward arc, forcing the spring rods with their pistons into the cylinders and compresses the counterbalance spring. A boss cast on the carrier comes in contact with the piston rod of the breech-opening buffer, forcing it in against the resistance formed by liquid in the buffer cylinder; this cylinder is provided with ports to by-pass the liquid to the forward side of the piston as it is forced down. The after end of this piston takes up hard against a boss on the inside of the cylinder, which forms a positive stop for the mechanism. The buffer cylinder is bolted to the rear end of the recoil piston and is tilted at an angle of 5° from the horizontal. The counterbalance spring which encircles the right-hand closing cylinder is so designed that it assists in balancing the weight of the plug. Air is admitted to the closing cylinder by opening the closing valve by hand, thus admitting air behind the spring-rod pistons and closing the mechanism. The blow of the operating lever as it nears the closed position is taken up by means of a hydraulic buffer cast integral with the salvo latch, which locks the operating lever in its closed position. The salvo latch is automatically released by the recoil of the gun; it may also be operated by hand. In case of failure of air pressure, it is readily possible for three men to close the mechanism by means of the closing handle bolted to the plug. In closing by hand great care must be exercised to stand clear of the path of the operating handle.

FIRING MECHANISMS.

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

751. 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 either by batteries or by motor generators, connections being made so that either one may be used.

752. Definition of percussion and electric firing mechanism.—A percussion firing mechanism is one in which the blow of a firing pin explodes the 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 grounded in the gun. Electric current heats a fine wire or bridge in the primer to a sufficiently high temperature to explode the charge of the primer.

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 automatically during the opening of the breech mechanism.

The electric firing mechanism has an encased insulated firing pin. The electric contact is not made until the breech block is entirely closed.

753. The firing lock consists essentially of a receiver which screws on the rear of the mushroom stem (see Plates III and IV) and contains a wedge made so that the primer seat may be either closed or unmasked for priming. The receiver has a suitable catch for retaining the primer when priming, and an extractor for ejecting the primer case upon opening the breech after firing. For electric firing, the wedge contains an insulated firing pin which is in contact with the insulated plunger within the primer; the latter is grounded in the gun. For percussion fire, the wedge carries a hammer, firing spring, and cocking lever to deliver the blow to the same firing pin as that used for electric firing.

754. Safety is one of the most important functions of a firing mechanism and special care must be given to it in design. In general, the safety features consist of devices which prevent the firing of the gun until the breech is entirely closed; the details vary with each particular mechanism.

755. Definitions of firing attachments.—These are a part neither of the firing mechanism nor of the breech mechanism, but are certain appliances used to put in operation the firing mechanism. The firing lanyard, electric firing battery, wires, terminals, firing key, etc., are attachments.

The two terms *firing mechanisms* and *firing attachments* should not be confused.

DESCRIPTIONS OF FIRING LOCK, MARK XIV AND MODIFICATIONS.

(Plate XXI.)

756. This firing lock, which is the standard equipment for the latest 5-, 6-, 8-, 12-, 14-, and 16-inch breech mechanisms, consists of a receiver, wedge, operator bar, extractor, and primer-retaining catch. The wedge is actuated by means of a cam attached to the operating lever of the breech mechanism. This cam withdraws the wedge and ejects the primer as the breech is opened. Priming is accomplished by hand, and in case of misfire, the lock can be reprimed without opening the breech mechanism, by rotating the wedge hand-operating lever, thus lifting the wedge-operating plunger from the cam; the lock-operator bar can then be drawn out, carrying with it the wedge. The wedge actuates the extractor and causes the ejection of the primer. After the new primer has been inserted, the lock-operator bar is pressed in against its stop; the wedge-operating plunger re-enters the cam slot and gun is again ready to be fired. The firing lock is the same for all mechanisms; operator bars of different lengths, however, are necessary for the various breech mechanisms.

757. The receiver, approximately rectangular in shape, is milled out to receive the wedge. It is secured to the breech mechanism by means of a bayonet joint on the end of the mushroom stem and is prevented from rotating by the operator bar which is fastened to the wedge. The receiver is drilled for the extractor pin and necessary clearances are milled for the extractor. On one side of the receiver is milled a slot into which a lug on the hammer slides, thus preventing the hammer from being pulled back for percussion firing after the wedge has started to retract. In the front face of the receiver on the side with the milled slot is fitted the hammer guide block. This block is milled so as to align with the slot and allows the hammer to be cocked only when the wedge is fully closed. It also serves to lift the hammer, thus breaking the contact with the firing pin and preventing electric firing except when the wedge is fully closed.

758. The wedge slides in the receiver and is operated by means of the operator bar. It is prevented from being withdrawn entirely from the receiver by means of a wedge-stop screw passing through the side of the receiver and fitting into a recess milled in the side of the wedge. The firing pin is mounted in insulating bushings at the inner end of the wedge. A hardened face plate is placed in the wedge next to the mushroom stem to take the thrust of the primer when fired. This wedge face plate has a striking lug for actuating the extractor as the wedge is retracted. The inner end of the wedge has a 45° sloping cut to permit pushing home the extractor, and a circular tapered cut to seat the primer. The wedge is drilled for the hammer thrust pin and the firing spring. The thrust pin, when the hammer is drawn back, protrudes through the wedge into a hole drilled in the crosshead bearing of the breech mechanism. This hole is in alignment with the thrust pin only when the breech plug is fully closed. The thrust pin, due to the action of the firing spring, keeps the hammer in contact with the firing pin except when the wedge is retracted. The wedge is secured to the lock operator bar by the operator bar pin passing through a hole in the outer end of the wedge. This hole is elongated to provide for any movement of the mushroom stem to rear at time of firing.

759. The hammer has fitted into its right-hand side a spring catch which acts in conjunction with the cocking lever. This catch engages

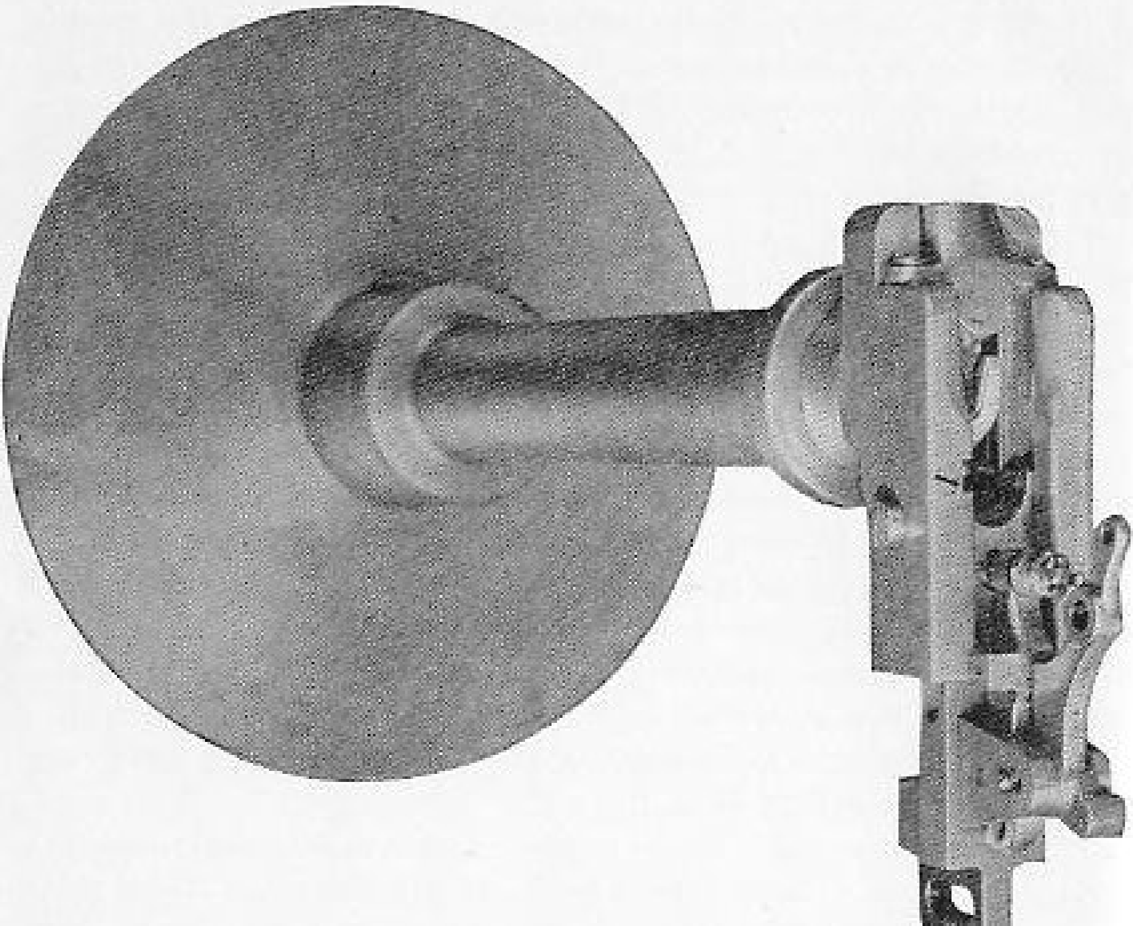


FIG. 707.—A FIRING LOCK MOUNTED ON END OF MUSHROOM STEM.

with the latch as the cocking lever is pulled back by the lanyard for percussion firing until their relative positions are such that the hammer is released. When the lanyard pull is released, the cocking lever spring throws the lever forward into its original position and the latch snaps over the hammer catch. The contact piece is housed in an insulated housing in the forward end of the hammer. The lower end rests upon the firing pin when the lock is closed; the upper end carries a terminal to which one side of the electrical firing circuit is connected.

760. The cocking lever turns on the cocking-lever axle, directly above and in the same vertical plane as the axis of the hammer. Incorporated with the cocking-lever bearing is a cocking-lever spring which has a torsional action tending to throw the left end of the cocking lever towards the lock. One end of the spring engages a recess in its housing in the cocking lever; the other engages a hole in the torsional washer that serves as cover to the spring housing and also as a bearing for the cocking lever. Adjustment of the spring tension is effected by turning the torsional washer in the direction of the arrow stamped on it until the zero mark is aligned with the index line on the wedge. A lug on the right-hand side of the cocking lever extends toward the face of the wedge and serves as a latch to engage the hammer catch when the hammer is to be pulled back for percussion firing. When the cocking lever is in its normal position, the under edge of the latch lug rests on the face of the wedge and transmits to the wedge, instead of through the hammer and to the primer, any accidental blow upon the cocking lever. This precludes accidental firing which might occur were the cocking lever struck when the lock is closed. The hammer, mounted between the wedge and the cocking lever, is amply protected from exterior blows. The slightest withdrawing of the wedge from the closed position removes the firing pin from the percussion cap of the primer and precludes firing electrically or percussively. The outer end of the wedge is so designed that it may be used in connection with the lock operator bars of any of the standard breech mechanisms. Lanyards are secured to the cocking lever by means of a hook. In addition to lanyard firing, the lock may be fired percussively by hand- or foot-operated firing mechanisms incorporated with the various mounts by an extension which may be attached to the outer end of the cocking lever.

761. The extractor is pivoted in the receiver and fits between the forward face of the wedge and the rear face of the mushroom stem. The extractor arms engage the primer shell on two sides, a clearance cut being provided in the extractor for the primer seat extension on the rear end of the mushroom. The extension is added to the end of the mushroom stem to give better support to the primer. The extractor is actuated by an *extractor cam* which turns on the same pin as the extractor. When the wedge is retracted the lug on the wedge face plate strikes the extractor cam, which, in turn, causes the extractor to swing to the rear, lifting the primer retaining catch out of the way and ejecting the primer. This extractor cam is also provided with a torsional extractor spring which returns it to the original position as soon as the wedge is sufficiently withdrawn. In priming, the primer is inserted between the arms of the extractor into the primer seat. The head of the primer, seating in a recess cut in the rear face of the extractor, pushes the extractor forward until the primer-retaining catch engages the primer. The extractor and primer are pushed entirely home by the tapered cut on the inner end of the wedge.

762. The primer-retaining catch consists of a catch housing which is secured to the upper end of the receiver by two screws, a catch which slides in and out of the housing, a guide screw which controls the outward movement of the catch, and a catch spring which keeps the catch in the correct retaining position. This catch sits in rear of the primer seat, and when the primer is inserted in the seat the catch is pushed in until the head of the primer is engaged by the forward face of the catch. When the wedge is closed and the primer is pushed home, the end of the wedge pushes the catch into its housing. When the primer is ejected, the arms of the extractor force the catch out of the way of the primer.

763. The lock-operator bar is secured to the carrier by means of a T-slot. The movement of the bar is controlled by a wedge operating plunger. The stop plunger is housed in the operating bar, being held in the housing by means of a stop-plunger key fitted in the forward face of the operator bar, a stop-plunger spring being used to keep the plunger against the key. A stop-plunger pull ring is attached to the end of the plunger to enable the plunger to be lifted over the cam surface when withdrawing the bar from the carrier. This plunger works against a machined surface in the carrier and only allows the bar to be moved the distance necessary to close the wedge and to align the firing pin with the primer.

764. The wedge-operating plunger is housed in the outer end of the operator bar, the end of the plunger entering the slot in the operating cam. This cam being secured to the operating lever of the breech mechanism causes the lock to open and close with the opening and closing of the breech mechanism. The wedge-operating plunger is secured in the housing by means of a wedge-operating plunger pin and plunger pin detent and is kept in the cam slot by means of a wedge-operating plunger spring. Over the housing for the wedge-operating plunger is secured the wedge hand-operating lever. This lever has two helical slots diametrically opposite, through which it is secured to the housing by a plunger pin and by which, when the lever is pushed outward, the wedge-operating plunger is lifted out of the cam slot. The operator bar can then be moved outward, withdrawing the wedge. The wedge hand-operating lever is used only for repriming or in assembling or disassembling the lock. The inner end of the operator bar is secured to the wedge by means of an operator-bar pin with a spring detent.

765. Safety features of the firing lock may be summarized:

(1) Unless the wedge is fully closed, (a) a lug on the hammer, sliding

in a slot on one side of the receiver, prevents the hammer from being pulled back for percussion firing; (b) the hammer lug slot in the receiver causes the hammer to be lifted, thus breaking the electrical firing circuit.

(2) Unless the breech mechanism is in the fully closed position, (a) the hammer cannot be drawn back for percussion firing as the hole in the crosshead bearing of the breech mechanism is not in alignment with the hammer thrust pin; (b) the operator bar and the attached wedge cannot be placed in the firing position, for the surface of the cam on the outer side of the cam slot is cut down to allow the wedge-operating plunger to move over it in withdrawing the operator bar from the slide, but the surface on the inner side of the cam slot is too high to permit the plunger to slide over it; (c) a shoulder on the end of the crosshead bearing of the breech mechanism prevents the wedge from being closed.

(3) Unless the wedge is retracted a pin, which is screwed into the carrier, prevents the rotation of the firing lock to the position for assembly or removal.

(4) When the cocking lever is in its normal position, the under edge of the cocking-lever latch rests on the face of the wedge, and transmits to the wedge, instead of through the hammer and primer, any accidental blow upon the cocking lever.

766. Briefly, the advantages of the Mark XIV firing lock are:

(1) It can be reprimed without opening the breech and without endangering personnel.

(2) By one pull on the cocking lever lanyard it can be cocked and fired by percussion, this eliminates separate cocking and firing operations.

(3) It has a short, well protected, insulated firing pin and a short, strong contact piece on the hammer.

(4) If the primer is inserted past the primer retaining catch, the latter keeps the primer in place and thus prevents the primer from being jammed or sheared by the wedge.

(5) The design of the lock prevents the possibility of firing the primer, either by percussion or by electricity, unless the plug is completedly closed.

CHAPTER VIII.

FIRING ATTACHMENTS AND GAS-EXPELLING DEVICES.

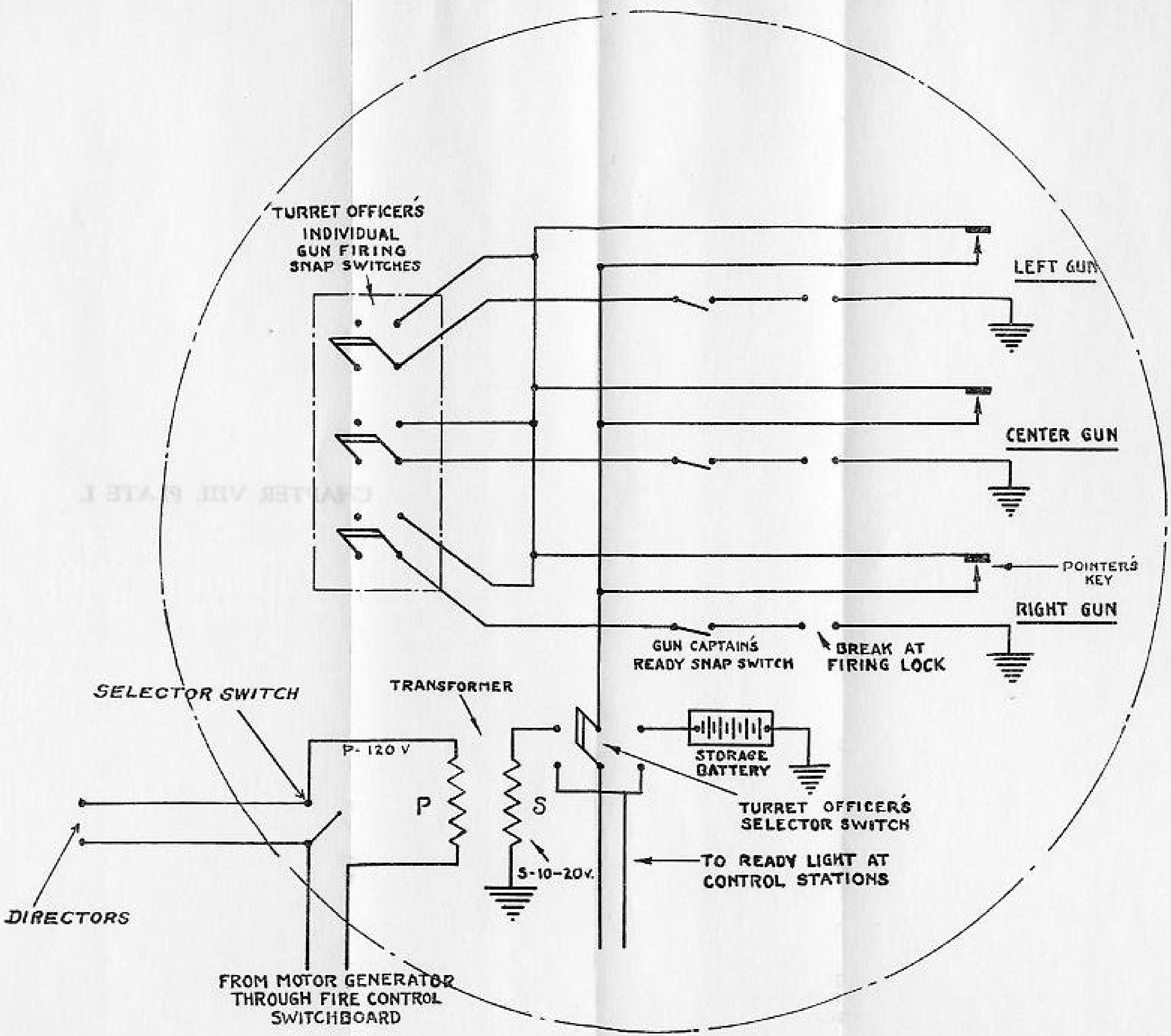
801. In U. S. naval guns the term *firing mechanism* is used to designate that part of the breech mechanism which directly explodes the primer and thus fires the gun. The *firing attachments* comprise those appliances fitted to the gun and mount, which put the firing mechanism in operation. The lock lanyard, electric firing battery, wires, terminals, and firing key are attachments.

802. Electric firing for large guns is the primary method of fire, 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 of co-ordinating mind and muscle, and (2) the time consumed by the travel of the projectile along the bore and by the mechanical action of the firing devices.

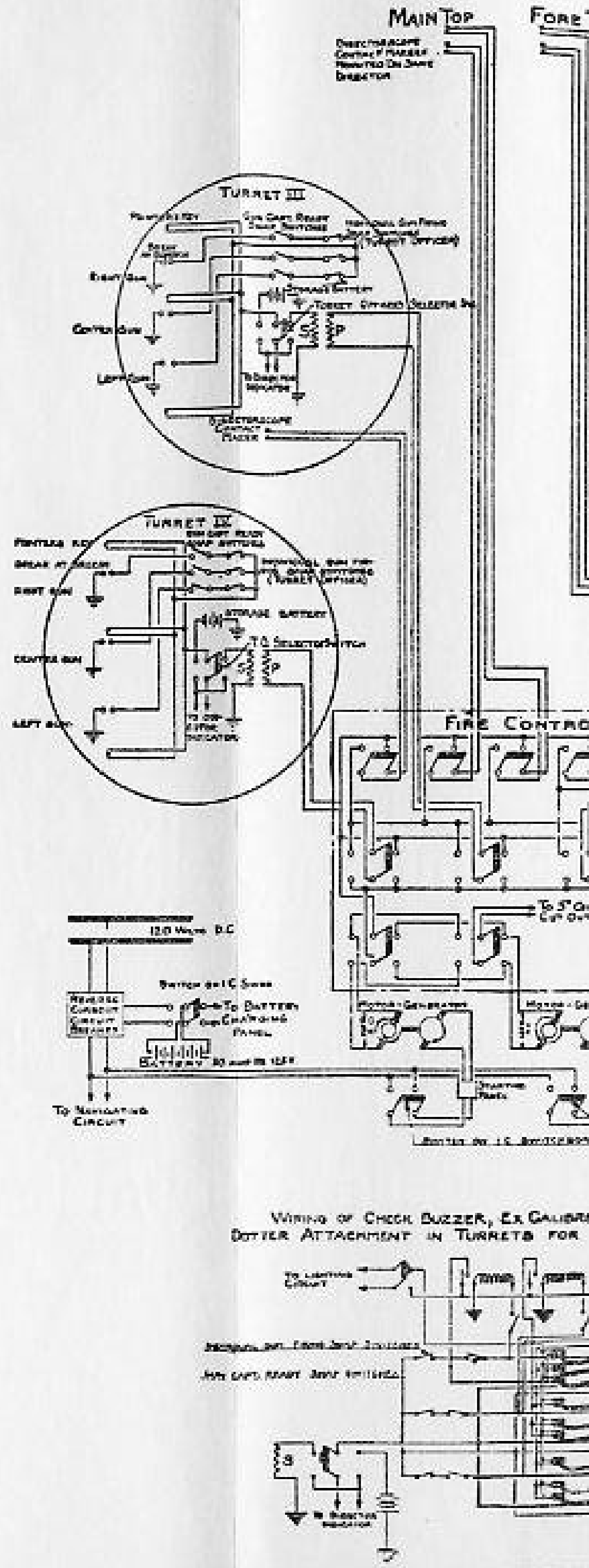
803. Current for electric firing is furnished by motor generators or by storage batteries, connections being made so that either may be used. The motor generators for this purpose, usually two in number, are located in an interior communication room of the ship, and take direct current from the ship's circuit. They deliver alternating current at 125 volts to the fire-control switchboard, where the various units of the battery are cut in or out in accordance with orders from the fire-control officer. Alternating current has several advantages over direct current for gun firing circuits. The principal advantage is that the presence of a transformer in each turret or gun circuit prevents a ground or short circuit in one turret or gun from putting the entire firing circuit out of commission.

804. Firing circuit for turret guns.—The wiring diagram for the firing circuit of turret guns on a battleship is shown on Plate 1. It will be seen that direct current for the motor end of the motor generators can be taken either from the ship's mains or from a storage battery discharging at the rate of 50 ampere hours, with a voltage of 125.

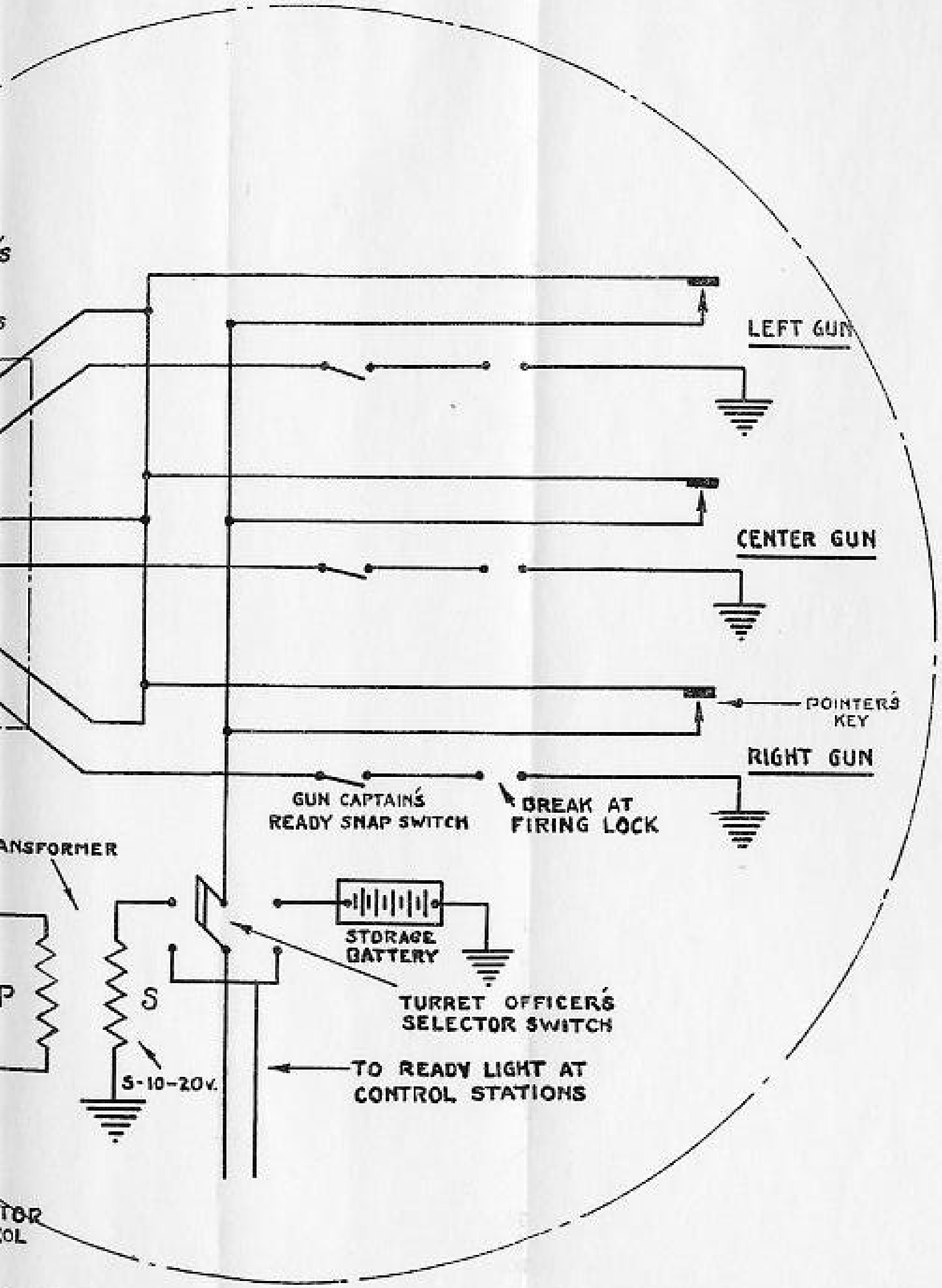
The motor generators serve merely to convert direct current into alternating current at the same voltage. The latter is led to the fire-control switchboard, which is shown to carry four cut-out switches,



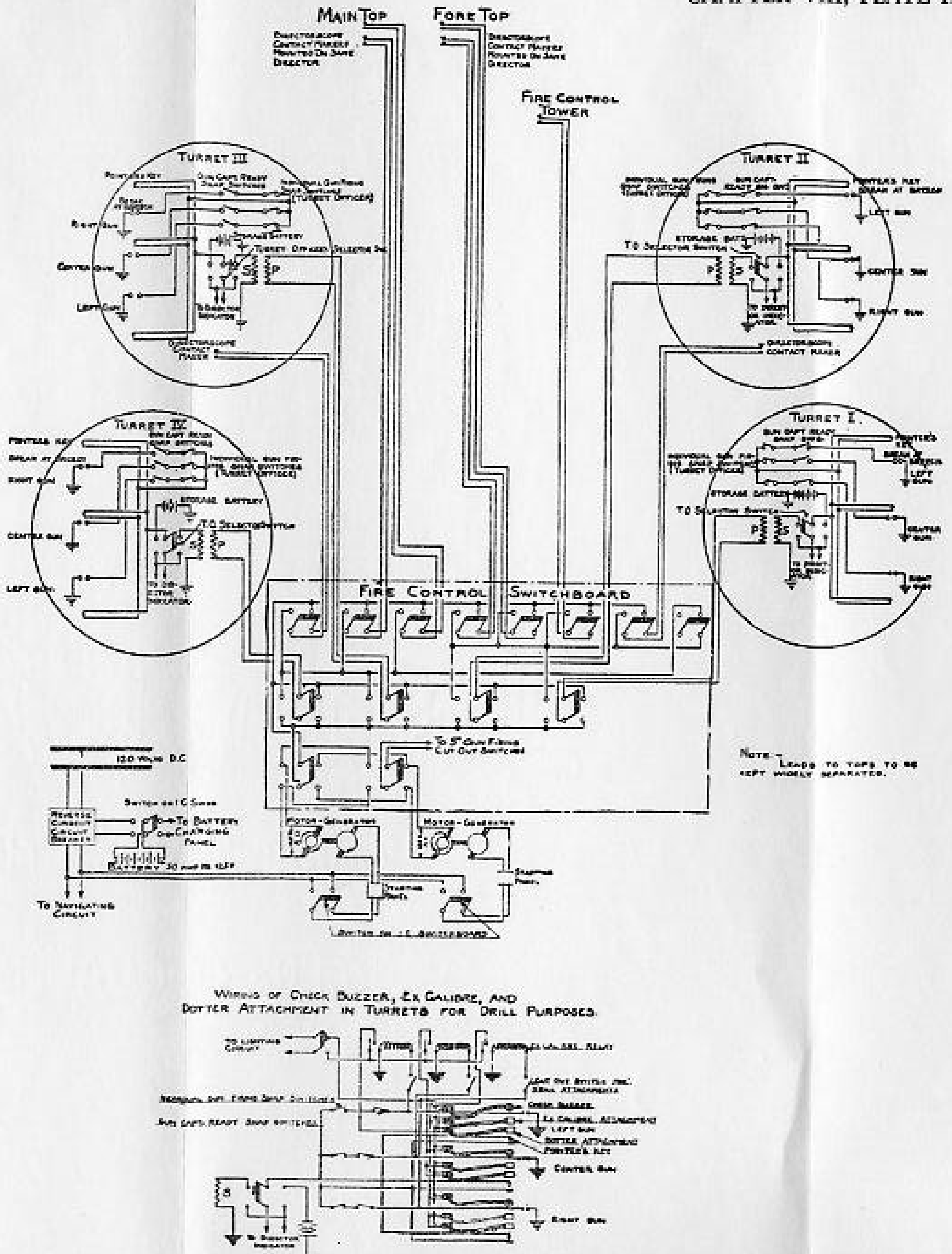
ENLARGED WIRING DIAGRAM FOR THE FIRING CIRCUITS OF THE THREE GUNS OF ONE TURRET ONLY.



WIRING DIAGRAM FOR FIRING



R THE FIRING CIRCUITS OF THE THREE GUNS OF ONE TURRET ONLY.



WIRING DIAGRAM FOR FIRING CIRCUIT FOR TURRET GUNS.

one for each of the four turrets. By closing these switches to the right, current is delivered directly to the primary coil of a transformer located in each turret. There the voltage is stepped down to 20 volts alternating current at the terminals, which is ample for firing the primers in the guns.

805. Located in the turret officer's booth in the turret is a selector switch for either director fire or local fire; when this switch is closed for local fire the current is completed to the primary coil of the turret transformer. There also is a selector switch whereby current for firing can be taken either from the secondary of the transformer or, in case of failure of the motor generator, from a local storage battery in the turret. This is a separate battery from that mentioned in Art. 804, which may be used to supply the motor generator. Following the diagram, it will be seen that the path of the current leads from this switch to the pointer's firing key at each gun, thence, individually for each gun, to the turret officer's snap switch (which is closed unless he wishes to cut out a gun from firing), then to the gun captain's ready switch (which is closed as soon as the gun is loaded and primed), thence to the terminals at the breech of the gun (which make contact as soon as the breech is closed and locked), from this point to the primer bridge, and thence to ground. It is apparent, therefore, that as soon as the gun is loaded, primed, and ready, the only break in the circuit is the pointer's key which is closed when the pointer's sight is on the target and the firing signal is sounding. All guns of the turret may be fired from any one of the gun firing keys, the pointer being designated as the firing pointer.

806. The portion of the firing circuit described so far is sufficient to enable the guns to be fired by the pointers. This method or system of firing, known as "pointer fire," was the only one in use until about 1914. Since that time, however, "director fire" has been introduced under which the guns are laid to a predetermined angle of elevation, and the actual sighting and firing is done from a station located usually aloft. The remainder of the firing circuit shown on Plate 1 covers this director feature, and consists of the necessary switches and leads to the various gun directors installed on the ship.

As will be seen from the diagram, directors are located in the fire-control tower, the foretop, the maintop, plot, and in high turrets Nos. 2 and 3. By proper manipulation of switches on the fire-control switchboard, any one of these directors can be made to control all turrets; or the control may be divided between two of them, the foretop director, for instance, being used for turrets Nos. 1 and 2 and, the maintop director for turrets Nos. 3 and 4.

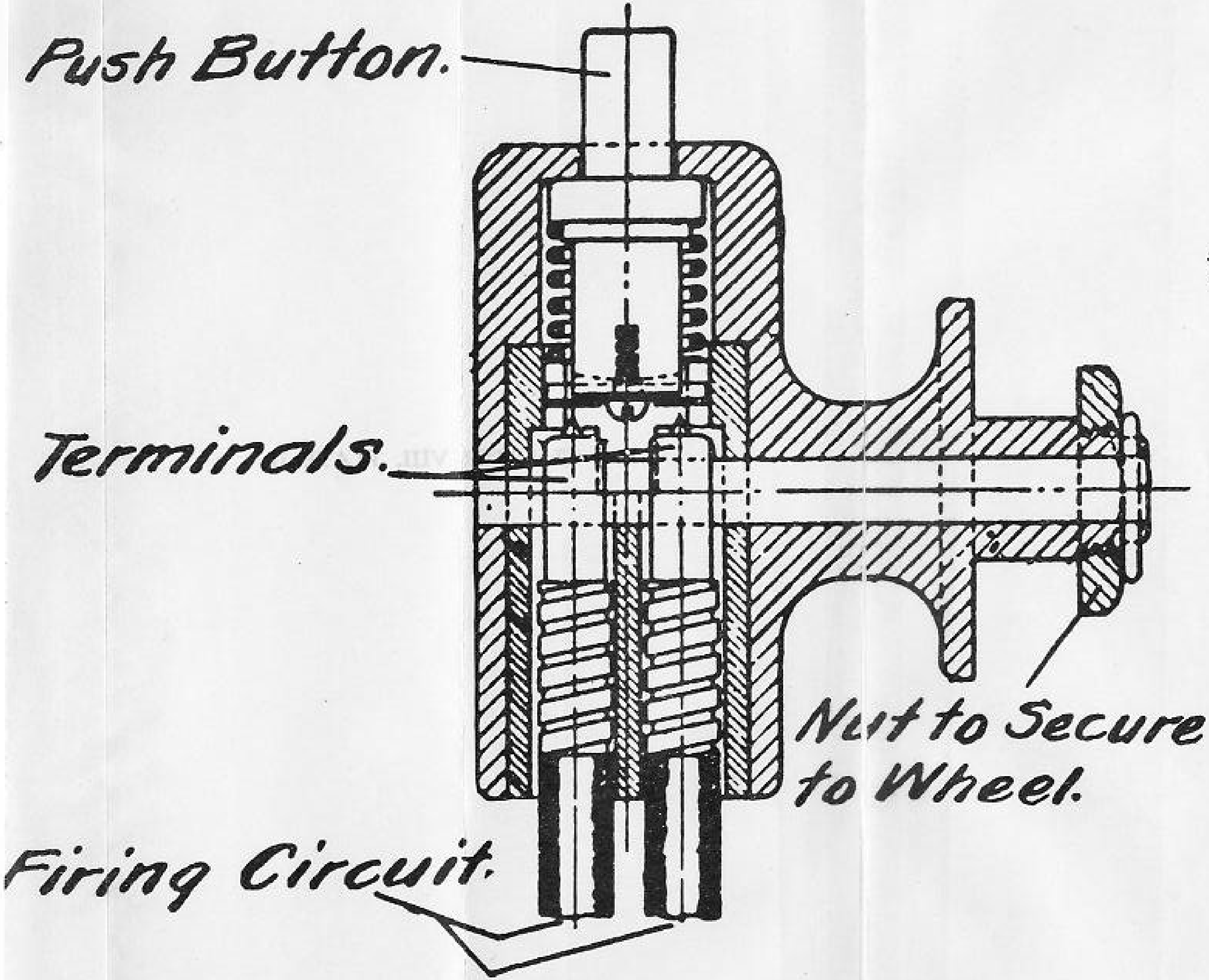
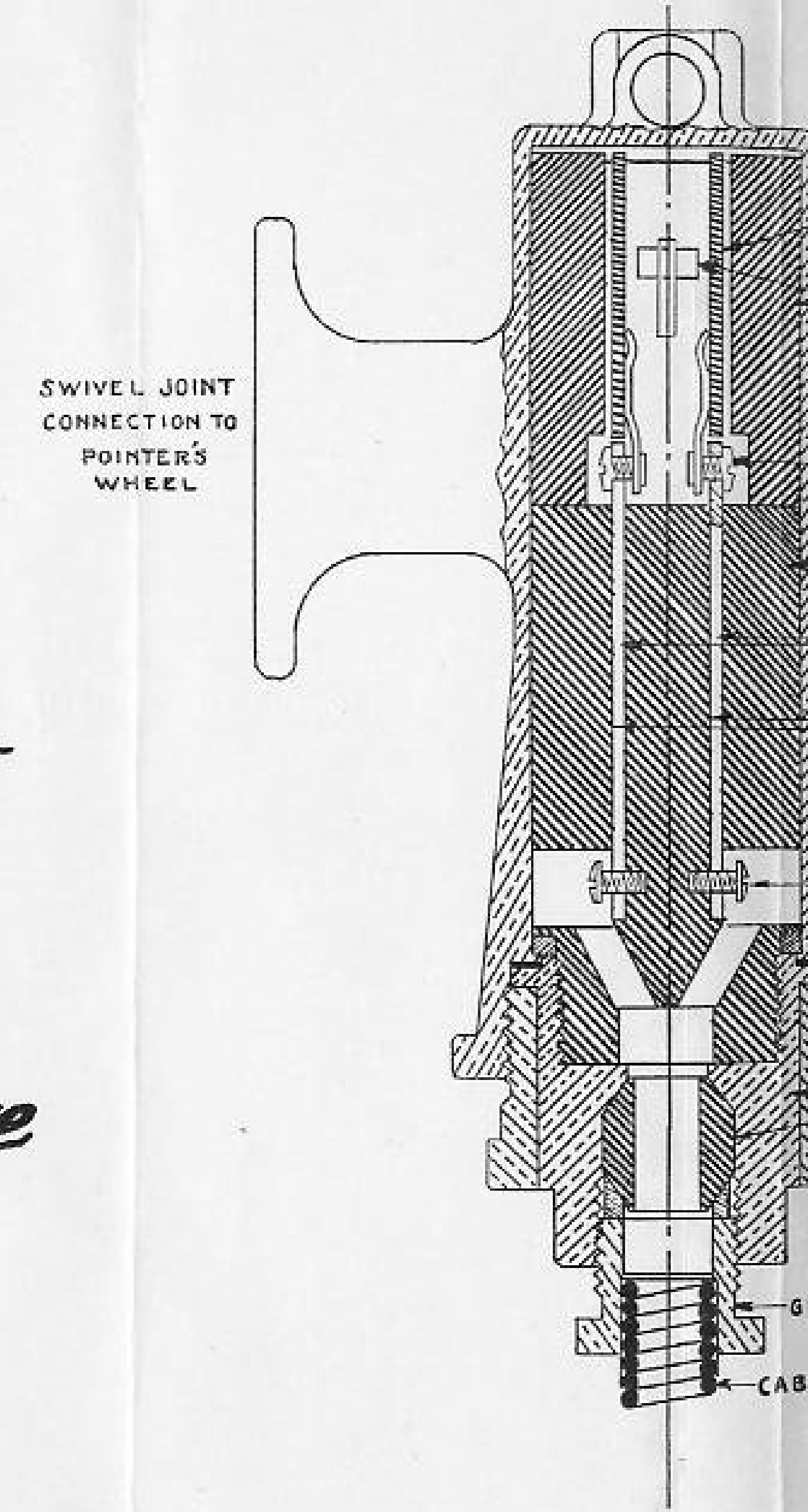
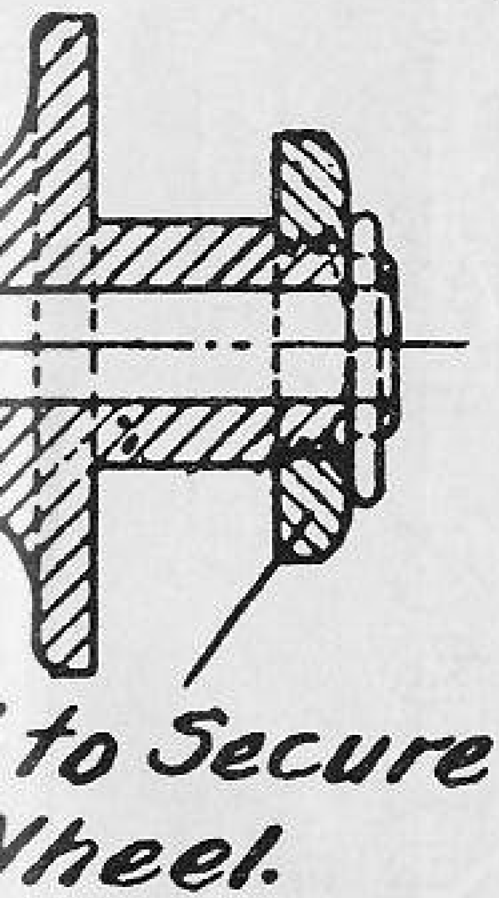


FIG. 1.—PUSH-BUTTON TYPE OF FIRING-HANDLE USED ON TWO-HANDED DRIVE-WHEELS





WHEELS

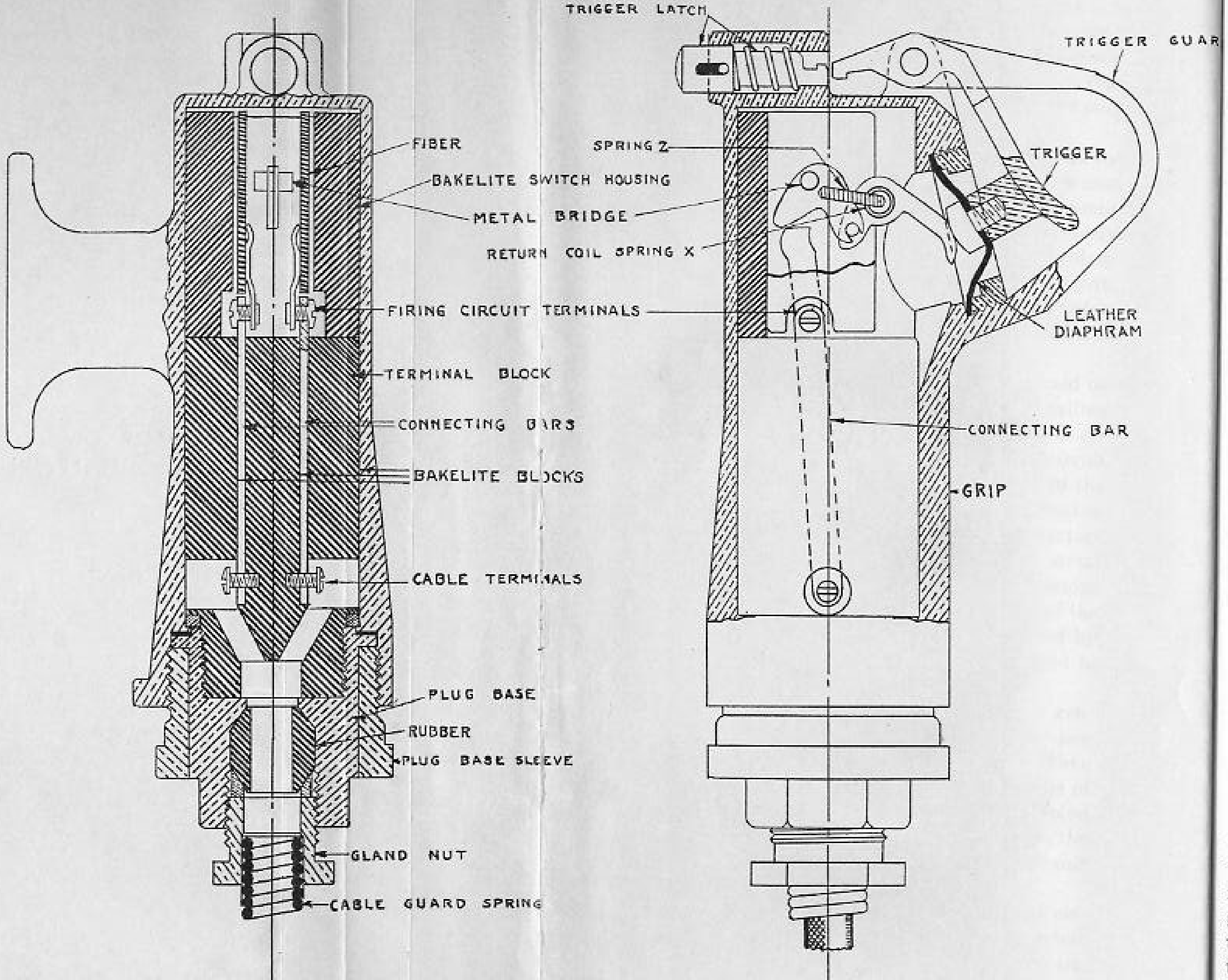
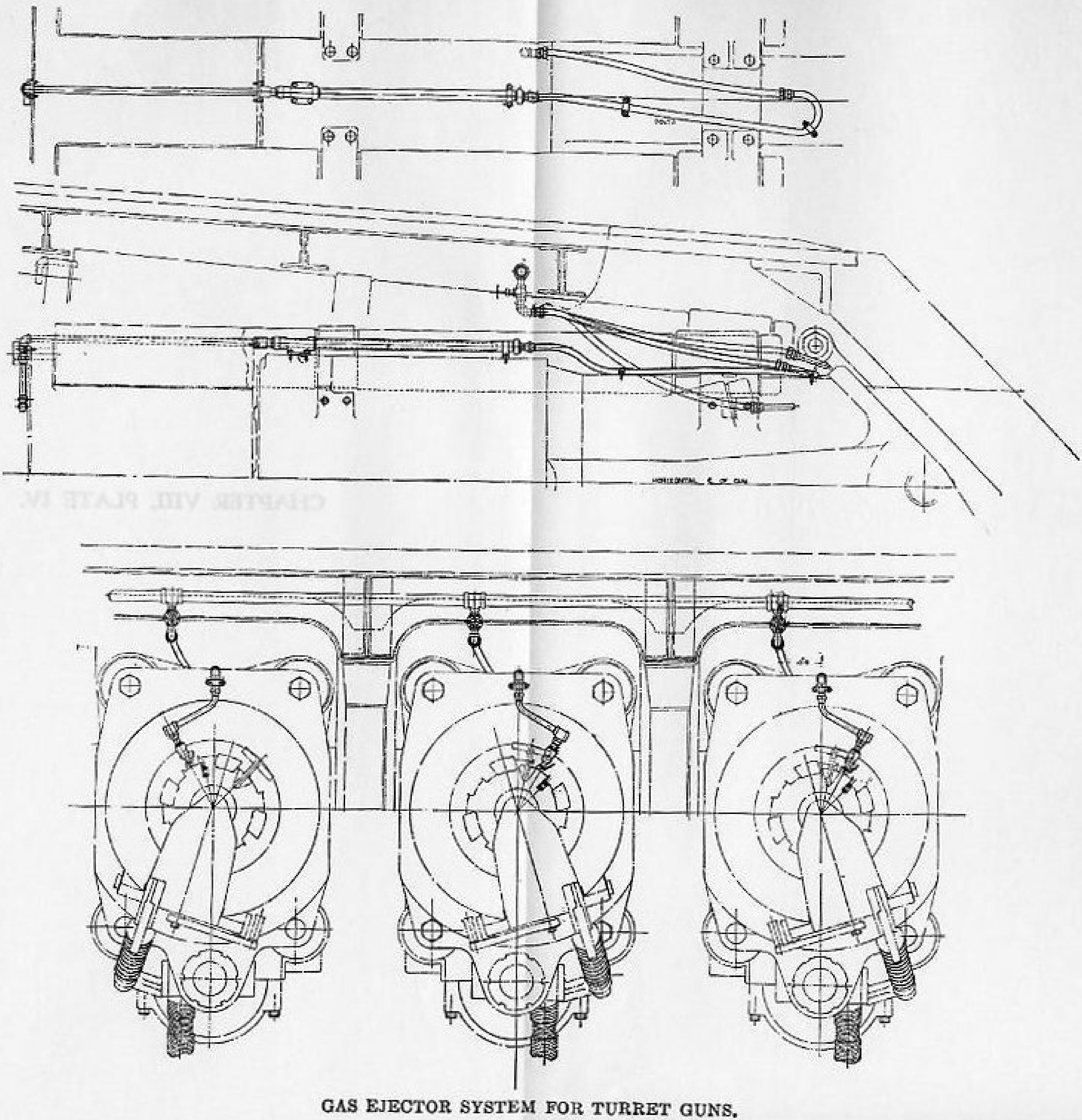


FIG. 2.—MARK XVI FIRING KEY



GAS EJECTOR SYSTEM FOR TURRET GUNS.

When director fire is being used, the four turret switches on the fire-control switchboard are thrown to the left. The firing pointers' keys in the turrets are closed when the guns are laid, and held in that position, so that, as soon as the guns are loaded and ready, the only break in the circuit is the firing key at the director. It is customary to have a firing pointer in addition to the elevating pointer in each turret. The firing pointer, observing an elevation indicator and with a separate firing key on another lead, keeps the circuit closed if the guns are loaded and the pointers of the gun elevation indicator remain matched. The guns in the turrets, all laid to the desired angle of elevation, fire in salvo as the director key is closed.

When the turret officer's selector switch is thrown either for battery or motor generator, it closes at the same time the ready-light circuit, lighting the ready lights in plotting room and control stations, to indicate that the turret is ready to fire. This is a 110-volt circuit entirely independent of the firing circuit, but the throw of the double-pole selector switch closes one break in each circuit.

It will be noted that both the foretop and the maintop are provided with double leads to the director. This is due to their exposed position. The extra leads provide a stand-by in case one circuit should be cut.

807. Plate I shows also the wiring in the turret for dotter gear, sub-caliber, and other drill purposes. For simplicity and clarity these circuits have been omitted from the drawing of each turret. No special description of this material is required, since the diagram indicates clearly the various connections.

808. The firing circuit for broadside guns, together with the lighting circuit, is shown in Fig. 801, which represents a 5-inch, 51-caliber gun and mount with firing attachments.

In order better to follow the various leads, a diagrammatic layout of the circuit is shown below the mount. For simplicity the switching arrangements of the interior-communication and the secondary-battery switchboards have been omitted from the diagrammatic sketch. Plate I shows the connections on the fire-control switchboard for the lead to the primary windings of the secondary-battery transformers. It will be seen that current for firing may be taken either from the secondary winding of the transformer or, in case of failure of the motor generator, from a local battery, the transfer switch being thrown as desired. From this switch, the path of the current leads to the pointer's firing key, then to the breech of the gun where a break in the circuit occurs in the firing lock until the breech is fully closed and locked, and thence through the primer bridge and primer wall to ground. The other end of the circuit is shown grounded at the transformer and battery.

809. Branching from the lead from battery is shown the lighting circuit, which serves to illuminate the cross wires in the pointer's and trainer's telescopes as well as the sight scales and the training indicator in the base of the gun mount. It is apparent from the diagram that current for lighting is taken only from the battery. The lamps, which are small and of low voltage, are grounded on one side in order to complete the circuit back to the grounded battery terminal.

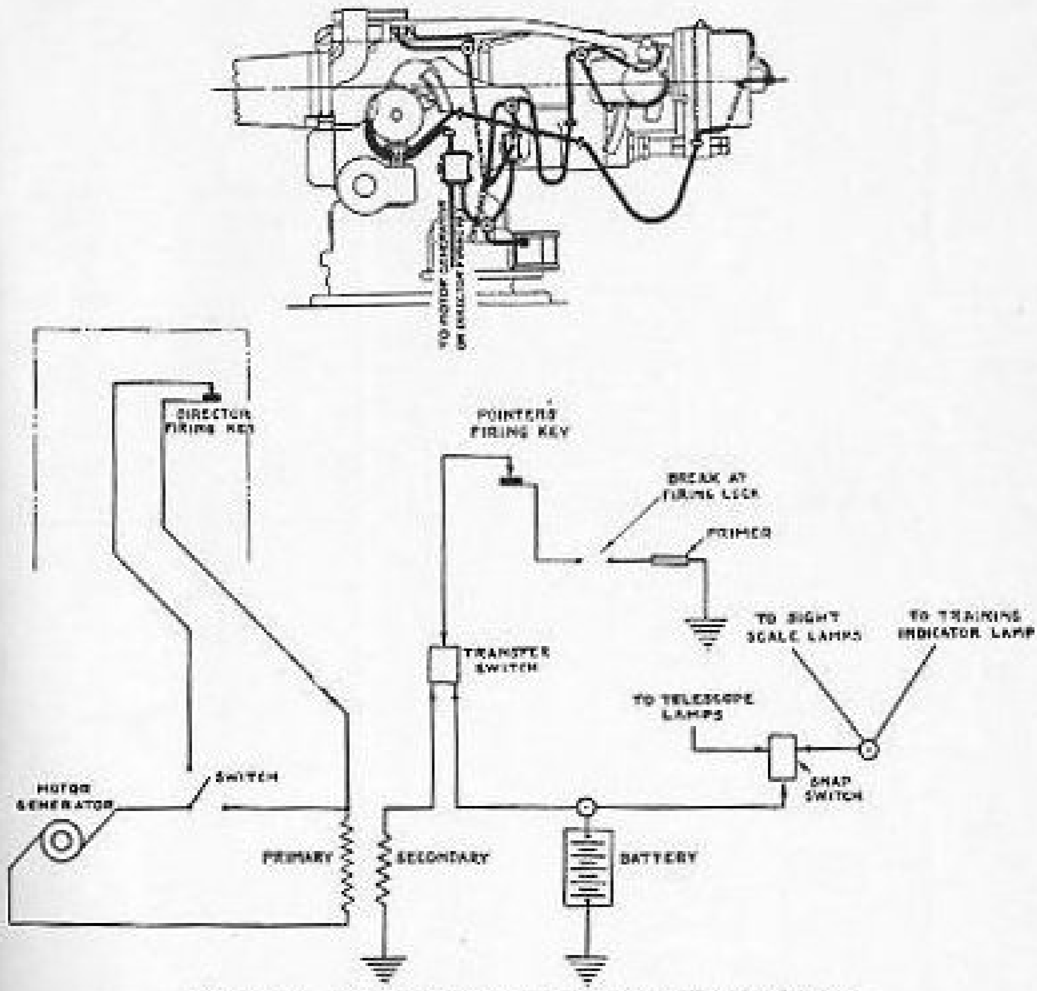


FIG. 801.—FIRING CIRCUIT FOR BROADSIDE GUNS.

810. For director firing of broadside guns, additional leads extend to the director station. There the director is located, provided with a key for firing all guns of a group or broadside. These leads are indicated for convenience in Fig. 801 which shows the firing circuit of one gun only. Actually the complete wiring diagram would resemble somewhat the diagram for turret guns shown on Plate I, where one director can be cut in to fire a number of guns.

Referring to Fig. 801, by closing *downward* the switch shown in the lead from the motor generator, the director is cut out, and current is provided at the gun for "pointer fire." Closing the switch *upward* cuts in the director and puts the circuit in readiness for "director fire." When the latter method of firing is used it, of course, becomes necessary to close the pointer's firing key at the gun and maintain it in that position when the gun is in all respects ready to fire, so that the only break in the circuit will be at the director firing key.

811. In all electric firing chief dependence is placed on the motor generator. The battery is used as a stand-by source of current in case of failure in the motor-generator line. For director fire it is apparent that the battery cannot be utilized at all, since its use is confined solely to the gun or turret where it is located, whereas director fire involves the firing of several guns in salvo, all from the same source of current.

812. Firing keys.—In the discussion of firing circuits above, reference has been made to the pointer's firing key, and to the director firing key.

Figure 1, Plate II, shows the form of firing handle formerly used on two-hand drive wheels, such as were provided for 5-inch, 51-caliber guns. The firing handle is simply a push button carrying on its lower end a metal bridge to close the gap between the insulated firing circuit terminals. In its normal position, the metal bridge is held clear of the terminals by means of the spiral spring shown. Pressing the push button serves to compress this spring and bring the metal bridge into contact with the terminals. It will be noted that the mounting of the metal bridge at the bottom of the push button is such as will allow the bridge to adjust its position to accommodate itself for unequal lengths of the terminals of the firing circuit. This type of key has been displaced by the Mark XVI firing key, but it may be occasionally encountered in service.

Figure 2, Plate II, shows the handwheel grip firing key now in general use for main, broadside, and anti-aircraft batteries. The same key is adapted to the form of the pistol grip for use on the directors. When the trigger is squeezed, the metal bridge is forced down by means of the lever system shown, thus closing the gap between the insulated firing circuit terminals. When pressure on the trigger is released, the metal bridge is thrown out of contact with the terminals and the circuit broken by action of the two springs X and Z.

813. Care of electric firing attachments.—All batteries, firing circuits, and firing locks should be frequently tested. Batteries are tested for voltage and specific gravity of the electrolyte. Firing circuits are tested for resistances from the switchboard to the grounded leg of the primary winding of the transformer (both direct and via the directors), from the grounded leg of the secondary of the transformer to the firing locks, and from the binding posts of the latter to the firing pin points. On all tests on open circuit, the resistances should not be less than one megohm. On closed circuit, they should not exceed one ohm. Due to the action of grease the insulation material of firing locks has a short life and requires frequent renewal. The insulation, if possible, should be kept free of grease.

It is of the utmost importance to keep firing locks and firing attachments in efficient condition. The failure of the firing circuit of a gun impairs, to a great extent, the offensive power of the ship. The faults most frequently found are broken wires and grease or other foreign matter in the connections. Plugs should be well secured to prevent them from being jarred loose by gunfire. Wiring should be properly covered with insulating material to prevent the possibility of short circuits. Electric primer failures are generally due to poor contacts or poor insulation in the firing locks. The primer seats and primers especially should be kept clean and free of grease. The surest test of electric firing circuits is the firing of primers.

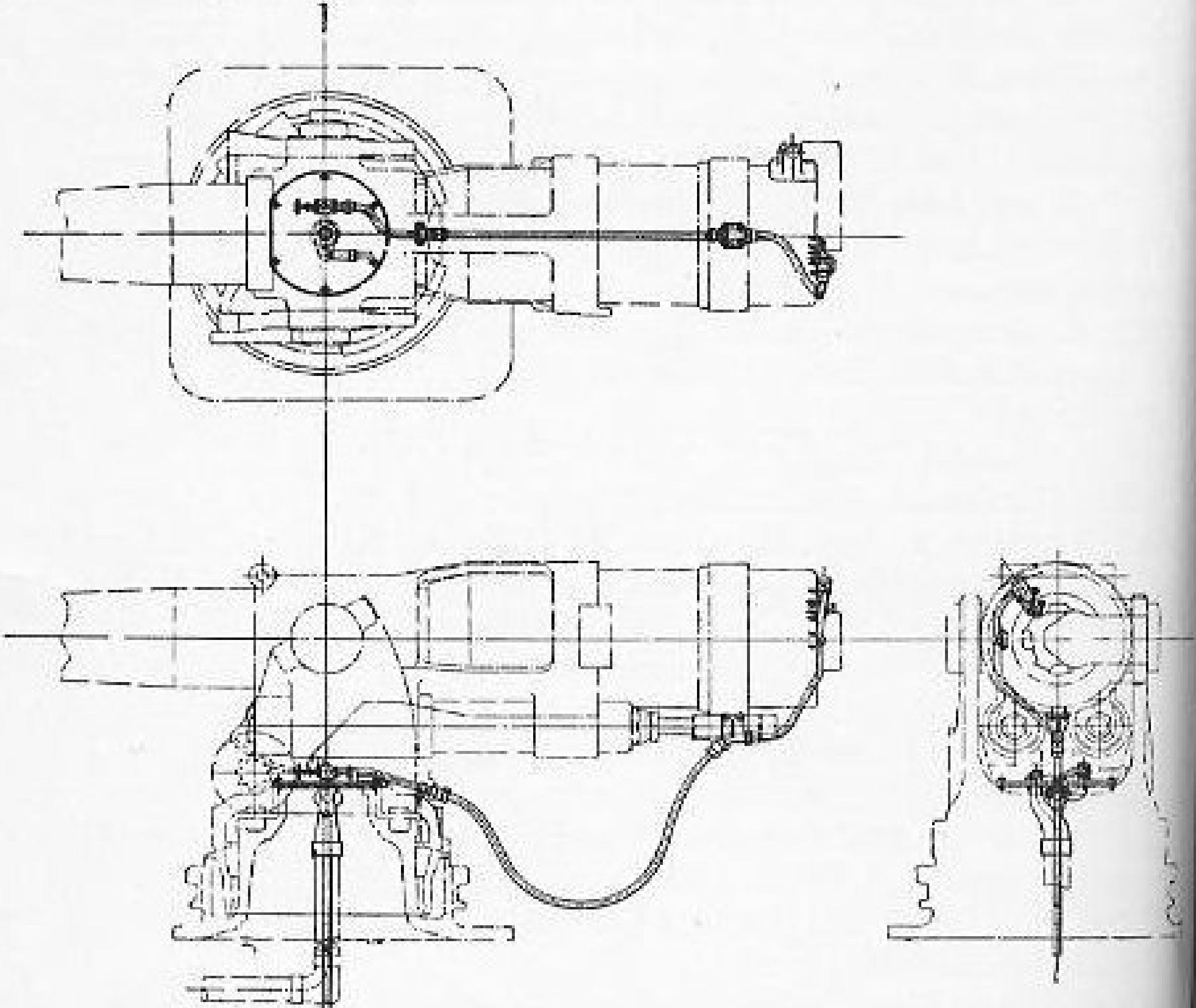
GAS-EXPELLING APPARATUS.

814. Flarebacks.—The smokeless powder used in the United States Navy leaves in the bore, after firing, an inflammable gas (carbon monoxide) which sometimes becomes ignited on opening the breech plug, causing what is called a flareback. With bag guns this flareback is very dangerous, since the powder charges may be ignited by it in loading, as happened with disastrous results in the after 12-inch turret of the U.S.S. *Missouri* on April 13, 1904.

815. Gas-expelling device.—To guard against flarebacks, an air blast device is now fitted to all bag guns to blow out through the muzzle the gases remaining in the gun after firing. Plate III shows the device fitted to a 5-inch gun, and Plate IV shows a similar one for 14-inch and 16-inch turret guns.

Referring to Plate III, air at about 150 pounds pressure is brought from an *accumulator* through a brass pipe extending up through the mount. A swivel joint in the lower part of the mount (turret) permits the gun (turret) to be trained without rupturing the air line. Directly beneath the gun is a stop valve by means of which the air pressure can be placed on the gun or shut off as desired. Beyond this valve extends a section of flexible metal hose, of length sufficient to allow for the recoil of the gun. The after end of this hose is coupled to a section of copper piping, which in turn leads to the *gas-ejector valve* located on the breech of the gun. Figure 802 shows this valve. Instead of a bight of flexible tubing, broadside guns are frequently fitted with a tele-

CHAPTER VIII, PLATE III.



GAS EJECTOR FOR BROADSIDE MOUNT.

scoping air line, the pipe section attached to the gun telescoping in and out of the pipe section attached to the slide.

816. Operation.—The operation of the gas-ejector valve can be readily understood from the figure. The valve seats downward, being held against its seat by a spiral spring and by the air pressure in the line. Against the bottom of the valve rests one end of the valve plunger, the other end being in contact with the cam-shaped valve trigger. There is a cam plate on the breech plug, so located that the first motion of rotation of the plug in opening brings this plate against the valve trigger, revolving it beyond the dead center and thus pushing the valve

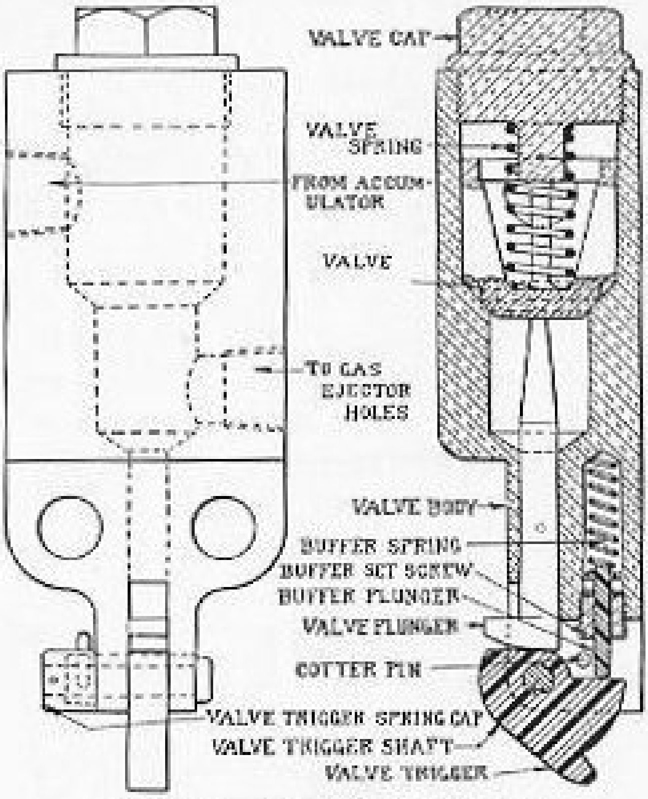


FIG. 802.—GAS-EJECTOR VALVE.

plunger upward and unseating the valve and leaving it open until closed by hand. This allows the air to rush past the valve to an annular passage cut between the screw-box liner and the jacket, and thence through equally spaced holes leading to the screw box. As soon, therefore, as the breech plug has been withdrawn sufficiently to unseat the gas check, air is forced through the muzzle of the gun, taking with it the gases lingering in the bore. When the breech is fully opened, and the bore is seen to be clear, a member of the gun crew touches a lever on the valve-trigger shaft, which trips the valve and closes it, thus shutting off the air. During firing, air pressure is kept turned on and maintained on the piping up to the gas-ejector valve.

817. Below the armored decks, automatic closing valves are installed in the air lines to the guns mounted in exposed parts of the ship, such as the upper decks. Should these unprotected (by armor) lines be pierced, the resulting escape of air would diminish quickly the pressure in the accumulators. These valves are so adjusted that the fall of pressure due to opening the breech of a gun does not affect them, but an abnormal fall, such as that caused by a rupture of the air line, causes them to close immediately.

818. The gas-ejector system for turret guns, shown on Plate IV, is similar to that described for broadside guns. Air from the accumulators is led to a point overhead near the roof of the turret, where an athwartship pipe distributes it to the guns. Each gun is fitted with a telescoping air line, extending to the breech where the gas-ejector valve is located. For both broadside and turret guns, the original design for maintaining the integrity of the air line during recoil was to connect the terminal of the air system on the breech with that on the slide by means of a section of flexible metal hose. The later and more usual practice for both broadside and turret guns is to fit telescoping air lines in place of the flexible metal hose. Whichever method is used between gun and slide to provide the necessary flexibility during recoil, it is also necessary to install a flexible metal hose or a flexible ball and socket coupling in the air line between the carriage and the slide to provide the required flexibility during elevation.

The gas ejector system is shown attached to the gun in Plates XII–XX, Chapter VII.

819. Air pressure in turrets.—It is customary to close the openings to the turret and maintain the turret chamber under an air pressure above atmospheric from the turret's ventilating system during firing. This is done as an auxiliary to the gas-expelling device, but never replaces it.