CHAPTER IX.

NAVAL GUN MOUNTS.

Section I.—General.

901. The mount is the entire system interposed between the structure of the ship and the gun.

The principal functions that a mount must perform are: (1) support the gun in such a position that it can readily be used, (2) provide for elevation and train, (3) provide for recoil and counter-recoil.

The principal requirements of a modern gun mount are: (1) Safety under all conditions, which necessitates proper design and requisite strength of materials, so that the mount will perform its functions with the least danger to the personnel operating it; (2) rapidity, ease, and smoothness of operation; (3) facility of adjustment; (4) simplicity and reliability; (5) gradual absorption of the shock of recoil and its distribution over a sufficient area of the ship to prevent injury to the ship's structure; (6) accurate and reliable control of power, either hand or motor.

902. Shipboard installations include many types of mounts, some of which are: (1) turret mounts, in which the guns are housed in an armored structure capable of rotation, the guns elevating independently of the structure.

(2) Pedestal mounts, in which a *carriage* rotates on a stationary *pedestal* or stand bolted to the ship's structure. Broadside and anti-aircraft mounts are usually of this type, as well as most other 3", 4", 5" and 6" mounts.

(3) Rail sockets, for use in mounting light guns at the ship's rail.

(4) Military top mounts, for use in mounting light guns in the tops.

Mounts sometimes used by the Navy elsewhere than on board ship are:

(1) Boat mounts, for use of one-pounder or other guns in the ships' boats.

(2) Field mounts, for use of field guns ashore with a landing force.

(3) Railway mounts, for use of large guns on railway cars ashore.

903. For purposes of introduction, a brief idea is here given as to the relation which the component parts of a representative shipboard mount bear to one another:

(1) The *slide* is a cylindrical casting within which the gun slides axially in recoil and counter-recoil. In elevation, the slide with its contained gun, operates independently of the rest of the mount. From either side of the slide, in a horizontal plane, project the trunnions, which rest in suitable bearings in

(2) The *carriage*. This is the part which rotates in train, carrying with it the slide and gun. In a turret mount the *deck lugs* and *gun girders* are together analogous to the carriage. The carriage rests upon and rotates on a roller path on a stationary member called

(3) The *stand*. This is bolted to the ship's structure. In a turret it is a heavy assemblage of girders built into the ship's structure.

904. Modern naval gun mountings are designed to have arcs of elevation approximately as follows: 8-inch mounts on heavy cruisers 40°, turret mounts on battleships of the *California* and *Maryland* classes 30°; turrets on earlier classes of battleships were designed for 15° elevation, but on the *Oklahoma*, *Pennsylvania*, and *New Mexico* classes, this elevation was, on modernization, increased to 30°; broadside guns, 20° elevation, and anti-aircraft guns 90° elevation. Turret guns have 5° depression and broadside and anti-aircraft guns have 10° depression. The train is usually limited only by the ship's structure and the location of the mount in the ship.

905. The metals used in naval gun mounts are cast steel, forged steel, and special bronzes. Cast iron is not used. Cast steel is used for the principal strength members, such as the carriage, slide, and stand, and also for the larger castings of the elevating and training gear. Bronze is used for all plain bearings and bushings where moving parts are of steel. Bronze is also used for the smaller castings, where the use of cast steel is impracticable, on account of the difficulties of casting, and for all metal parts coming in contact with the powder.

906. Stresses in deck structure and mount due to firing.—The bolts securing the mount to the deck and the deck structure itself must be capable of withstanding the weight of the gun and mount and the turning moment produced by the reaction of the slide trunnions in the trunnion seats of the carriage.

The forces acting on the deck structure and mount when the gun is fired are shown in Fig. 901.

R_r is the force of resistance to recoil exerted by the recoil cylinder. R_1 is the force tending to push the breech side of the stand down into the deck. R_2 is the force tending to tear the bolts at the muzzle side of the stand out of the deck. H_s is the shearing force, tending to shear off the bolts in a horizontal plane. W is the weight of the entire mount, including the gun. These forces, R_1, R_2, and H_s may be determined as follows:

For equilibrium, the summation of all horizontal forces is equal to zero, or

$$R_r - H_s = 0. \tag{1}$$

Taking moments about R_1 we get

$$R_r h - Wm - R_2 l = 0, \tag{2}$$

or

$$R_2 = \frac{R_r h - Wm}{l}. \tag{3}$$

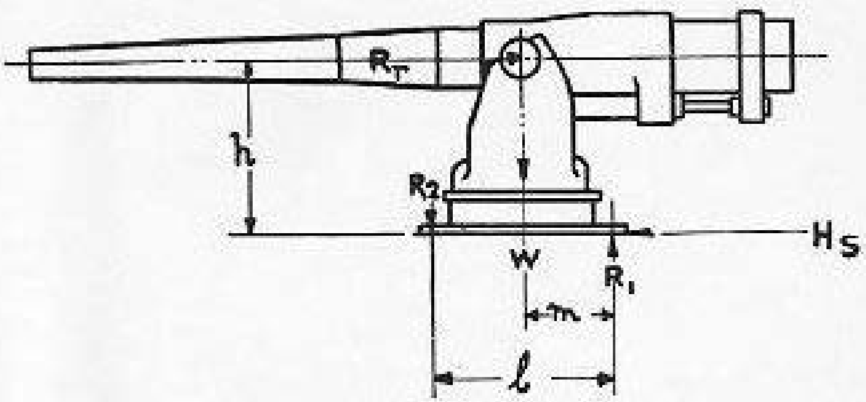


FIG. 901.

Taking moments about R_2, we get

$$R_r h + W(l - m) - R_1 l = 0 \tag{4}$$

or

$$R_1 = \frac{R_r h + W(l - m)}{l} \tag{5}$$

R_1 and R_2 are expressed in terms of R_r, the other quantities being known. R_r can be found by methods outlined in Art. 1004.

Equations (3) and (5) give the value of the reactions at the beginning of recoil. The value of the reactions with the gun at extreme recoil may be determined by making the proper allowance for the movement of the weight of the recoiling parts through the distance of recoil.

When the gun is elevated the force R_r can be resolved into a vertical component acting downward with the weight of the gun and a horizontal component acting similarly to R_r above, but of less magnitude.

The computations above can be used in designing the strength of the mount, and the strength of the deck structure on which the mount is placed.

By taking the resultant of (1) R_r acting parallel to the axis of the gun and (2) the weight of the parts supported by the trunnions, acting vertically downward, the pressure on the trunnions during firing may be computed and the necessary strength of those parts then determined.

907. In the following pages descriptions of typical broadside, anti-aircraft, and turret gun mounts are given. These mounts are the ones most often encountered aboard ship. Further information as to special types of mounts is given in the chapters on naval landing guns and machine guns. The subjects of *sights*, and of *recoil and counter-recoil mechanisms* are not treated in detail in this chapter, being sufficiently covered in the chapters specially devoted to those subjects.

Section II.—A Broadside Gun Mount.

908. The following description of a typical broadside gun mount is to be studied with frequent reference to Plates I, II, III, and IV. The plates being in great detail, the description is intended to supplement a study of the plates, rather than the reverse.

The slide (Plate IV) is a cylindrical steel casting fitted with bronze front and rear liners in which the gun slides in recoil and counter-recoil. In the slide liners is cut a keyway into which the gun is keyed to prevent rotation. Cast solidly with the slide are two trunnions, with projecting bosses. The trunnions rest in bearings in the carriage arms and thereby support the slide and gun in the carriage. At the lower forward end of the slide is cast a pad to which is attached the adjustable elevating arc. The slide may be moved in elevation in a vertical plane about the trunnion axis, the gun moving with it in elevation. Beneath the slide and cast integrally with it are circular brackets that support the two recoil and counter-recoil cylinders. In the type of mount illustrated the recoil and counter-recoil elements are both contained in each of the two cylinders. Recoil is checked by the combined action of the recoil piston and liquid and of the counter-recoil springs, the gun being returned to battery by the energy stored in the compressed springs. Lugs are provided on the slide for the sights and other accessory apparatus. Pressure grease fittings on the slide force grease into grooves cut in the inner surfaces of the slide liners. In train the slide (and gun) move with the carriage.

909. The carriage (Plate III) consists essentially of a hollow cylindrical base with two upward-projecting arms cast integrally with it. These terminate in seats for the trunnion bearings and frictionless bearings. The trunnions are retained in their bearings by means of the cap squares. Elevation of the gun is accomplished through a two-hand drive mounted on the left-hand side of the carriage and functioning through bevel gears and a worm to the elevating pinion, which meshes with the elevating arc attached to the slide. Brackets are bolted to the side of the carriage to support this mechanism. The arc of elevation is from 10° below horizontal to 20° above. The gun carriage is trained by means of a two-hand mechanism carried on brackets on the right-hand carriage arm, operating through bevel gears to a worm meshing with the training circle, which is a worm rack secured to the stand. Platforms for the pointer and trainer are secured to the base of the carriage. A bracket for supporting the battery box may be secured to the carriage base. The arms of the carriage are now made with extending shoulders to which may be bolted shields for the protection of the gun pointers.

910. The stand (Plate II) projects into the hollow base of the carriage, where it is guided by upper and lower bushings bearing against the bearings within the carriage base. The weight of the carriage is borne by rollers or balls which turn on hardened steel roller paths, housed in the carriage base and stand. A flange projecting upward from the base of the stand supports the training circle and the azimuth indicator arc. Water-tight handholes on opposite sides of the carriage base make the bearings readily accessible for inspection and give access to the holding-down clips. Holding-down clips are heavy metal lugs bolted to the stand and projecting over a flange of the carriage or, vice versa, for the purpose of holding the carriage on the stand when firing.

911. Frictionless bearings.—The upper surfaces of the carriage cheeks are machined to provide slots into which fit *cap squares* secured with cap-square bolts (see Fig. 902). Lost motion resulting from wearing of the trunnion bushings or seats is eliminated by tapered cap-square shoes or adjusting wedges fitting into slots in the cap squares and bearing against the trunnion bushing. These wedge-shaped shoes are forced into the slots by means of cap-square adjusting nuts or knobs turning on cap-square studs and bearing against shoulders on the outer ends of the cap-square shoes.

The knife-edges, upon which the oscillating parts rock when the gun is elevated or depressed, are housed within pockets cut in the extending lugs on the outer ends of the trunnion bosses. Each knife-edge slides in the lower end of the recess of the trunnion boss and is adjusted and secured in position by an adjusting screw which threads through the extending lug and is maintained in the desired position by a locking clamp secured by a locking-clamp bolt. The dead weight of the oscillating parts is transferred from the knife-edge to a knife-edge bearing held by a drive fit in a slot in the upper surface of the spring bar. The spring bar is supported on two alloy-steel rollers. Curved recesses at each end of the spring bar serve as upper roller

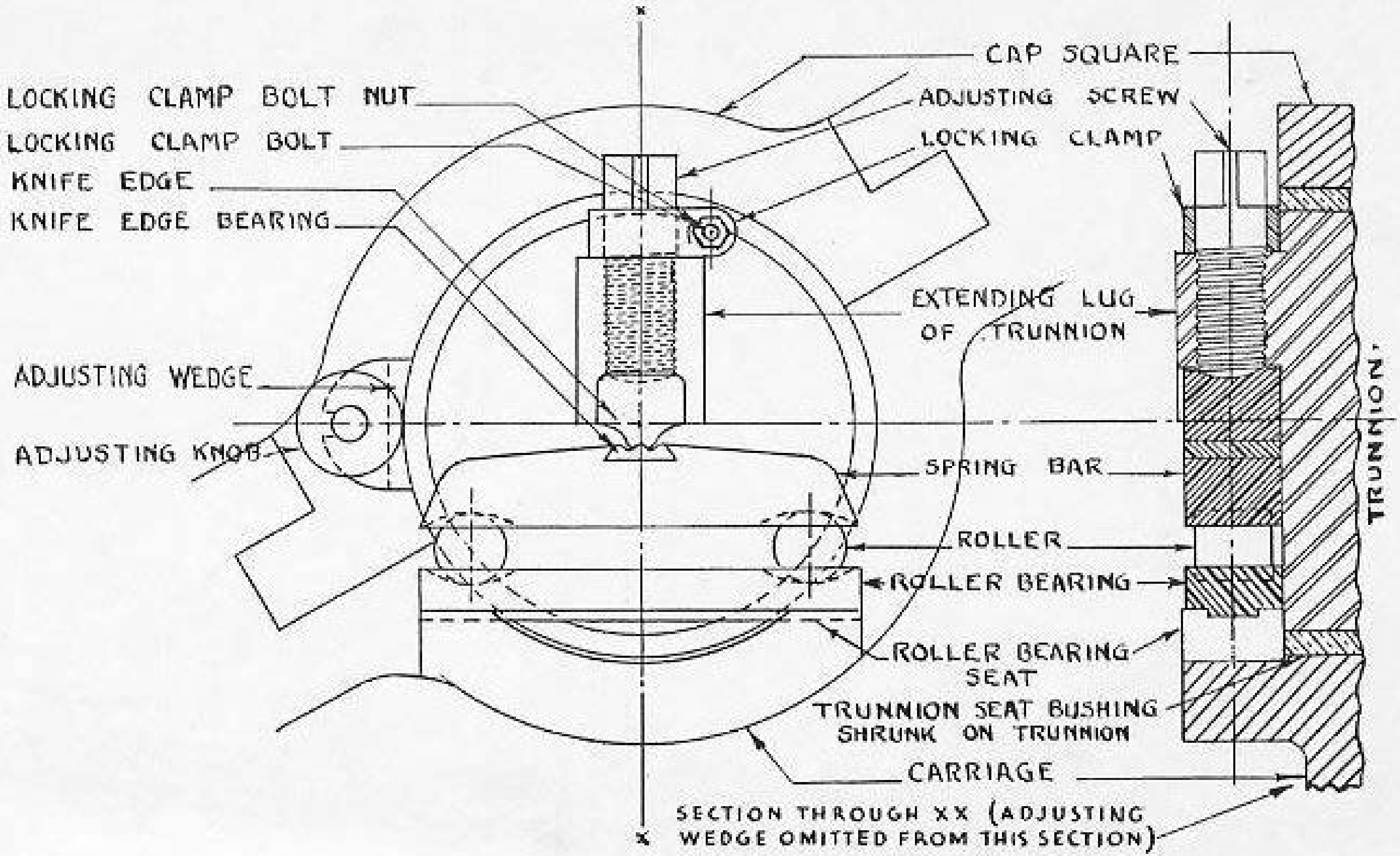


Fig. 902.—Details of Frictionless Trunnion Bearing.

paths; similar recesses in the roller bearing function as lower roller paths. The roller bearing rests upon a projecting shoulder cast on the carriage arm below the trunnion seat. When the gun is at rest, the weight of the oscillating parts is carried by these frictionless bearings which transfer the weight directly to the carriage arms; but when the pressure on these bearings is increased by firing, the spring bars deflect and allow the trunnions to bear against the trunnion seats, providing ample support for the gun and slide. The frictionless bearings are protected by trunnion bearing covers bolted to the carriage arms.

912. Adjustment of frictionless bearings.—If the gun and slide are not properly and accurately balanced on the trunnions, the elevating gear will operate with difficulty, especially in one direction. If the elevating gear for a properly balanced gun does not operate properly, the cause will normally be found due to the improper adjustment of the frictionless bearings. If the adjusting screws are not adjusted so as to transfer the weight of the gun and slide to the spring bars, or if they are so adjusted that the trunnions are forced against the upper surfaces of their bearings, then the frictionless bearings will not function properly and elevation and depression will be difficult. These discrepancies may occur in either one or both bearings. Accurate adjustment of these bearings is easily accomplished by turning the adjusting screws until thin feelers may be inserted between the trunnions and their bearing surfaces, after which the adjusting nuts may be locked securely with the locking clamps provided.

Section III.—Anti-aircraft Mounts.

913. General.—In addition to small-caliber machine guns, our Navy now has the 3-inch 50-caliber, the 5-inch 25-caliber, and the 5-inch 38-caliber semi-automatic guns mounted on board ship for anti-aircraft batteries.

Anti-aircraft guns must be mounted on weather decks where they can fire at maximum elevation, have minimum interference from the ship's structure, and be reasonably clear of the blast of other guns.

The following are desirable features for anti-aircraft gun mounts:

(1) High elevation.

(2) Low trunnion height.

(3) Ease and rapidity of elevation and training.

(4) Rapidity of loading and firing.

Obviously some of these features can be obtained only at the expense of others.

To utilize economically on board ship the available gun positions, the tonnage, and the personnel, it is necessary that all anti-aircraft guns also be efficient guns for firing at surface targets. The 5-inch 38-caliber guns for recent construction are two-purpose guns, *i.e.*, for use against surface and aircraft targets.

914. Plates V and VI show the 3-inch, 50-caliber anti-aircraft gun and mount.—As will be noted, the trunnion height is considerable—about 66 inches—and the mount is cut away at the rear to allow for 90° extreme elevation. Located on the upper deck, the gun is capable of training through 360° and, except over small arcs where the masts and stacks may interfere, it can be fired at all angles of train.

The details of the mount are shown in Plates V and VI. It will be seen that the carriage, which forms the greater part of the mount, rests over a low cylindrical stand that is bolted to a foundation plate in the deck. The carriage is supported on the stand by two ball bearings, an inner and an outer ball bearing. These two bearings are designed to

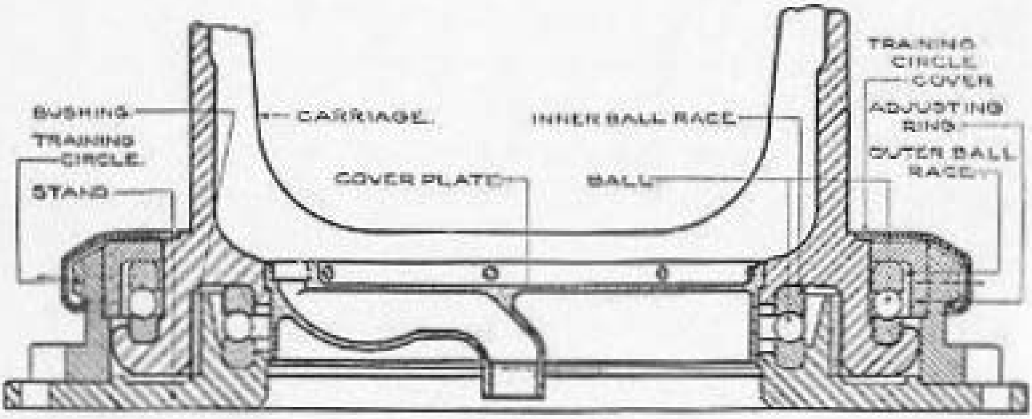
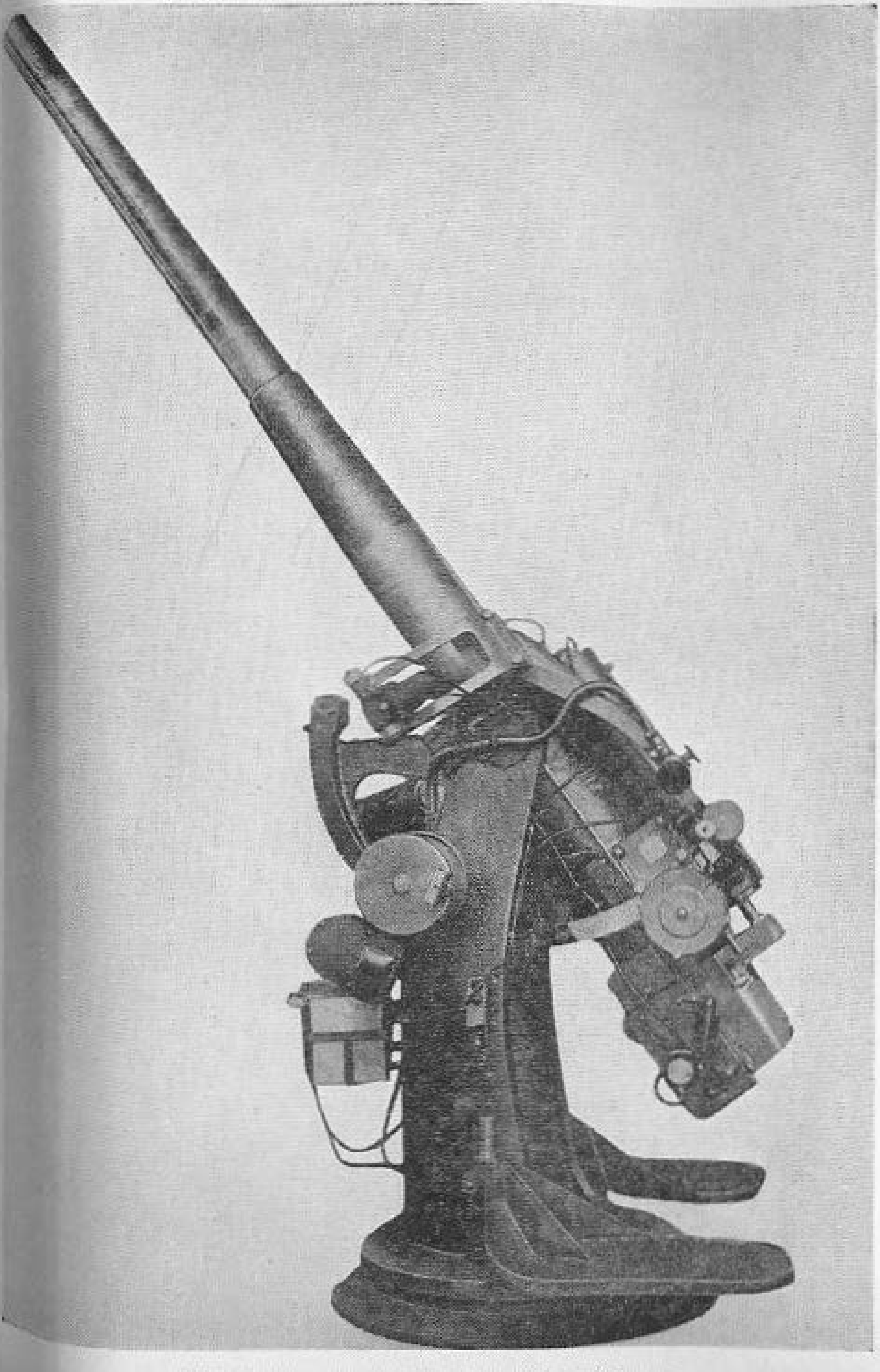


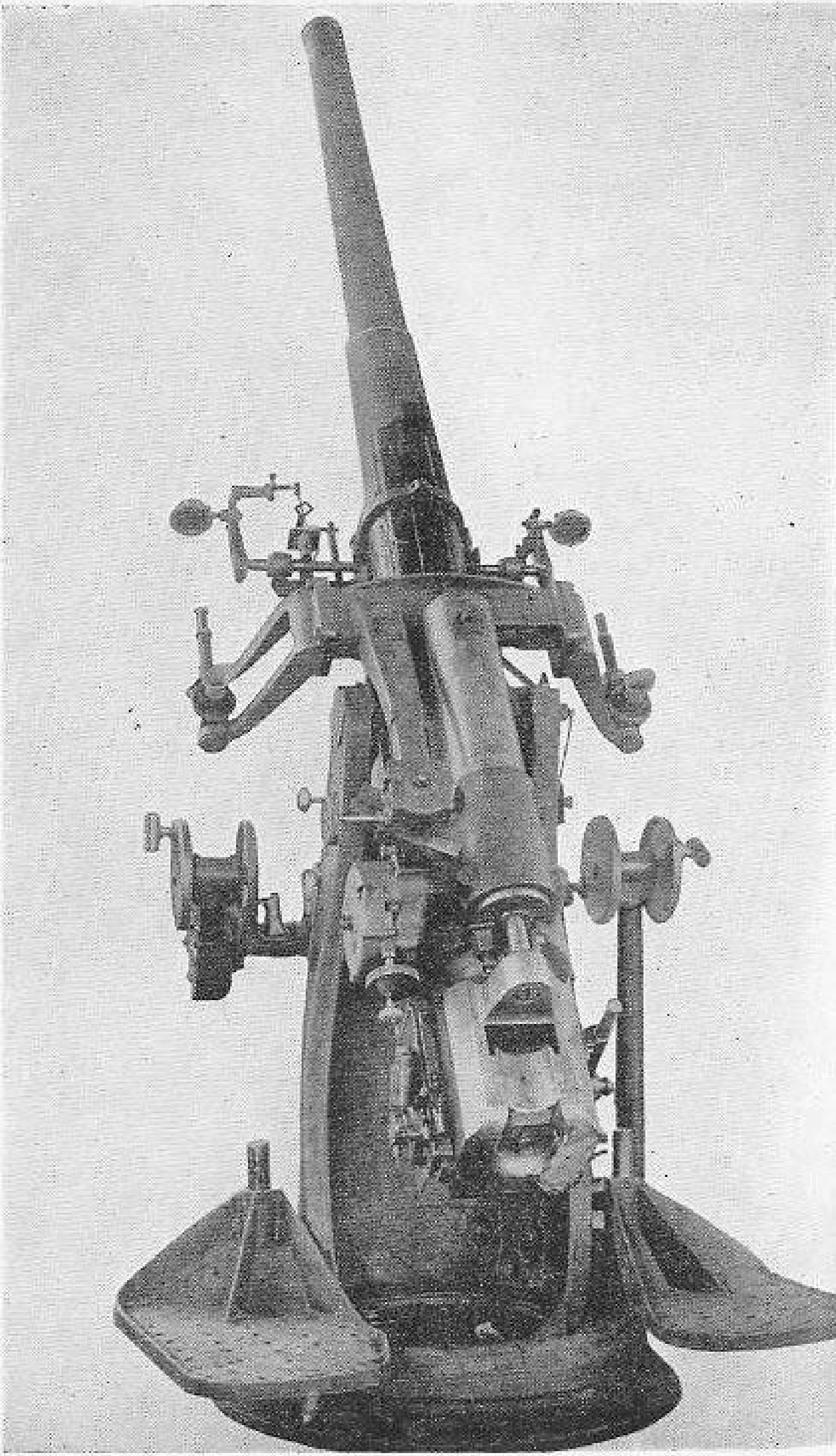
FIG. 903.—THE 3-INCH CARRIAGE, MARK XI, IS SUPPORTED ON TWO BALL BEARINGS AND IS HELD TO THE STAND BY AN ADJUSTING RING.

reduce friction to a minimum. The inner bearing takes the compression load, weight, and vertical downward thrust of recoil when the gun is fired. The outer bearing holds the carriage on the stand and thus takes the tension load due to roll of the ship and to upward thrust of recoil when the gun is fired at low angles of elevation. This is the function of the holding-down clips in the conventional broadside mount. Figure 903 shows the stand and a portion of the carriage, in section, and clearly indicates the details of assembly and the means by which the carriage is retained upon the stand. The bolts for securing the flange of the training circle to the flange of the stand have been omitted in the figure for the sake of clearness.

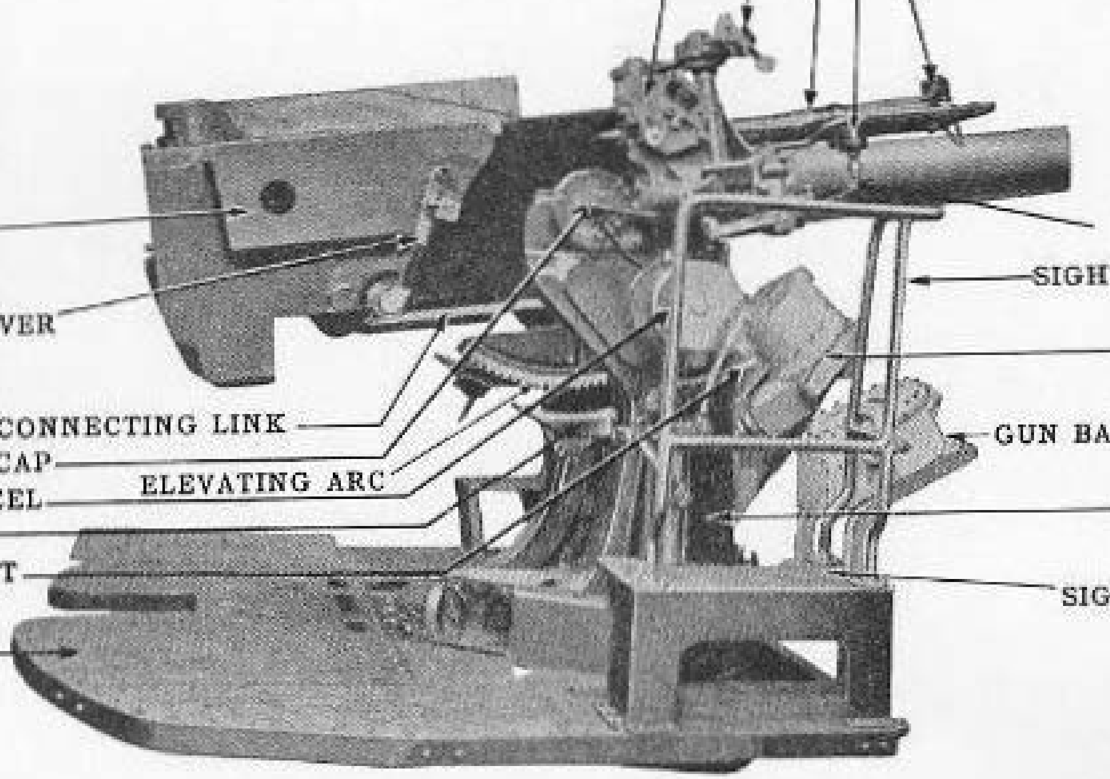
A training worm, meshing with the training circle, is connected by a suitable shaft and gearing with the trainer's two-hand drive shown at the right of the gun.



3-Inch 50-Caliber Anti-Aircraft Gun and Mount.

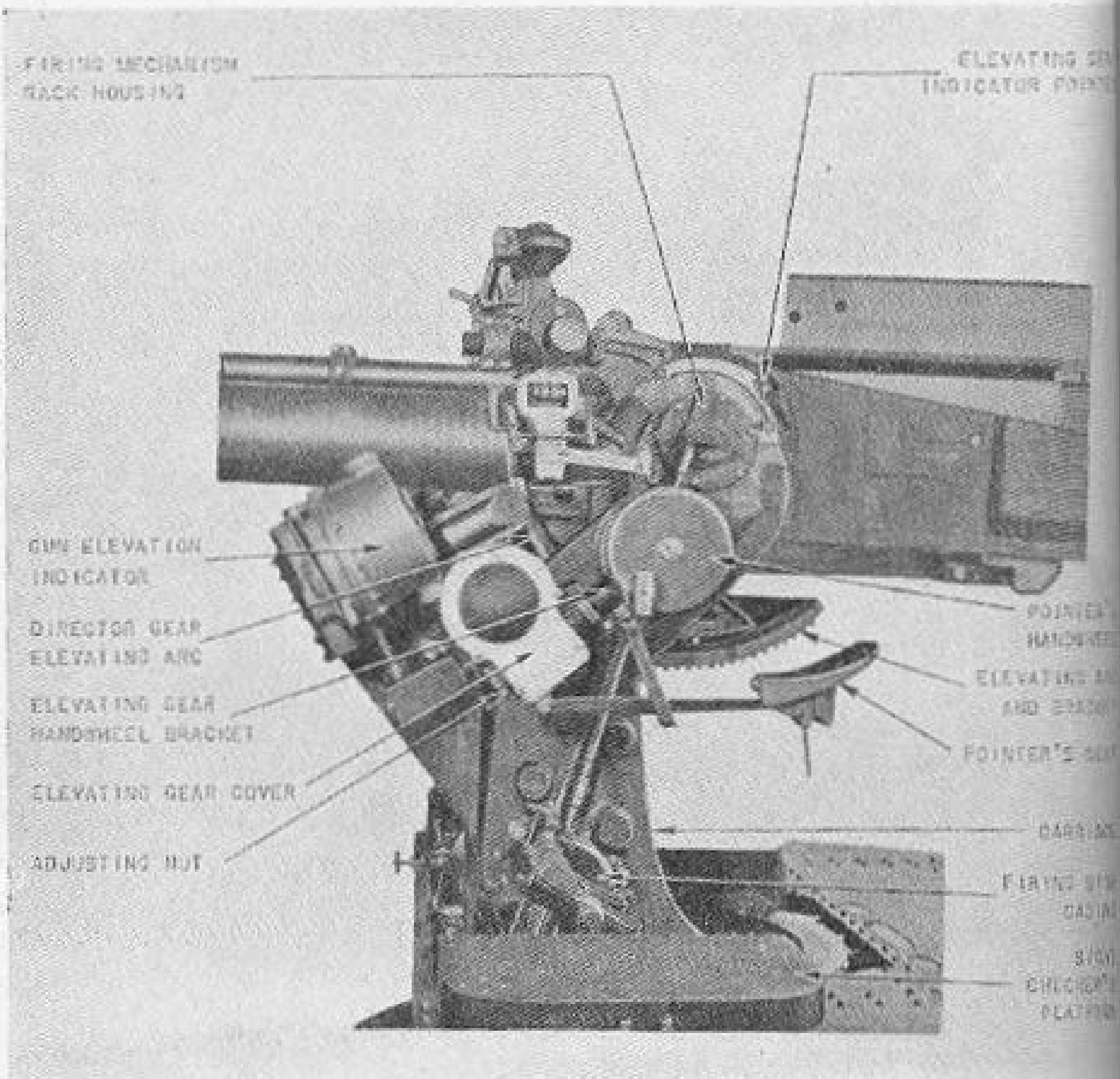


3-Inch 50-Caliber Anti-Aircraft Gun and Mount.



5-INCH ANTI-AIRCRAFT MOUNT, MARK XIX AND MARK XIX, MOD. 1, ASSEMBLY—RIGHT SIDE.

CHAPTER IX, PLATE VIII.



5-INCH ANTI-AIRCRAFT MOUNT, MARK XIX AND MARK XIX, MOD. 1, POINTER'S SIDE. FUZE SETTER NOT SHOWN.

On the left side of the carriage is the pointer's two-hand drive, which actuates a pinion meshing with the elevating arc shown in Plate V.

The training and elevating gears are of the standard broadside mount type.

At the top of the carriage are the trunnion seats in which the trunnions rest. The latter form part of the slide through which the gun slides on recoil and counter-recoil.

915. The 5-inch, 25-caliber anti-aircraft gun was designed and developed by the Navy to fill the need for an anti-aircraft gun of larger caliber with high rate of fire. This gun is semi-automatic and is invariably used as such when firing at aircraft targets. While designed primarily as an anti-aircraft gun, it may also be used for firing at surface targets. The following brief description is intended to supplement a study of Plates VII and VIII.

The slide is a large box-shaped steel housing with a rear plate bolted on its after end.

(a) The slide houses the breech of the gun and guides the gun during recoil and counter-recoil.

(b) The forward ends of the two recoil piston rods are secured to the forward end of the slide. The recoil system is of the hydraulic type.

(c) The after end of the counter-recoil plunger is secured to the after end of the slide (rear plate). The counter-recoil system is of the hydraulic-pneumatic type.

(d) The trunnions are on the outboard sides of the slide, and, through them, the weight of the gun and the force of recoil are delivered to the carriage.

(e) The elevating arc is secured to the slide directly under the forward part.

(f) The breech mechanism hand-operating lever is mounted on the right side of the slide.

(g) The power rammer is mounted on the right side of the slide and above it.

The carriage is supported on the stand by two ball bearings, an inner and an outer ball bearing. The outer bearing takes the compression load, weight, and vertical downward thrust of recoil when gun is fired. The inner bearing holds the carriage on the stand and thus takes the tension load due to roll of the ship and to upward thrust of recoil when firing gun at low angles of elevation. It is thus seen that the functions performed by the inner and outer bearings of this mount are respectively performed by the outer and inner bearings of the 3-inch, 50-caliber mount illustrated in Fig. 903. The training and elevating gears are of the standard broadside-mount type.

The stand is a low heavy steel casting having a square base. The stand contains the lower ball race for the outer ball bearing and the upper ball race for the inner ball bearing.

The fuze setter is mounted to the left and aft of the breech of the gun on a platform which is attached to the gun carriage.

This gun can be moved rapidly in both elevation and train. The trunnions are equipped with roller bearings which serve both as main trunnion and frictionless trunnion bearings. These bearings are similar to those shown in Plate XIII.

Section IV.—Turret Mounts.

916. General considerations.—The turret installation on each class of ship varies, being a gradual development from type to type. In general, the developments in turret design have progressed from the use of a single gun in a turret, to a maximum of four guns in a turret. It may be accepted that this development is based upon sound principles and follows a corresponding increase in the size of the navies of the principal powers.

From the constructor's point of view, it has been practically demonstrated that the weight of installation per gun is the least for a three-gun turret, and increases in both directions from this number, due to the fact that the space occupied by that portion of the three guns contained inside the turret pan is bounded very nearly by a square, which is the largest rectangle which can be inscribed in a circle of a given size. It is also true that the least weight is required for designs where all guns are carried in one slide, but flexibility is thereby lost.

The primary objects to be accomplished in the design of a turret are accuracy and rapidity of gunfire, and efficiency and reliability of all mechanical features of the turret, combined with the maximum possible protection against damage by the enemy's gunfire. The details of gun and mount should be worked out to eliminate excessive dispersion in the fall of shot, and to avoid any increase in dispersion, caused by any progressive permanent deflection in metal which is strained by the forces resulting from the discharge of the guns. The various machines installed for use in the service of the guns should be designed with a liberal factor of safety to insure continuous operation over an extended period of time, and should be simple in design to facilitate upkeep, and to avoid the necessity of too much mechanical skill and experience on the part of the personnel. Protection is similar to insure against accident and should be the maximum which can be obtained without undue sacrifice of accuracy of gunfire and mechanical reliability.

917. Historical.—The earlier turret designs in the U. S. Navy were two-gun turrets with what is known as a *single-stage hoist.* That is, the powder and shell were taken from the magazines and shell rooms and placed in an open car for each gun, which was hoisted to the breech of the gun, traveling up and down in an open well. The guns were loaded, using rammers fixed in the rear of the turret so that the guns had to be brought to the horizontal position to be loaded.

When modern target practice was introduced in the Navy, about 1903, there occurred several very serious turret accidents, due to this open type of construction; and all turrets were modified by fitting them with automatic shutters, to seal the handling room from the turret chamber, except at the instant the car was passing the shutter. This was not entirely satisfactory, and new designs were made on the two-stage hoist principle; that is, the powder and shell were brought up from the handling room to an intermediate compartment in one set of hoists, and there transferred to another set which carried them to the guns. This permitted the introduction of a more positive flame seal between the turret chamber and the magazines as this intermediate compartment was fitted with interlocks which did not permit doors to be open at the same time to both turret and handling room. Variable loading positions were also provided by putting the rammer on an arm from the gun slide, thus permitting the gun to be loaded at any angle of elevation.

In an effort to secure an increased rate of fire and increased reliability of turret gear, many turrets were converted to "hand loading." The ammunition cars were removed and tube hoists, power-whip operated, were installed for hoisting shell. The powder was passed up by hand by men standing on fixed platforms at different levels. The telescopic rammers then in use were taken out and hand rammers used. Hand loading required larger turret crews and required a larger amount of strenuous work by these crews.

918. Modern types.—Modern target practice created the demand for, and the Bureau of Ordnance designed, manufactured, and installed much faster and more reliable turret machinery that displaced hand loading for turret guns. All powder cars now in use are of the flame-proof type. The pusher type of shell hoist has practically displaced the whip type. The chain type of rammer has displaced the telescopic type. Turret machinery is, in general, both fast and rugged. In the development of turret powder hoists, the maximum number of flame-proof compartments, fitted with interlocking flame seals, compatible with an adequate ammunition supply have been installed between the magazines and the guns.

A 14-INCH, 3-GUN TURRET.

The description which follows applies generally to all modern turrets, 8-inch to 16-inch inclusive.

919. Major structural subdivisions (See Plates IX and X).

(a) **The barbette.**—This is a cylinder of heavy armor surrounding the turret structure from the lowest protective deck up to the armored turret proper. The barbette is stationary and is not joined to the rest of the turret.

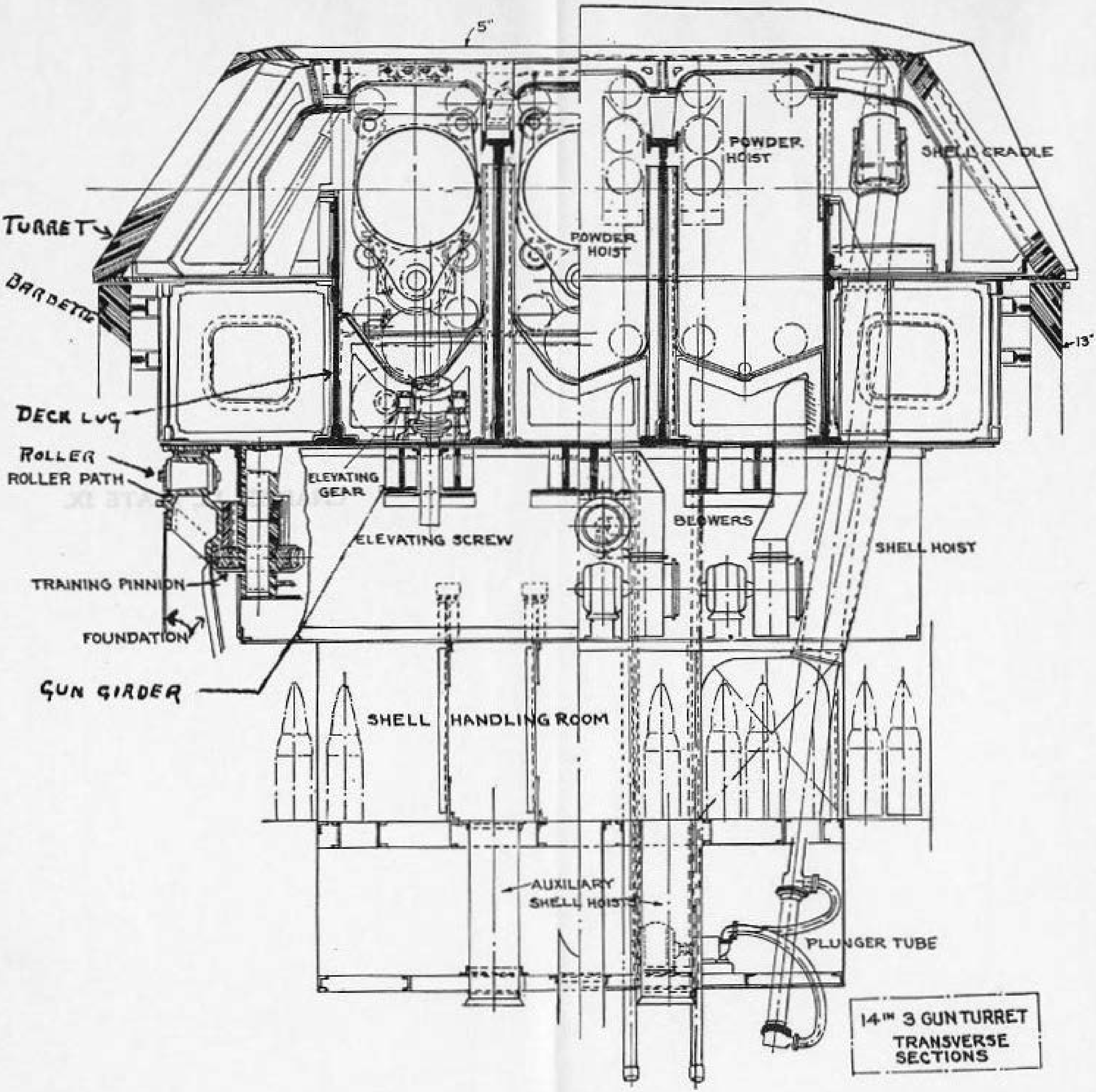
(b) **The turret foundation.**—This is a heavy structure of girders and beams built into the structure of the ship. It is cylindrical in shape and extends upward close to the inner surface of the barbette, to a point near the top of the barbette. At its top it supports the circular roller path, carrying the rollers on which the entire revolving portion of the turret rotates.

(c) **The turret proper.**—This is the heavily armored box-like structure from which the guns protrude, and which may be seen to rotate from the outside. The circular barbette armor extends from a point just below the armor secured to the revolving portion of the turret, down to the lowest protective deck of the ship, so that the turret roof, front, and side plates, together with the barbette and protective deck armor afford protection to the guns and machinery within the turret and to the magazines beneath the turret.

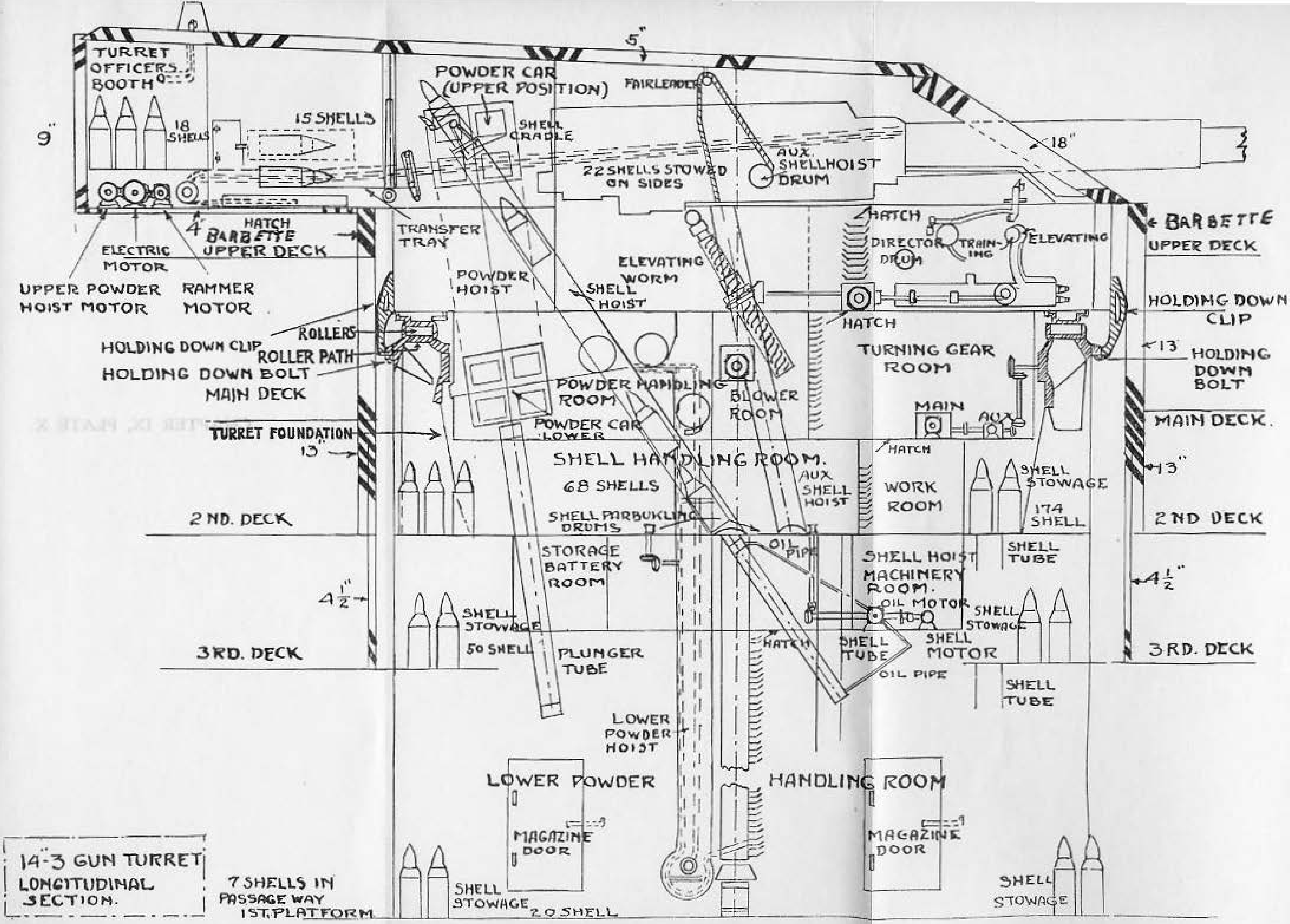
(d) **The revolving turret structure.**—This is all of the inner structure forming one assemblage with the turret proper, and extending downward within the turret foundation to the deck of the lower powder handling room. The weight of this structure and the turret proper rest and rotate on the rollers on the roller path. All the operating compartments, machinery, and other gear are in the turret revolving structure and turret proper.

920. Interior subdivisions.—(a) **The turret chamber** is that part of the turret surrounding the gun positions. It includes the gun chambers and the gun pits. The gun breeches are in the gun chambers, as well as the delivery ends of the shell hoists and powder supply. It is here that the guns are loaded.

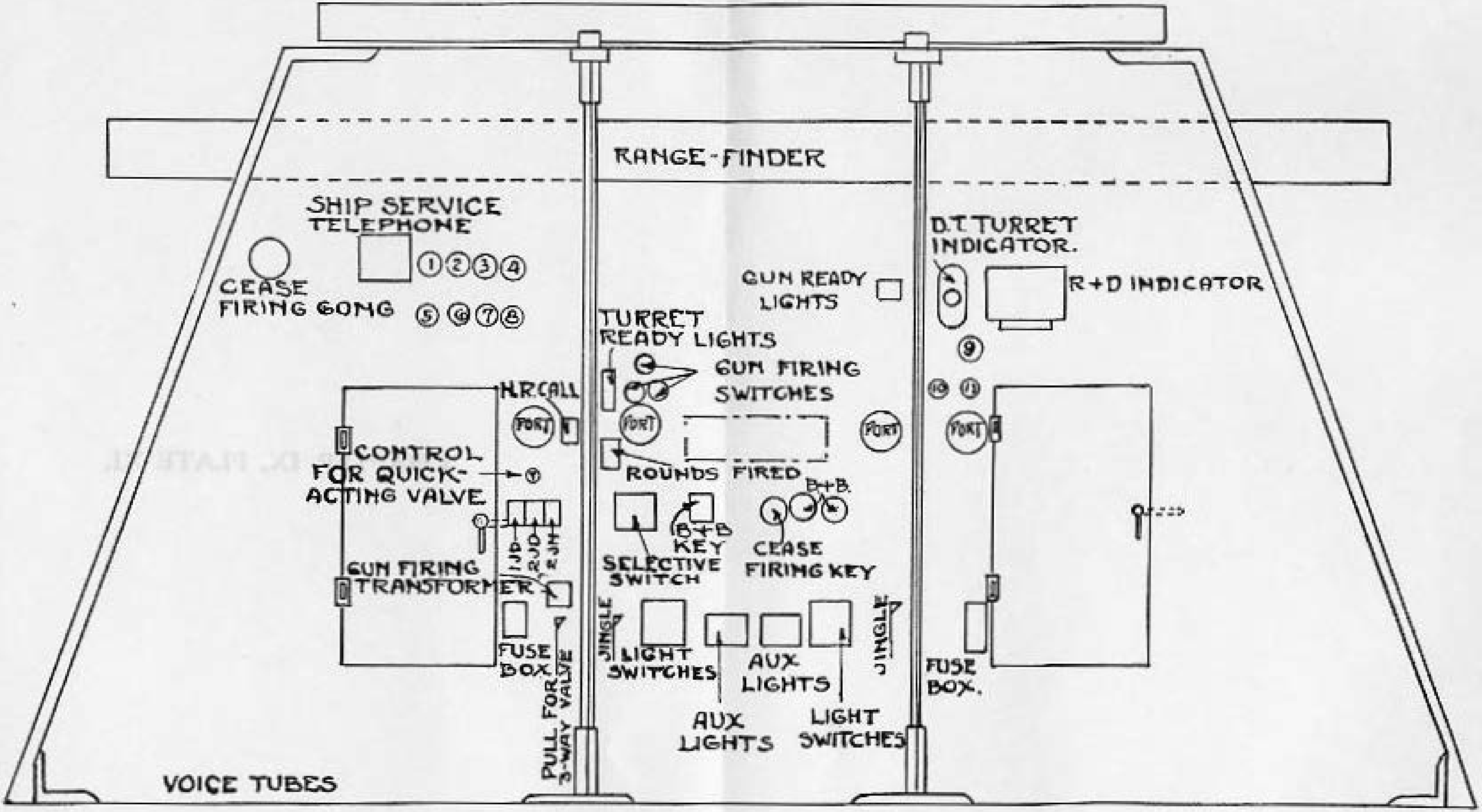
(b) **The turret booth,** at the rear of the turret proper, is separated from the turret chamber by flame-proof bulkheads, and is so designed as to give the turret officer a direct view of the guns through suitable dead lights. (Plate XI.) Access to the turret chamber is obtained through doors. Each turret booth has a quick-acting lever or other device for operating the sprinkling system in the turret chamber and also in upper and lower powder-handling rooms and to drench powder in the train between lower and upper handling rooms. The turret booth



14IN 3 GUN TURRET TRANSVERSE SECTIONS



TURRET OFFICERS BOOTH
18 SHELLS
15 SHELLS
9"
5"
POWDER CAR (UPPER POSITION)
FAIRLEADER
SHELL CRADLE
18"
AUX. SHELLHOIST DRUM
22 SHELLS STOWED ON SIDES
4"
ELECTRIC MOTOR
UPPER POWDER HOIST MOTOR
RAMMER MOTOR
HATCH
BARBETTE UPPER DECK
TRANSFER TRAY
POWDER HOIST
ELEVATING WORM
SHELL HOIST
HATCH
DIRECTOR DRUM
TRAINING
ELEVATING
BARBETTE
UPPER DECK
HOLDING DOWN CLIP
ROLLERS
HOLDING DOWN CLIP
ROLLER PATH
HOLDING DOWN BOLT
MAIN DECK
HATCH
TURNING GEAR ROOM
13
HOLDING DOWN BOLT
POWDER HANDLING ROOM
BLOWER ROOM
MAIN
AUX
MAIN DECK.
POWDER CAR LOWER
TURRET FOUNDATION
13"
SHELL HANDLING ROOM.
HATCH
68 SHELLS
AUX SHELL HOIST
WORK ROOM
SHELL STOWAGE
174 SHELL
13"
2 ND. DECK
SHELL PARBUKLING DRUMS
2 ND DECK
OIL PIPE
STORAGE BATTERY ROOM
SHELL HOIST MACHINERY ROOM.
SHELL TUBE
4 1/2"
4 1/2"
OIL MOTOR
SHELL STOWAGE
SHELL STOWAGE
50 SHELL
PLUNGER TUBE
HATCH
SHELL TUBE
SHELL MOTOR
3RD. DECK
3 RD. DECK
OIL PIPE
SHELL TUBE
LOWER POWDER HOIST
LOWER POWDER HANDLING ROOM
MAGAZINE DOOR
MAGAZINE DOOR
14" 3 GUN TURRET LONGITUDINAL SECTION.
7 SHELLS IN PASSAGE WAY 1ST. PLATFORM
SHELL STOWAGE 20 SHELL
SHELL STOWAGE



1 WORK SHOP
2 OVERHANG TURRET
3 BREECH OF EACH GUN
4 SHELL HANDLING ROOM
5 POWDER HANDLING ROOM
6 LOWER HANDLING ROOM
7 TRAINERS + POINTERS
8 SHELL HANDLING ROOM

9 _ TO OTHER TURRETS OF SAME GROUP
10 _ TO PLOTTING ROOM FROM RANGE FINDER
11 _ TO SUB

NOTE: - ALL VOICE TUBES TURNED THRU ANGLE OF 90° INBOARD

14 IN 3 GUN TURRET

TURRET OFFICERS' STATION

is also fitted with a lever or other device for operating an emergency alarm. The turret booth is habitually occupied by the turret officer when the turret is in operation.

(c) **Handling rooms.**—The handling rooms are spaces which are habitually utilized in the ammunition supply train for transferring powder or shell from the stowage to the supply hoists, from one hoist to another, or from one means of supply to another means of supply. These may be further distinguished as powder-handling rooms and shell-handling rooms. Shell stowage is the term used to designate open spaces where shells are stowed within the turret barbette on the circle decks at various heights and throughout the turret structure.

The magazines and lower powder handling room are adjacent to the bottom of the turret revolving structure. They are not in the turret proper but form an essential part of the ammunition supply facilities.

(d) **Other spaces** are the storage battery room, training gear room, hand passing platforms (for powder), tank compartment for the sprinkler water tanks, blower rooms, etc.

921. Special apparatus.—The general requirements regarding turret construction require that nothing shall be attached to the turret armor except fittings required by the structure, or fittings which by their nature and use cannot otherwise be placed for the efficient operation of the turret. Means are provided to prevent bolts, nuts, rivet heads, etc., flying in the turret as the result of shell impact. In all turrets, except single-slide turrets, flame-proof bulkheads separate the several guns.

A gun spray is installed near the breech of each gun and fitted with a quick-acting valve controlled from the turret booth, turret overhang, and gun chamber. Another water spray is fitted on the end of a flexible hose capable of being used in the gun breech or any other part of the turret gun chamber.

Each gun in the turret is fitted with a gas expelling device. Blowers are installed in the turret for ventilating purposes, and during gun firing the turret is maintained under a slight air pressure.

The intakes of the turret ventilating system are so located as to minimize the possibility of drawing into the system gases from fires in action. Care is taken, so far as practicable, to keep water and spray from entering the turrets through the gun ports, and sighting slits, while the turrets are being operated.

A sprinkling system is installed to drench powder in the gun chambers, upper handling room, lower handling room, and the powder train between upper and lower handling rooms where exposed in case of fire.

Voice tubes, bells, buzzers, telephone, and fire-control instruments are installed.

922. The turret mount.—The principal parts of a turret mount are (1) the gun, with breech mechanism and yoke, (2) slide, including recoil and counter-recoil mechanisms, (3) deck lugs and gun girders, (4) elevating and training gear, including rollers and roller paths, (5) shell and powder hoists, (6) rammer and spanning trays, (7) sights. (See Plates IX and X.)

The gun, yoke, breech mechanism, and sights are described in other chapters and will not be dealt with here.

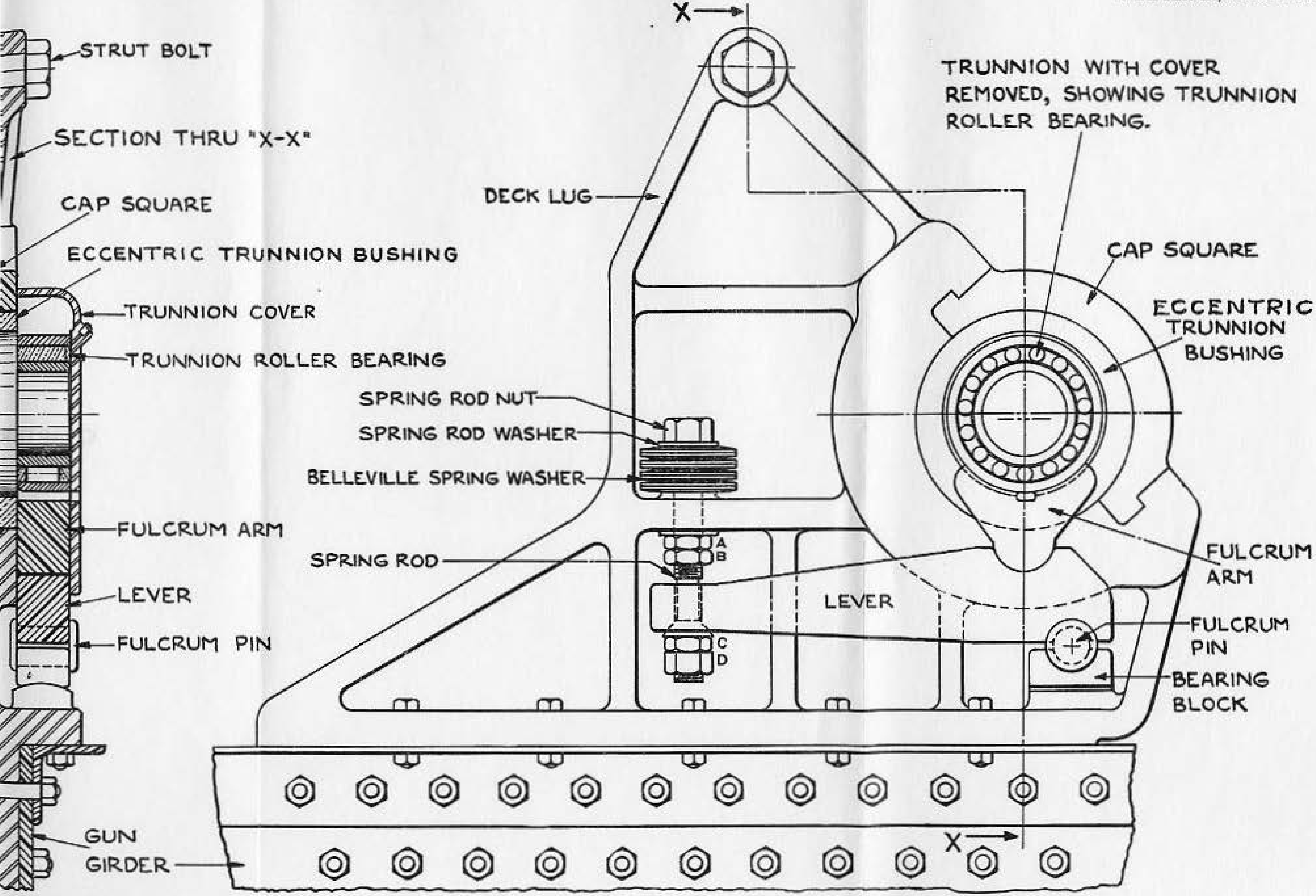
923. The gun slide, of which the trunnions are parts, supports the gun and the recoil and counter-recoil mechanisms. The slide, essentially a hollow cylinder, is of cast steel and is lined with bronze. The trunnions, about which the guns are moved in elevation, are located approximately at the center of gravity of the oscillating weights which they support and as close as practicable to the turret face plate in order that the port openings may be reduced to a minimum. On the gun slides of the *California* and *Maryland* classes, the trunnions are semicylindrical bosses, the upper forward sectors being cut away to permit installation closer to the turret face plate. Trunnion and deck lug of a modernized 14-inch battleship mount are illustrated in Plate XII; those of an 8-inch gun mount for a heavy cruiser in Plate XIII.

It will be noted that the 14-inch mount, having 30° elevation, adheres to the earlier method of a small frictionless bearing about which the gun is moved in elevation and a separate larger main bearing through which the forces of firing are transmitted to the ship's structure through the deck lugs and gun girders. The end thrust is taken up by the key and keyway of the trunnion bushing and deck lug. This trunnion bushing is eccentric. Rotation of this eccentric bushing permits adjustment for parallelism of the guns,

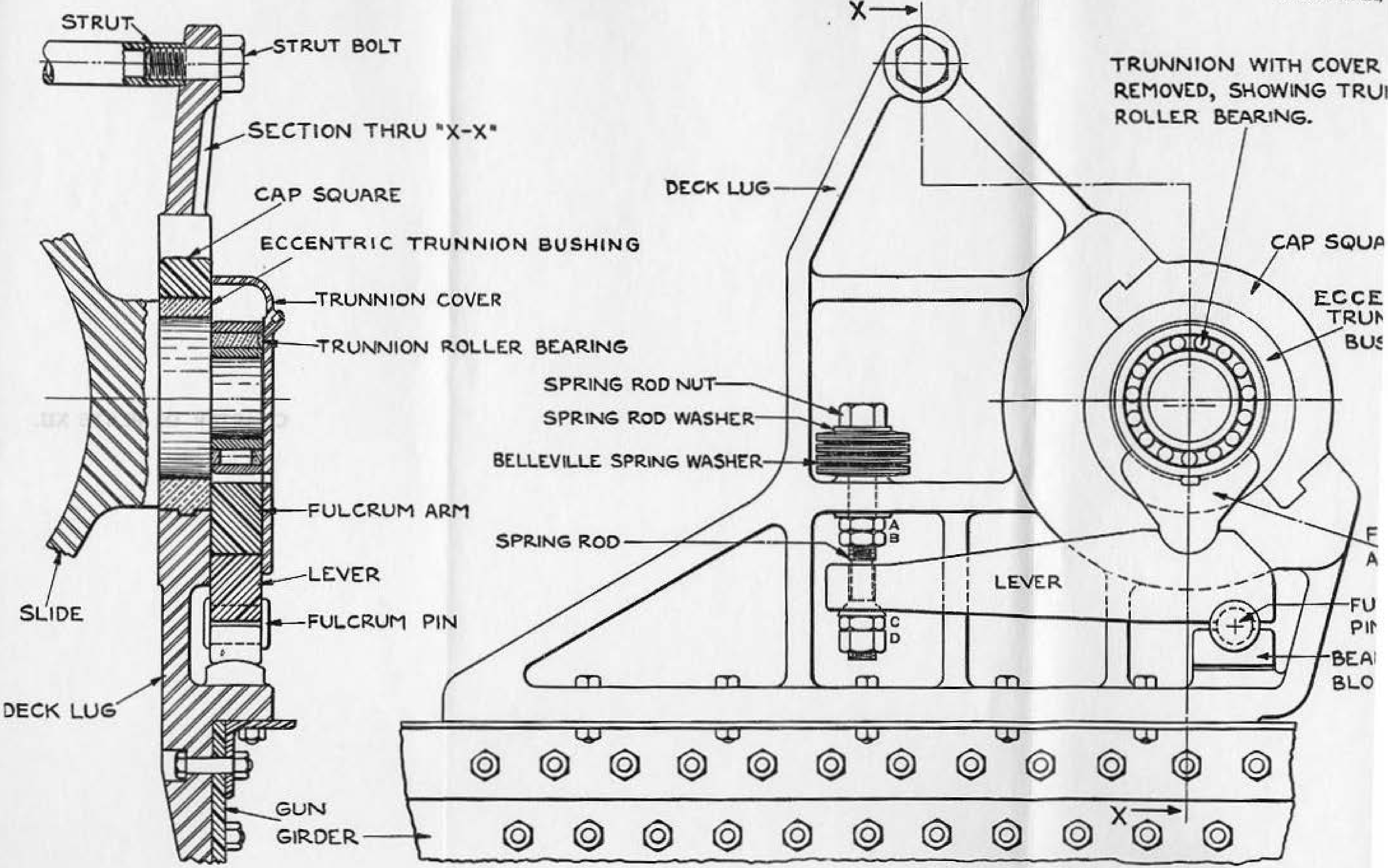
In the 8-inch mount, having 40° elevation, the main bearing is rendered as nearly frictionless as possible by the rollers. These roller bearings serve both as frictionless trunnion bearings and as the main trunnion bearings which take the entire load and shock when the guns are fired. These roller bearings have no adjustment of any sort. Note that the axial length of the rollers is divided into two to reduce the possibility of cracking the rollers due to their length or due to their being slightly canted. Due to greater roll and pitch of the heavy cruisers, this mount is fitted with thrust rings to transmit the end thrust.

To adjust the clearance of the trunnion bearing of the 14-inch mount (Plate XII): With all parts in place and nuts *A* and *B* slacked off,

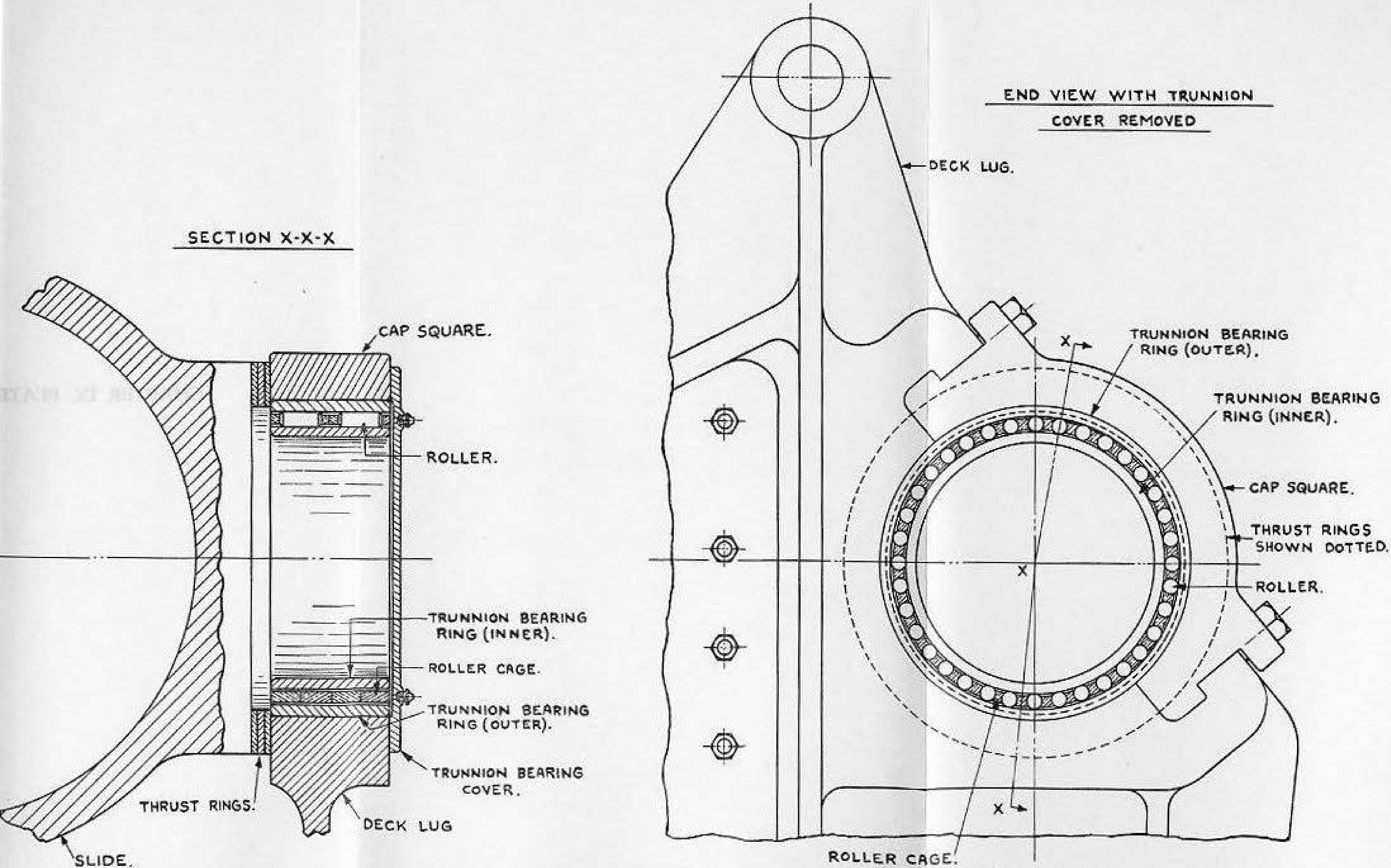
(1) Screw up nuts *C* and *D* until trunnion is lifted from its bearing



NION, TRUNNION BEARING AND OUTBOARD DECK LUG FOR 14-INCH MOUNT OF MODERNIZED BATTLESHIPS OF THE *OKLAHOMA* CLASS.



TRUNNION, TRUNNION BEARING AND OUTBOARD DECK LUG FOR 14-INCH MOUNT OF MODERNIZED BATTLESHIPS OF THE *OKLAHOMA* CLASS.



TRUNNION, TRUNNION BEARING AND LUG FOR 8-INCH TRIPLE MOUNT FOR HEAVY CRUISERS.

sufficiently to permit insertion of trunnion feeler gauge on under side of trunnion.

(2) Screw up nut *A* until firmly in contact with boss of deck lug, then screw up one-fourth of a turn additional. Set locknut *B* until in contact with *A*.

(3) Readjust nuts *C* and *D* by screwing up *C* until trunnion feeler gauge can again be inserted on under side of trunnion, set locknut *D* until in contact with *C*.

With the bearing adjusted as above, the entire weight and friction of moving the oscillating weights in elevation are borne upon the frictionless roller bearings and transmitted to the deck lug through the following parts: fulcrum arm, fulcrum pin, lever, spring rod, Belleville spring washers, spring rod washer, and spring rod nut. The Belleville spring washers are heavy saucer-shaped washers, alternate washers being inverted as shown. When the guns are fired the shock transmitted through the fulcrum arm, lever, spring rod, etc., causes the pairs of Belleville spring washers to dish or flatten, thus permitting the spring rod, spring rod washer, and spring rod nut to be lowered sufficiently to permit the lever and fulcrum arm to deposit the main trunnion in its bearing and so utilize its greater area to transmit the shock of firing to the deck lugs and to the ships structure.

924. The recoil mechanism, consisting of the recoil cylinder and throttling rods, is attached to the slide. The piston rod is attached to the gun yoke and recoils with the gun. During recoil, the liquid in the cylinder is forced through the orifices formed between the throttling rods and the apertures in the piston. The method of computing the proper dimensions of throttling rods is discussed in Chapter X.

The energy absorbed by the hydraulic brake results in a considerable heating of the recoil cylinder liquid. The expansion of the liquid is compensated for by means of an *expansion chamber* which has been provided for all turrets. This chamber is connected to the forward end of the recoil cylinder. It functions automatically, and requires no attention except the exercise of ordinary precaution, during the process of filling the recoil cylinders, to see that the expansion chamber remains empty.

The recoil mechanism performs its primary function during recoil, but it has a limited effect also on counter-recoil.

925. The counter-recoil mechanism, which is also attached to the slide, is provided for the primary purpose of returning the guns to the battery position at all angles of elevation. However, it does have a limited effect during the recoil.

Until recently, the force for returning the guns to battery was derived entirely from the compression of the helical springs, but on account of the large increase of the recoiling weights and the angles to which guns are now elevated, springs are impracticable. In battleships of the *California* and *Maryland* classes the return of the guns to battery during counter-recoil is accomplished by a combination of springs and compressed air. In these mounts there are four counter-recoil spring tubes per gun. (Six in the case of 16-inch guns.) These spring tubes, two on top and two on the underneath side of the slide, are secured by means of straps bolted in place.

Secured to the yoke and running through each spring tube is a piston rod which has its piston at the end farthest removed from the yoke. Between this piston and the head of its tube nearest the yoke are six sets of double spiral springs, each two sets being separated by a disk that is supported on the rod.

The function of these springs is to return the gun to battery after recoil, and in order to do this at maximum elevation the springs are assembled with initial compression of approximately fifty inches. Air is also injected into the tubes from the gas-ejecting system at an initial pressure of 50 pounds per square inch, which is further compressed along with the springs when the gun recoils.

Upon counter-recoil the force of impact caused by the expansion of the counter-recoil springs and air is resisted by the necessity of returning the liquid in the recoil cylinder to the after side of the piston. There is also a counter-recoil check plunger which, as the gun returns to battery, enters a small cylinder provided at the forward end of the recoil cylinder. The fit of the plunger is such that a relatively good cushioning effect is realized. Counter-recoil systems of the modernized battleships are described in Art. 1021 *et seq.*

926. The deck lugs, which contain the trunnion seats and cap squares, are heavy steel castings bolted to the gun girders. Their function is the same as that of the carriage of a broadside mount. The gun girders form the supports for the deck lugs and elevating gear; and through them the firing forces, at the trunnions, are transmitted to the roller path. (See Plates XII and XIII.)

927. The elevating gear[1] (Plates IX and X).—In the latest turrets the guns are arranged to elevate independently. Under normal conditions, however, all three elevating gears are locked together by clutches so that all guns elevate together. The elevating gear provided

[1] All machinery of a modern turret is electrically operated. Speed control of elevation, train, some rammers, and pusher-type ammunition hoists is obtained through the use of universal speed gears. Other motors have straight electrical control. For a description of the universal speed gear, see Art. 932 *et seq.*

for all guns is similar. Sufficient power is provided in each set so that all three guns may be operated by any single set of electric and hydraulic motors. In case of a casualty which would increase the resistance imposed upon the elevating gear, the guns may be elevated with all three electric motors and speed gears operating simultaneously. The elevating gear for each gun consists of an electric motor driving a universal speed gear. The B-end of the speed gear connects to the elevating nut which drives the elevating screw attached to the slide. The elevating nut is supported by the oscillating bearing which in turn is supported by the transom casting attached to the turret structure. Rotation of the elevating nut imparts an upward or downward motion to the elevating screw depending on the direction of rotation of the nut.

The rate and amount of elevation of the guns are controlled through a two-hand drive connecting to the control shaft of the A-end of the hydraulic speed gear. This two-hand drive is located in a convenient position with reference to the sight telescope and gun-pointer's seat, so that the gun pointer may keep his eye on the telescope for all positions of the gun in elevation.

The follow-up type of control is used; one turn of the handwheel produces a definite angle of elevation of the gun; and the direction of rotation of the gun about the trunnion axis corresponds to the direction of rotation of the handwheel. A definite ratio also exists between the rate of rotation of the handwheel and the rate of elevation of the guns, and when the handwheels come to rest the gun is brought to rest. With the type of control described the guns can be operated with the same facility as a hand-operated mount.

928. The training gear.—The turret-revolving structure is rotated by the training-gear machinery driven by an electric motor and universal speed gear. (See Art. 932.) The driving end of the speed gear connects directly to the worm shaft which drives the worm wheel attached to the training pinion shaft. The *training pinion* (see Plate X), which is secured directly to the training-pinion shaft, meshes with the training rack secured to the turret foundation.

In the latest ships, one worm wheel and one pinion are used. The gear is driven by one main electric motor through a universal speed gear with a follow-up arrangement as for the elevating gear. The torque is transmitted from the motor to the training pinion direct without the use of friction discs, such as were used in the older turrets. In this case the gear is designed with sufficient strength to withstand the forces resulting from the firing of the guns, and the inertia of the turret due to starting and stopping.

Auxiliary training gear is provided for use in case the main electric motor or speed gear becomes disabled. This gear consists of a low-powered electric motor receiving current from storage batteries stowed in the revolving structure of the turret. The speed of train, as in the case of the main gear, is controlled through a small universal speed gear. Hand training is also provided for emergencies when power is not on the turret. This gear is not efficient, and is inadequate for training the turret at any satisfactory speed, being provided as a last resort.

As has been mentioned, the turret revolving structure rests on rollers which rest on a roller path supported on the turret foundation. The rollers, which are frustums of cones, are spaced by a separator ring floating on the roller axles. The weight and vertical forces resulting from firing are supported by the conical surface of the roller, and the horizontal thrust due to firing is transmitted from the revolving structure to the turret foundation through the roller flanges. The turret is also provided with holding-down clips attached to the revolving turret structure and projecting under the stationary turret roller path or vice versa, to prevent it from being thrown from its foundation by force from any outside source.

929. Powder supply (Plates IX and X).—The powder is stowed in the powder magazines in air-tight powder tanks. In supplying powder to the guns the powder is taken from the tanks and passed through flame-proof scuttles in the magazine doors to the lower powder-handling room. From this point the powder is carried by hand to the lower end of the powder conveyor where the powder bags are fed into the receiving end of an endless-chain conveyor hoist. Two hoists of this type are used. These hoists deliver the powder bags to the trays located in the upper powder-handling room beneath the pan separating the turret gun chamber from this room. One charge for each gun is assembled in this room for transmittal to the guns as required.

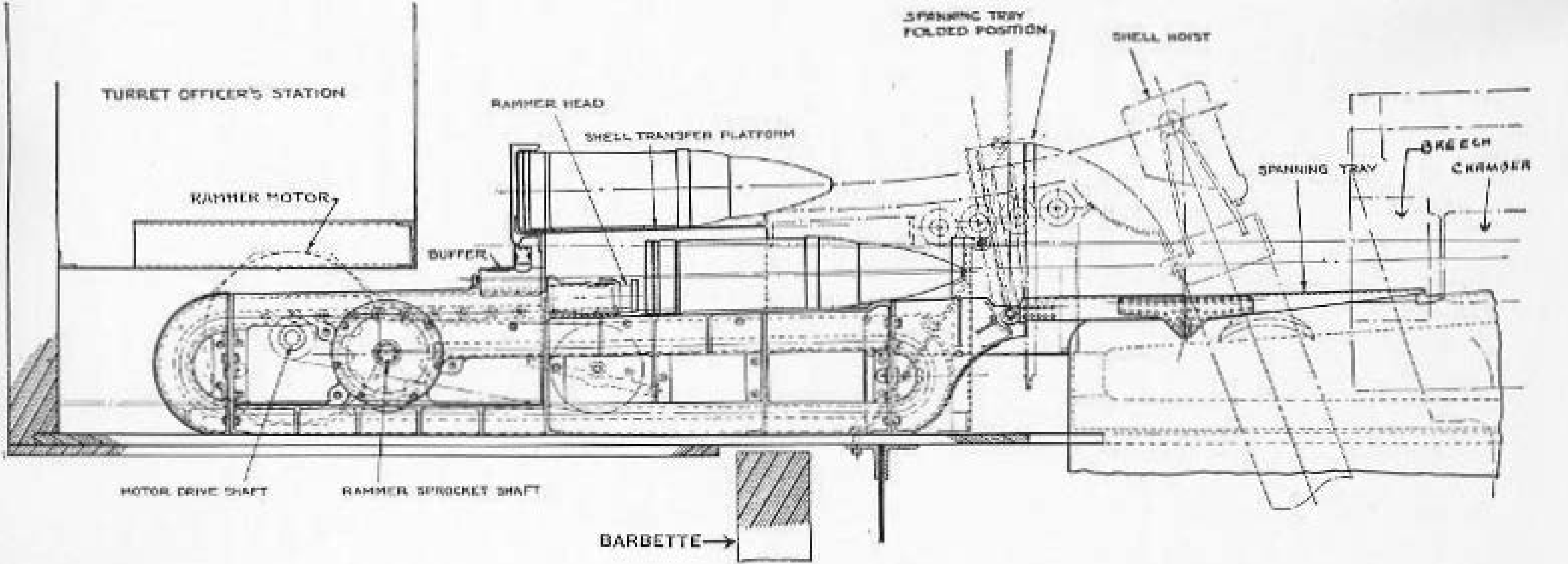
In the upper powder-handling room, the powder bags are loaded into the powder cars which convey the powder from the upper powder-handling room to the breech of the guns. One powder car is provided for each gun, and each car is arranged to carry a complete charge per trip. The charge is hoisted while the shell is being rammed into the gun. The powder car is flame proof so that the charge is completely protected from flarebacks until the bags are dumped out into spanning trays prior to being rammed into the gun. The upper powder hoist is of a reciprocating type, hydraulically operated. An A-end of a speed gear serves as a pump and delivers liquid under pressure. The motion of the car is controlled by the movement of the control screw of the speed gear. Flame-proof doors fitted with interlocks form a seal between the upper powder-handling room and the gun chamber of the turret, so that there can be no direct communication at any time between the gun chamber and the lower powder-handling room.

In case power is not available for hoisting powder, the powder bags may be hoisted from the lower handling room to the upper powder-handling room by means of a whip hoist provided. Upon arrival in the upper powder-handling room the powder bags are passed through hatches in the upper powder-hoist trunk to the breech of the gun by hand. Platforms are provided for the use of the powder-passing crew.

930. Shell hoists (Plates IX and X).—The shell hoist, which is a standard navy type, extends from the shell-handling room, located directly below the upper powder-handling room, to the gun chamber, at a point opposite the breech of each outboard gun. Two hoists are used. Shells are stowed on platforms in the turret foundation space and in the shell-handling room. The shells are stowed on their bases in such a way that one shell can be removed from its fastenings without disturbing the adjacent shells. The shell is parbuckled from its stowed position to the hoist by means of a manila rope running over a winch driven by the shell-hoist motor.

From its position in the lower end of the shell hoist, the shell is raised by a series of short strokes to the gun chamber above. After the hoist has once been filled, a shell arrives at the gun at the termination of each upward stroke. Another shell is then loaded into the lower end of the tube. The hoist is hydraulically operated by means of an A-end of a hydraulic speed gear. The speed gear, which acts as a pump, delivers liquid under pressure to a ram which actuates a rack bar and pawls which raise the column of shells in the hoist through a distance of one shell height on each upward stroke. During the return stroke of the ram the shells are supported by a series of pawls fixed to the shell tube. The motion of the hoist is controlled through the control screw of the hydraulic speed gear. The shells are dumped out of the upper end of the hoist by means of a cradle. From this point the shells are rolled to the guns. It is impossible to strike the shells below by means of this hoist. When power is not available in the turret for running the shell hoist, shells may be hoisted to the turret chamber by means of a chain purchase using an auxiliary tube.

931. Rammer and spanning tray (Plate XIV).—The shell and powder charge are rammed into position in the gun by means of a chain rammer. The guns are loaded at a fixed loading angle. After opening the breech, the spanning tray is carried forward from its folded position, at the forward end of the rammer, so as to extend into the chamber of the gun. The shell is then rammed from its position in the rammer tray



TURRET OFFICER'S STATION
RAMMER MOTOR
RAMMER HEAD
SHELL TRANSFER PLATFORM
BUFFER
SPANNING TRAY FOLDED POSITION
SHELL HOIST
SPANNING TRAY
BREECH
CHAMBER
MOTOR DRIVE SHAFT
RAMMER SPROCKET SHAFT
BARBETTE

to its position in the gun by means of a chain. After loading the gun the tray is folded back clear of the recoil position of the gun. The rammer head is attached to the end of the chain that comes in contact with the shell, and is provided with hydraulic buffers to relieve the rammer mechanism of shock. The chain is contained in a rammer casing and is driven by a sprocket which in turn is driven by a hydraulic speed gear or some form of clutch. Direction of motion is controlled through the control shaft of the speed gear or by means of a clutch.

Section V.—The Waterbury Hydraulic Speed Gear.

932. The Waterbury hydraulic speed gear (Plates XV and XVI) is a machine for transmitting rotary power at variable speeds and in either direction without steps or abrupt gradations, while the source of power rotates continuously in one direction without any necessary change of speed. This source may be an engine of any kind, an electric motor, a shaft, or any rotating mechanism from which it is desired to transmit power. The medium of transmission is oil. This being practically incompressible, the driving is very positive, except to the extent of the very slight leakage necessary for lubrication.

933. A-end and B-end.—Functionally the machine consists of two separate mechanisms designated, respectively, the A-end and the B-end.

The A-end is an oil pump operated by the driving power, whatever that may be. Its function is to deliver oil to the B-end at any required rate and pressure and receive it back again, thus keeping up an oil circulation. The A-end contains a controlling device by which the quantity of oil delivered to the B-end is regulated exactly to meet the speed requirements of the B-end. The shaft of the A-end is supposed to rotate in one direction only, at a constant speed.

The B-end is a hydraulic engine. Its rotating parts are almost exactly like those of the A-end. In its capacity as an engine its shaft rotates at any speed and in either direction in exact obedience to the quantity and direction of delivery of the oil it receives from the A-end.

934. Arrangement of the ends.—When conditions permit, the two ends are united into one machine, a middle partition, called a *valveplate* or *midplate*, separating the two parts. If the two shafts are to stand in a straight line, the valveplate is a flat disc with parallel faces. If, however, the shafts are to stand in any other position than a straight line, the shape of the valveplate may be varied to meet the requirements.

The conditions of installation may be such as to require the locating of the A- and B-ends some distance apart. Each end will then have its

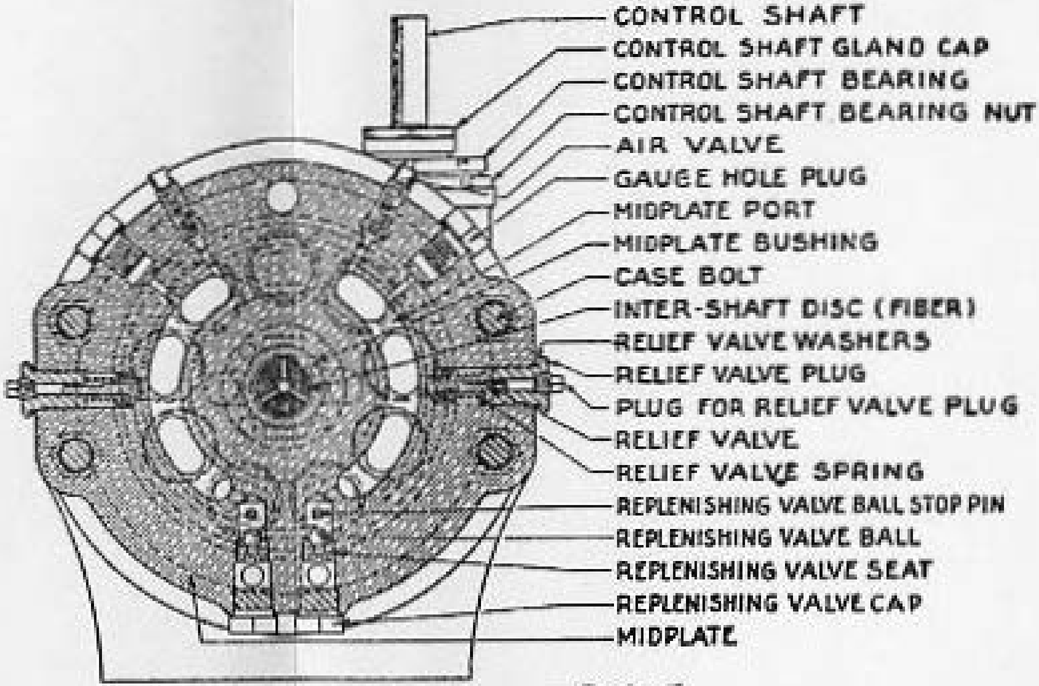
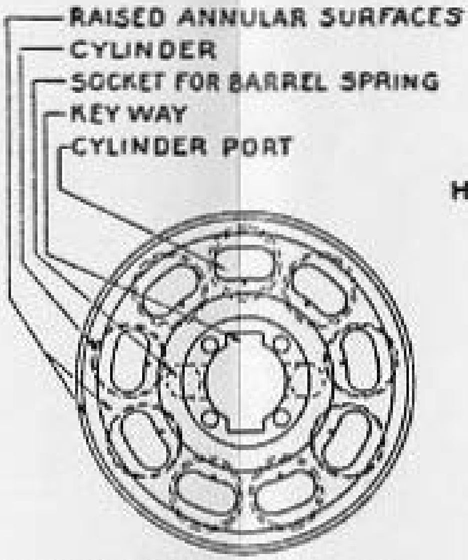


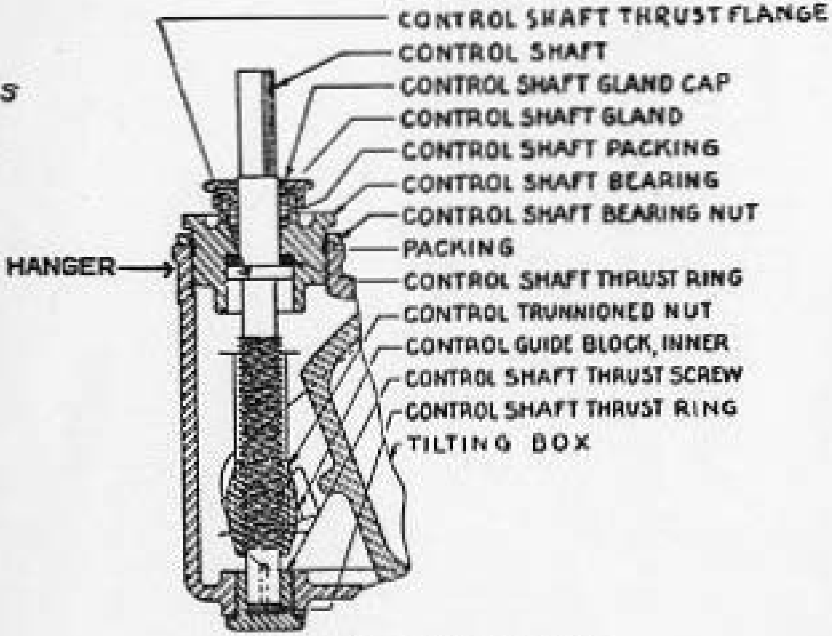
FIG. 3

TRANSVERSE SECTION OF MIDPLATE.



"A" CYLINDER BARREL AS SEEN FROM MIDPLATE.

FIG. 4



SCREW AND NUT TYPE OF CONTROL SHAFT

FIG. 5

VERSAL SPEED GEAR.

SECTIONAL PLAN

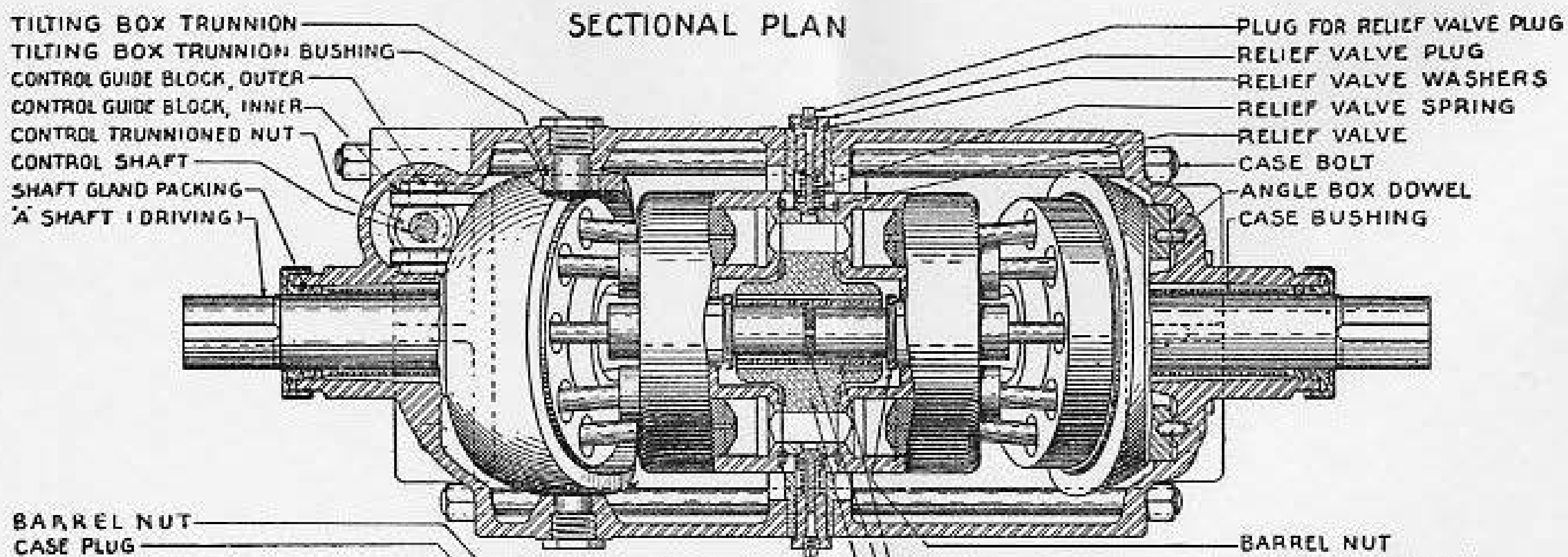


FIG. 1

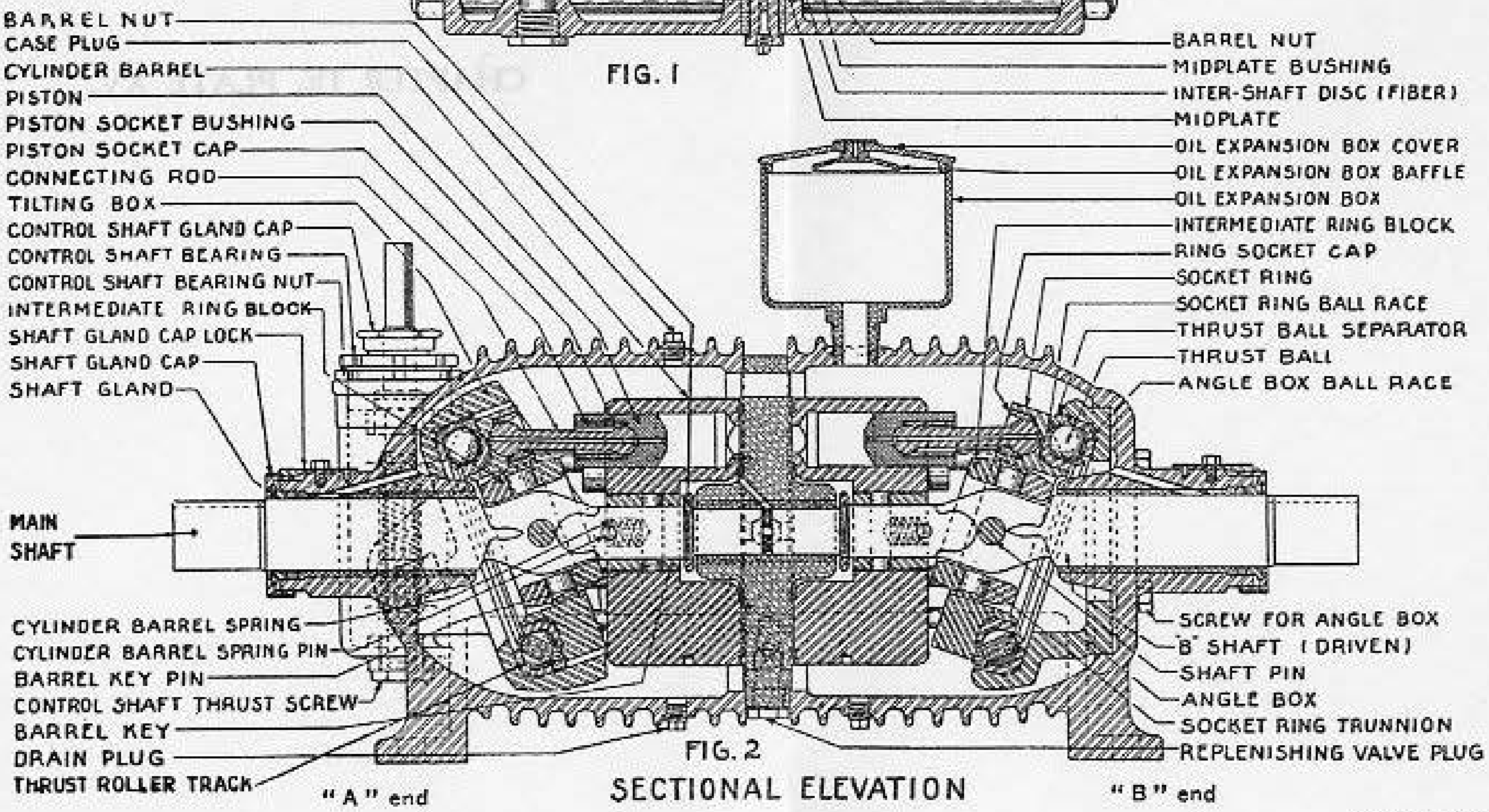
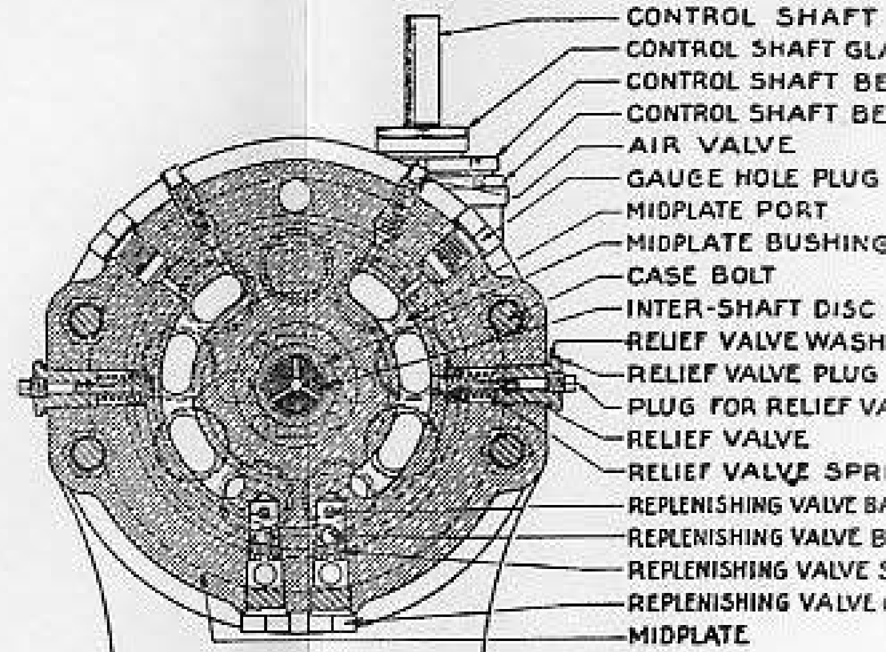


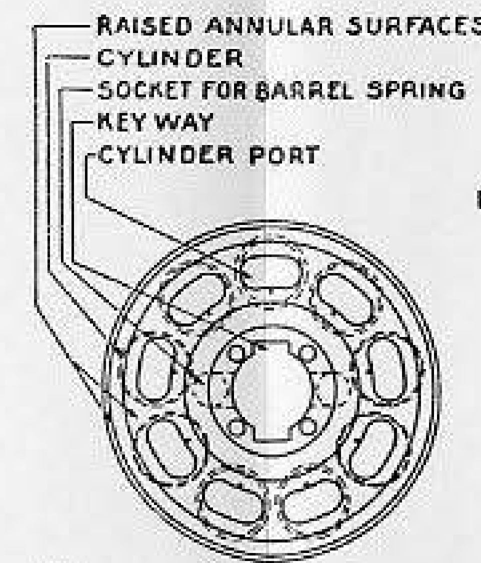
FIG. 2

SECTIONAL ELEVATION



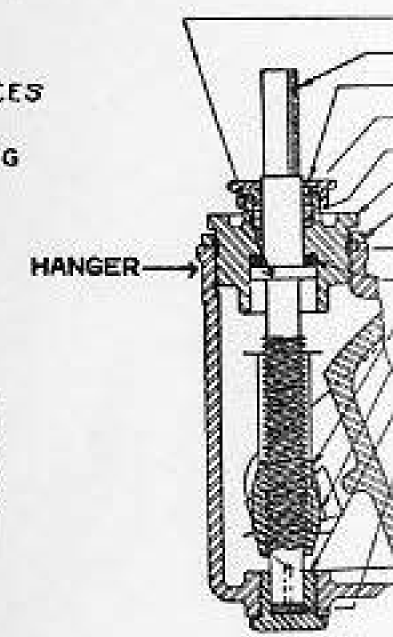
TRANSVERSE SECTION OF MIDPLATE.

FIG. 3



"A" CYLINDER BARREL AS SEEN FROM MIDPLATE.

FIG. 4



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THE UNIVERSAL SPEED GEAR.

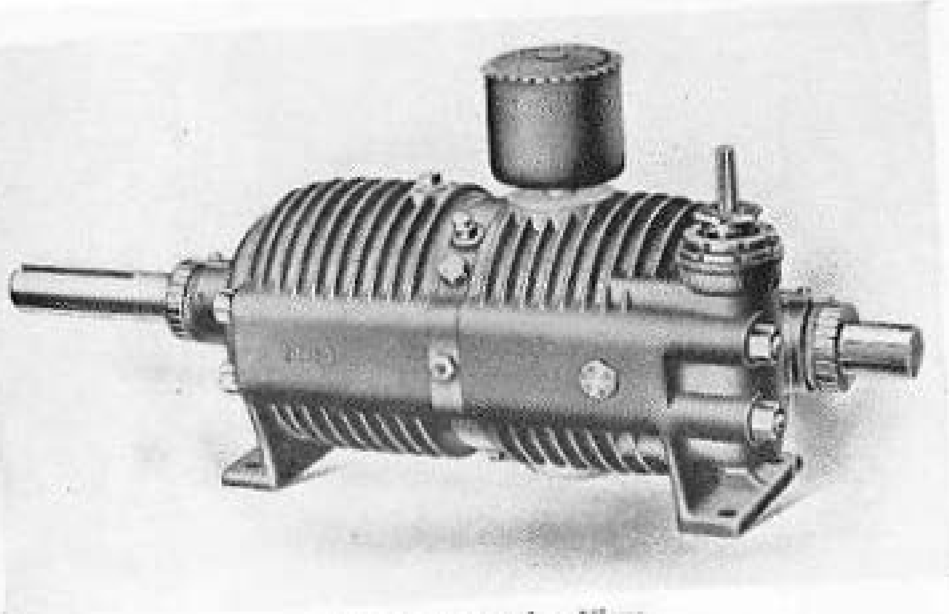


Fig. 1.—Exterior View.

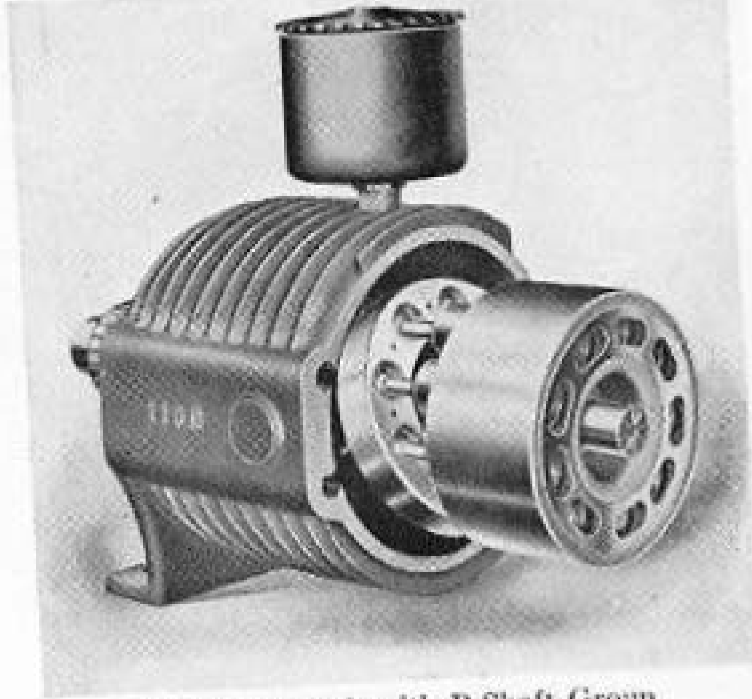


Fig. 3.—B-End, with B-Shaft Group.

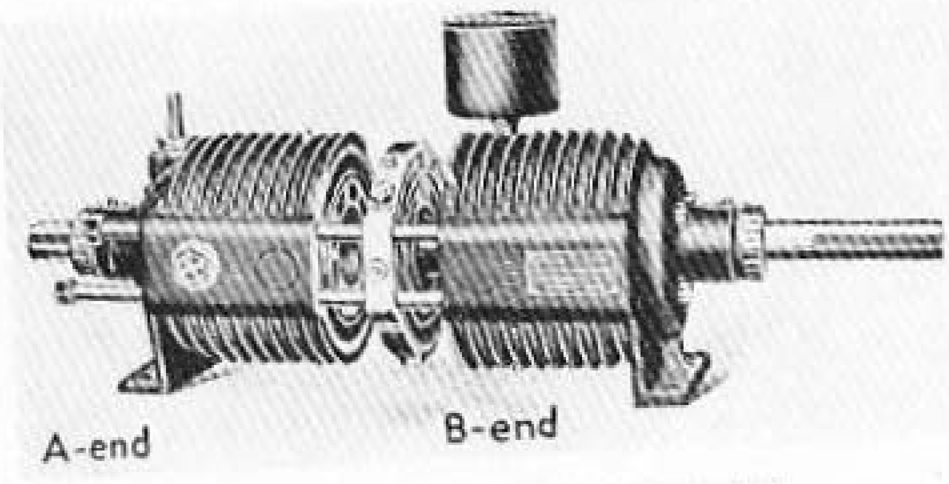


Fig. 2.—The Two Ends Partly Separated.

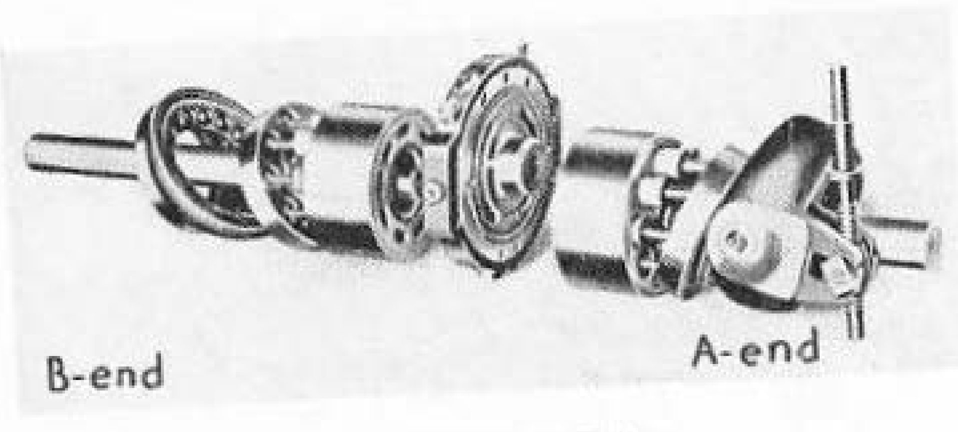


Fig. 4.—Internal Parts.

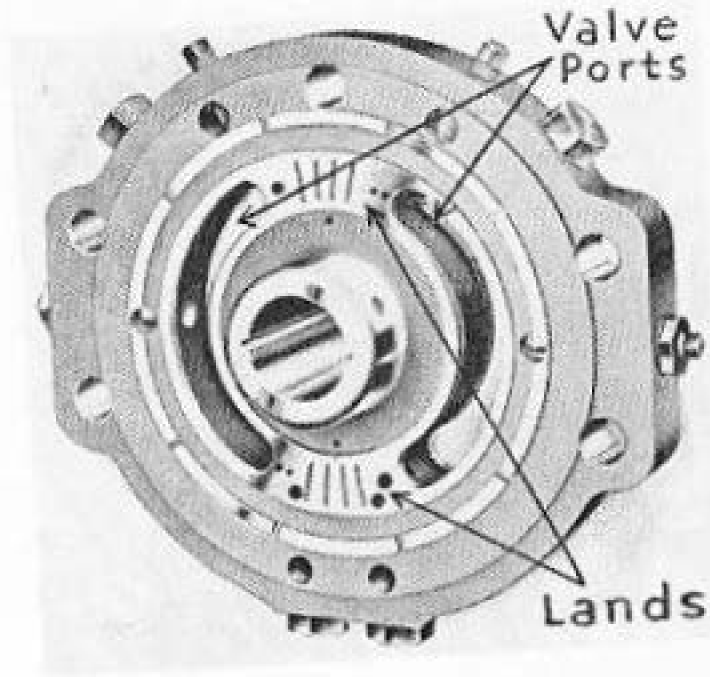


Fig. 5.—Midplate of Valveplate. (Showing the A-Face).

THE UNIVERSAL SPEED GEAR, TYPE C.

own valveplate, which may be appropriately termed an *endplate.* The two endplates will have their two main oil passages connected by two pipes. Since the chief function of the valveplate or endplates is to furnish passages for the circulation of oil between the two ends of the gear, it is evident that the connecting pipes may be so bent as to make possible an unlimited variety of arrangements.

935. Description.—To simplify the description let us consider only the unitized or C-type of machine wherein the shafts are in line with each other.

The fixed parts, which *do not* rotate with the shafts in the transmission of power, are the cases, the valveplate, the tilting box, the angle box, and the control shaft. It is important to remember these non-rotating parts.

All the working parts of the machine are enclosed within cylindrical shells, called *cases*, one for each end of the machine. The open, or large, ends of the cases are securely bolted against the opposite faces of the valveplate by long bolts passing through the cases and the valveplate. The other ends of the cases are closed in to form hubs through which the shafts extend. Legs cast on the cases provide means for securing the machine to its support.

Thus combined the cases form an oil reservoir within which the active parts rotate. The greater portion of the oil is not under pressure, but is in communication with the air through the *oil expansion box* on top of the case. The only active oil, which is directly used in transmitting the power, is enclosed within the *port passages* of the valveplate and within the cylinders ahead of the pistons.

936. Valveplate or midplate is a very important element of the machine. On each of its faces is carefully prepared a contact surface against which the face of a cylinder barrel rotates. Passing through the valveplate are two semi-annular passages, called *valveplate ports,* one in each half of the plate, extending from the A-face to the B-face, through which the oil circulates when transmitting power. Between the ports, both at the top and the bottom, are flat faces called *lands,* into which are cut short reduced extensions from the ports. As the cylinder barrel rotates, the cylinder ports pass in succession across these lands and the contents of each cylinder is for the moment imprisoned within the cylinder while being carried across from one port to the other. At the center of the valveplate are bearings for the inner ends of the shafts. Several valves are also located in the valveplate, which will be described further on under the heading *minor parts.*

937. Tilting box and angle box.—The purpose of the *tilting box* in the A-end is to carry a *thrust roller track* against which the *socket ring* may rotate in a plane at any desired angle to its shaft. In the earlier designs there were two tilting boxes, one in each end of the machine, but later the B-tilting box was displaced by a wedge-shaped casting, called the *angle box*, carrying its roller track at an angle of about 20 degrees from perpendicular, and screwed securely to the end of the inside of the B-case. This substitute for the tilting box is possible for the B-end, since the angle is not changed after once being set. But in the A-end the tilting box must be retained for the reason that the speed and direction of rotation of the B-end are controlled by *changing the angle of the tilting box*. The tilting box is suspended, and may be oscillated, on two trunnions, which are screwed through from the outside of the case and enter bronze bushed holes in the tilting box. An elongated hole is cut through the bottom of the box so as to give a free passage for the main shaft even when the box is tilted to its maximum angle.

Projecting from the bottom of the box are four fingers or prongs forming guides or slideways for the guide blocks connected with the control shaft.

938. Control shaft.—The purpose of the *control shaft* is to tilt the tilting box on its trunnions either way from the neutral or perpendicular position according to the direction and speed required of the B-shaft. It is a threaded shaft provided with a *thrust flange*, or collar, made integral with the shaft. This flange bears against a fiber thrust ring adjusted against the flange of the control-shaft bearing, which is screwed into the hanger which forms a part of the case. The control-shaft bearing is locked in the hanger by the bearing nut. The lower end of the control shaft bears very freely in a socket in the control-shaft thrust screw, which is screwed into the bottom or lower end of the housing.

The threaded portion of the control shaft carries a trunnioned nut, whose trunnions carry four guide blocks, two on each trunnion. The outer two of these blocks slide in guideways planed in the sides of the housing. The inner blocks slide between the fingers on the bottom of the tilting box.

The turning of the control shaft causes the trunnioned nut to move up or down, carrying with it the fingers of the box. The angular positions of the tilting box are therefore determined by the rotation of the control shaft.

The rotating parts of the A- and B-ends are alike except the location of the sockets in the socket rings and of the cylinders and ports in the cylinder barrels. We may, therefore, confine our attention to one end only. These parts are so assembled upon the shaft as to form what may be called a shaft group, comprising the shaft, the cylinder barrel with the keys that connect it with the shaft, the socket ring with the universal joint that connects it with the shaft, and the pistons and connecting rods.

939. Shafts.—The A- and B-shafts are alike. Bushings in the hubs of the cases form the main bearings, while the inner ends of the shafts are provided with roller bearings in the valveplate. The ends of the two shafts are separated in the valve plate by a fiber disc called the *intershaft disc.* At the intersection of the plane of the socket ring the shaft is formed into a closed yoke around the universal-joint parts described under *universal joint.*

Where the shaft passes through the *barrel* it is flattened on two sides and perforated to receive the *barrel keys* and is threaded to receive the *barrel nut.*

The barrel nut performs no other function than to prevent the barrel from sliding off the shaft when the assembled group of shaft, barrel, and socket ring are being handled. When the gear is fully assembled and in operation the barrel does not touch the nut.

940. Cylinder barrel.—The cylinder barrel contains nine cylinders. It is loosely attached to the shaft by two keys provided with pivots fitting loosely in a hole through the shaft. The loose fit of the barrel on the shaft together with the pivoted keys gives it a slight freedom of motion so that its face can rest squarely against the face of the valveplate. Moreover, it can slide freely endwise along the shaft. This endwise motion is aided by a *barrel spring* backing against a pin in the shaft. The purpose of the spring is to hold the barrel against the valveplate when not in operation. When the oil is under pressure, the barrel is held against the valveplate automatically by reason of the fact that the cylinder ports are smaller than the pistons, giving an excess internal pressure, forcing the barrel towards the valveplate.

The cylinder barrel and keys do not transmit any of the working torque.

941. Pistons.—There are nine pistons in each barrel, the pistons and cylinders being ground and lapped to a smooth working fit without any packing. Narrow shallow annular grooves are cut around the pistons, which serve to interrupt the leakage stream lines and to trap dirt.

Connecting rods.—Each piston is connected to the socket ring by a *connecting rod.* The rods have perfectly spherical ball ends of unequal diameters. The smaller end is secured into a socket formed in the piston, which it fits perfectly, by a bronze split piston-socket bushing which is secured in place by a finely threaded piston-socket cap.

The main purpose for having one ball end smaller than the other is to make it possible to string the ring-socket cap and the piston-socket cap over the smaller end; the smaller ball is prevented from being drawn back through the piston-socket cap by the split bushing.

The large ball end is secured in a socket in the socket ring by the ring-socket cap.

Through the end of the piston and through the whole length of the connecting rod is a small hole which feeds oil under pressure from the active oil system to lubricate the balls and sockets.

942. Socket ring.—The socket ring has cut into it nine sockets fitted with bronze ring socket caps against which rest the large ball ends of the connecting rods. These sockets are unequally spaced to correct certain irregularities of the universal joint.

The back of the socket ring is provided with a chrome-vanadium roller track which has two roller faces, one for the main conical thrust rolls and the other for the diagonal thrust, or cylindrical, rolls. (Plates XV and XVI and models in the Model Room illustrate the use of spherical rolls instead of cones and cylinders.)

On the inner body of the socket ring are formed the socket ring trunnions at right angles to the main shaft and shaft pin.

943. Universal joint connects the shaft and socket ring in much the same manner as a compass is mounted in its gimbal rings. This joint consists of a shaft-trunnioned intermediate ring block oscillating with the main shaft pin in the yoke of the main shaft, and oscillating about the socket ring trunnions at right angles to the shaft pin.

The entire working torque of the gear is transmitted through the socket ring, the universal joint trunnions, and the main shaft pin.

944. Minor parts. (a) **Replenishing valves.**—There is necessarily a small amount of leakage of oil from the high pressure active portion into the inactive body of oil enclosed in the cases. Provision must be made to replace this leakage as fast as it occurs, otherwise there would be a vacuum in the cylinders and port passages. For this reason there are two check valves in the lower part of the valveplate called *replenishing valves*. One of these is connected with each port passage and permits the oil to flow freely from the case space into the port passage, but prevents its flowing in the opposite direction.

The valve itself is a steel ball. The seat is a steel piece screwed in from the outside. The hole in the valveplate through which the seat is inserted is closed by a plug called the replenishing-valve cap.

(b) **Relief valves.**—In the transmitting of power at very low speed in the B-end it is possible that the oil pressure may rise to thousands of pounds per square inch should the resistance to be overcome be correspondingly great. It is therefore necessary to provide safety valves to be set at any desired maximum pressure, say 1,000 or 1,200 pounds per square inch. Should the pressure exceed this amount the oil will escape from the high pressure port passage through a *relief valve* into the case space and flow back again through a replenishing valve into the low pressure port passage.

The relief-valve group consists of a valve, a spring, a plug, and adjusting washers. The plug forms the backing for the spring, compression of which is adjusted by the use of more or fewer copper washers under the head of the plug.

(c) **Air valves.**—At the highest points in the two port passages are needle valves. The purpose of these is to allow any air that may be imprisoned in the passages to escape into the case space whence it can rise through the oil expansion box. It is only necessary to open these valves one or two turns during the filling process, after which they are to be closed tight; they perform no other function.

Thimble caps are screwed over the ends of these valve screws to prevent oil from leaking out or air from being sucked in.

(d) **Oil expansion box.**—As the proper functioning of the machine requires that the medium of power transmission be practically incompressible, it is important that no air be allowed to mix with the oil. The case must therefore be entirely full of oil. To meet this requirement fully it is necessary to have the oil in the machine connected with an external supply that will always be in communication with the interior and yet not permit the entrance of air. The oil expansion box serves this purpose. In the illustrations the box is represented as connected directly with the top of the case. In practice, however, the box may be located in any convenient place near by and connected with the case by a pipe. The connections should always be such as to allow the easy escape of air from the case.

In the lid of the box will be noticed a baffle. Immediately above this are holes in communication with the outside air. The baffle prevents the splashing of the oil in the box from stopping the air holes, should there be a sudden rush of oil from the case into the box. This is an interesting and important phenomenon. Should the machine become overloaded, the flow of oil through the relief valve is more rapid than the supply through the replenishing valve for the reason that the relief valve is acting under high pressure while the replenishing valve is acting only under atmospheric pressure. A momentary vacuum is produced in the active body of oil, which is the same in effect as if the whole volume of oil had suddenly increased.

(e) **Stuffing boxes and packing.**—Where the shafts pass through the cases there are stuffing boxes. These are of the ordinary type and need no special comment further than to call attention to the kind and shape of material used in packing. Leather cups of U-section are used, the U-channel being filled with pure asbestos yarn containing no paraffin, tallow, or wax filling. Two of these U-rings are used in each stuffing box. If they alone do not fill the box a sufficient quantity of asbestos yarn may be placed between the leather rings.

In the threaded surface of the control-shaft bearing is a groove which is to be filled with a leather strip called the control bearing thread packing. When the bearing piece is screwed into the hanger and the control-shaft bearing nut is screwed down tight, this leather strip is compressed into the channel between the top of the hanger, the nut, and the bearing so as to prevent any leakage of oil or air.

Where the end of the case fits against the valveplate, only a paper gasket is used. This is cut to fit that part of the face of the valveplate that comes in contact with the case. It is cemented to the valveplate with a solution of shellac in alcohol.

(f) **Plugs.**—The various plugs need only to be mentioned. In the valveplate are two gauge plugs. These close holes connected with each port passage for the attachment of pressure gauges when desired. In the cases are plugs for drainage, escape of air, equalizing pipes, etc.

945. The pressure of the oil in the valveplate passage depends upon the resistance offered to the turning of the B-shaft and not upon the speed. The pressure rises instantly to meet any resistance up to the capacity of the driving motor. If the A-socket ring stands almost perpendicular to the shaft, only a very small quantity of oil is transferred per rotation, which has the effect of giving a very great leverage, and even a small motor may produce a pressure of several hundred pounds, and, of course, a corresponding torque or turning effort on the B-shaft. The actually permissible pressure in any particular machine depends upon the strength of the parts, but is limited by the setting of the relief valves.

946. Operation of the gear.—In order that the functioning of the various parts of the machine may be understood, let us assume that the gear is assembled and filled with oil ready for running.

The entire space within the cases and valveplate not actually occupied by metal is filled with oil. No air pockets exist, and in order that no air may enter the case, the oil is made to fill the expansion box about half full. A definite portion of the oil is enclosed within the cylinders ahead of the pistons and within the port passages of the valveplate. This is the really active portion of the oil, and if there were no leakage this is all the oil that would be used in transmitting energy. The inactive oil which fills the space within the cases is never under pressure. It is simply a supply for lubrication, into which leakage from the active oil may flow and from which this leakage is replenished through the replenishing valves, the total quantity remaining constant.

With our attention directed to the A-end of the sectional views, let us first assume that the A-tilting box with its socket ring is set at the neutral position, that is, perpendicular to the shaft. Under these conditions the shaft in rotating will carry around with it the socket ring and the cylinder barrel together with the pistons and connecting rods, but the pistons will have no tendency to reciprocate in the cylinders. There will, therefore, be no drawing of the oil in nor forcing it out through the valveplate. The only work done will be the stirring of the oil in the case by the revolving parts and the light friction of the shaft bearings and the sliding of the face of the cylinder barrel against the face of the valveplate. The B-end will not be disturbed.

If the control shaft be turned a little so as to move the top of the tilting box away from the valveplate and if the A-shaft be rotating over towards the observer, then the shaft will rotate the socket ring, which is attached to it by the universal joint, and will also rotate the cylinder barrel, which is keyed to it. The pistons and piston rods will rotate with these two parts, since they are contained in them. The tilting box remains stationary and the socket ring rotates within it, but is constrained by the roller bearings to maintain constantly the angle at which the tilting box may be tilted. All the pistons, as they move up on the far side of the machine, will draw in oil through the port in the far side of the valveplate; all the pistons as they move down on the near side will slide in towards the valveplate and force the oil through the port in the near side of the valveplate. The near port will thus be under pressure while the far port is in suction.

It should be noticed that when a piston reaches the top or higher position, in its revolution, it for an instant makes no end movement and the oil in that particular cylinder is carried across the land, or space between the two valveplate ports, from the suction side to the pressure side. The same condition exists when a cylinder is passing its lowest position, except that the piston is then at the inner end of its stroke and is passing from the pressure side to the suction side.

The quantity of oil forced through the valveplate port depends upon the angle at which the tilting box stands and consequently the length of the piston stroke.

We have spoken of forcing the oil through the valveplate port, but this cannot take place unless there is some means acting to receive the oil and carry it across to the port that is under suction. This is the function of the B-end. The B-socket ring always stands at an angle of about 70° to the B-shaft, and when the B-shaft rotates the B-pistons will make their full stroke as they pass between the bottom and the top positions. Now, when the A-cylinders are moving down on the near side, as described above, oil is forced through the valveplate port of this side into the B-cylinders of the near side. But they cannot receive the oil unless their pistons move back to give space. *This movement of the pistons communicated to the inclined socket ring through the connecting rods causes the socket ring to rotate* on its roller thrust bearing, and to carry the shaft around with it. The shaft in turn rotates the cylinder barrel keyed to it, and the whole group rotates in the opposite direction to the rotation of the A-shaft. (See Fig. 904.)

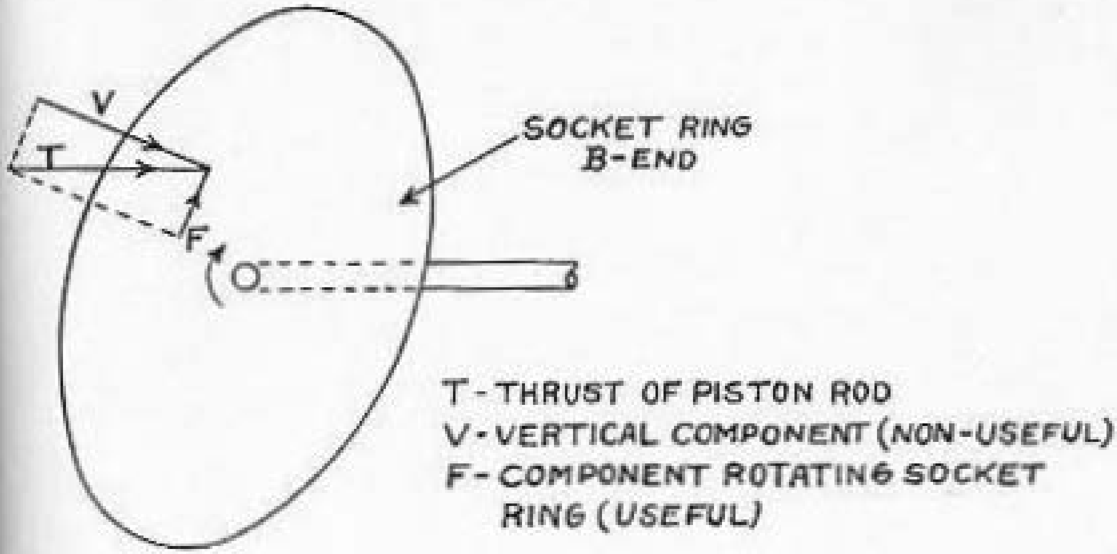
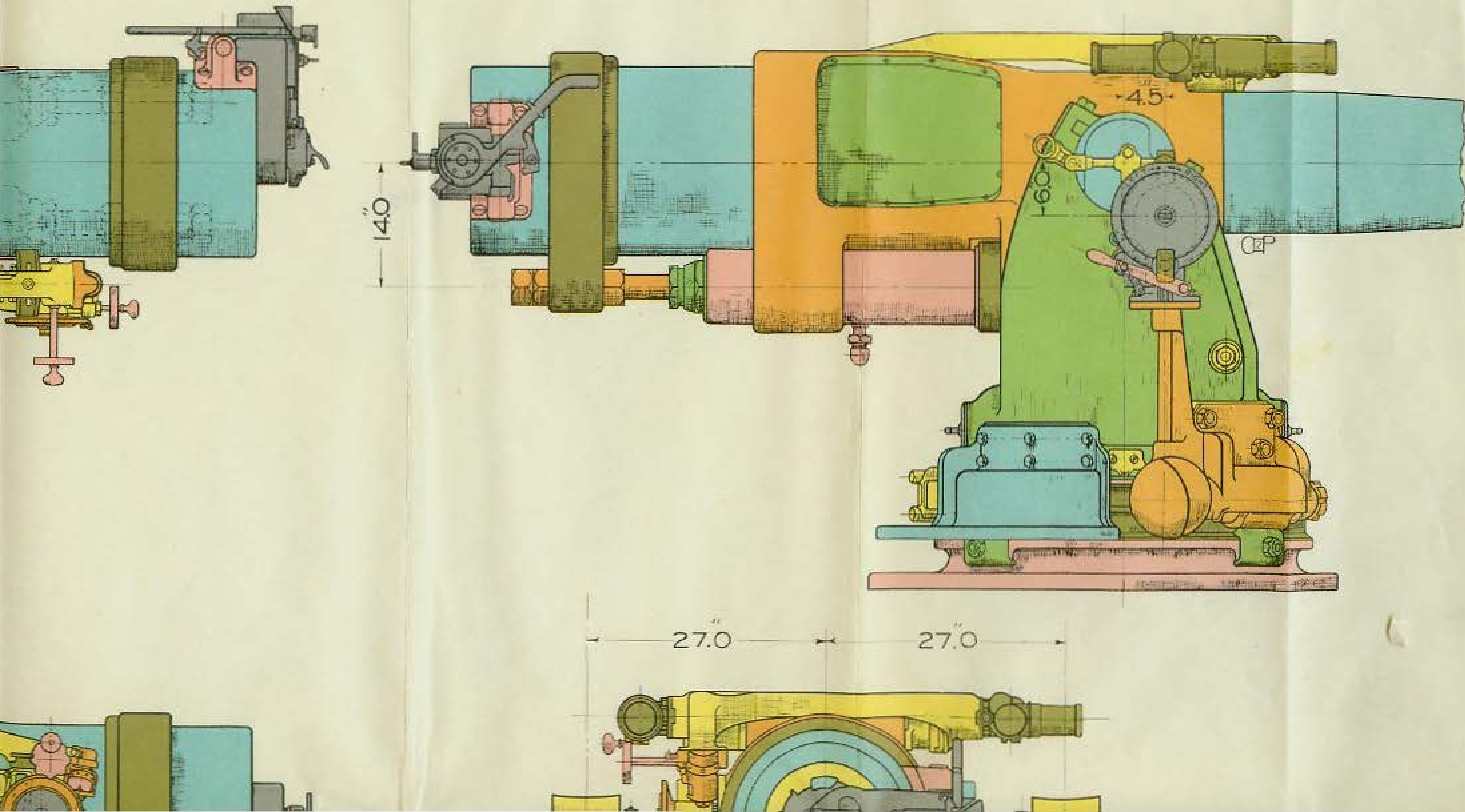
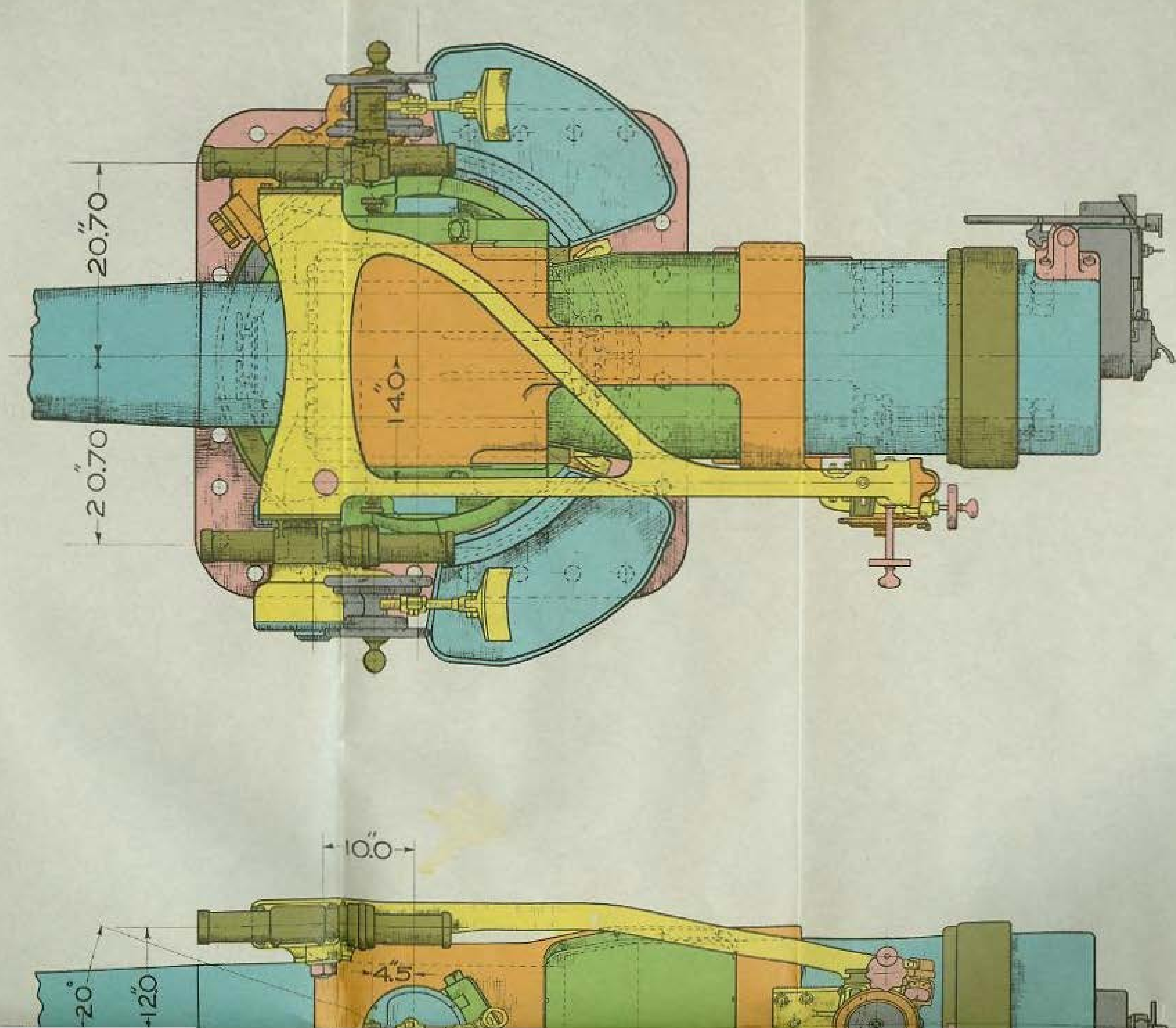


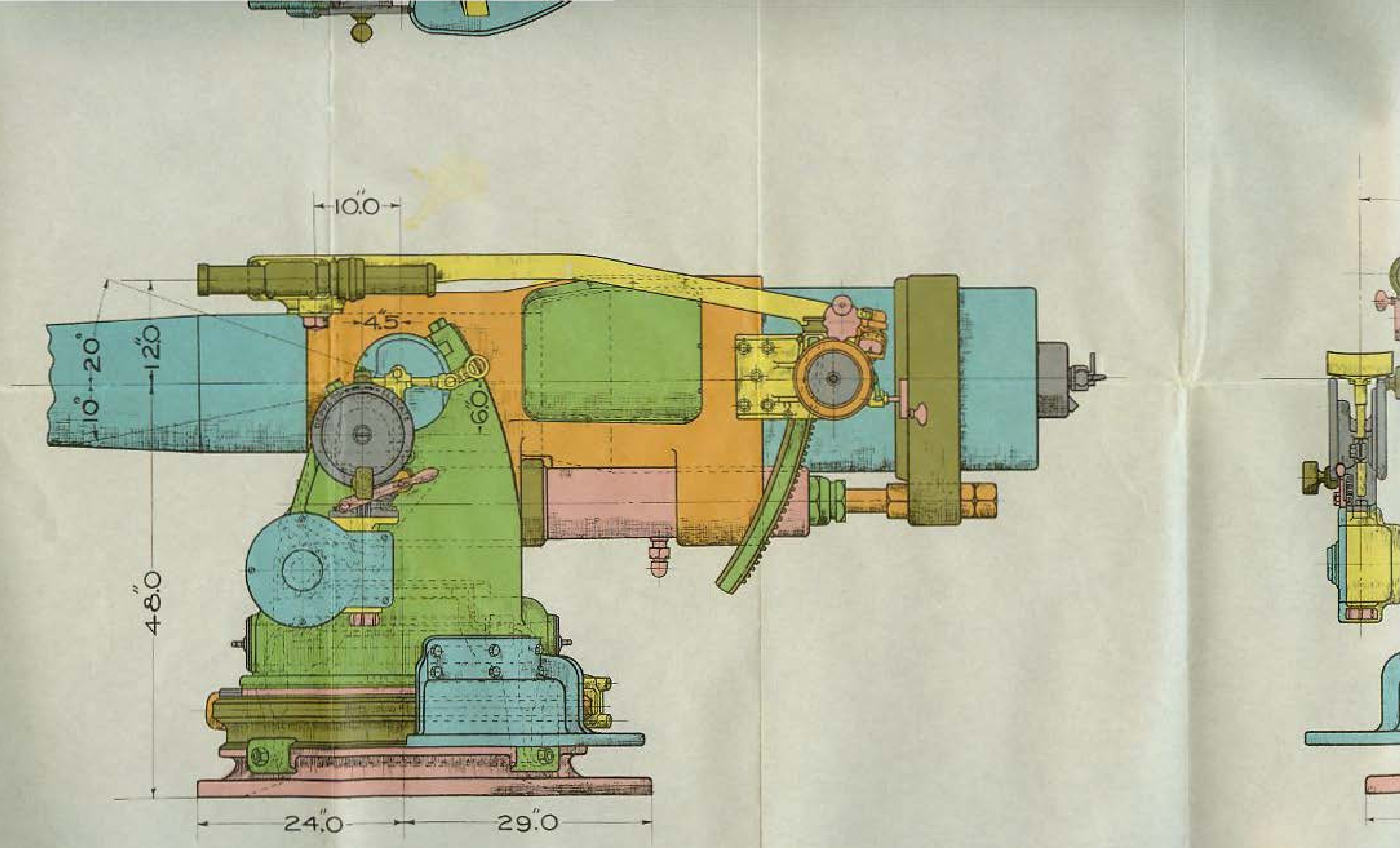
FIG. 904.

The speed of rotation of the B-shaft depends upon the quantity of oil it must take care of. The B-socket ring being always set at its maximum angle gives the pistons their full stroke. If each cylinder has a capacity of say 3 cubic inches, the revolving of all nine of the B-cylinders would transfer 27 cubic inches of oil from the near side to the far side. If now the control shaft of the A-end be turned so as to tilt the A-socket ring only a little, say enough to reciprocate each piston to the extent of displacing 1-100 of a cubic inch, all nine of the A-cylinders will together transfer 9-100 cubic inches of oil from the far side to the near side at each rotation of the shaft. Since the capacity of the B-cylinders per rotation of the B-shaft is 27 cubic inches, 300 rotations of the A-shaft will be necessary to rotate the B-shaft once. If the A-socket ring be tilted still farther, the B-shaft must rotate proportionately faster. The speed of the B-shaft is thus dependent upon the angle through which the tilting box has been turned.

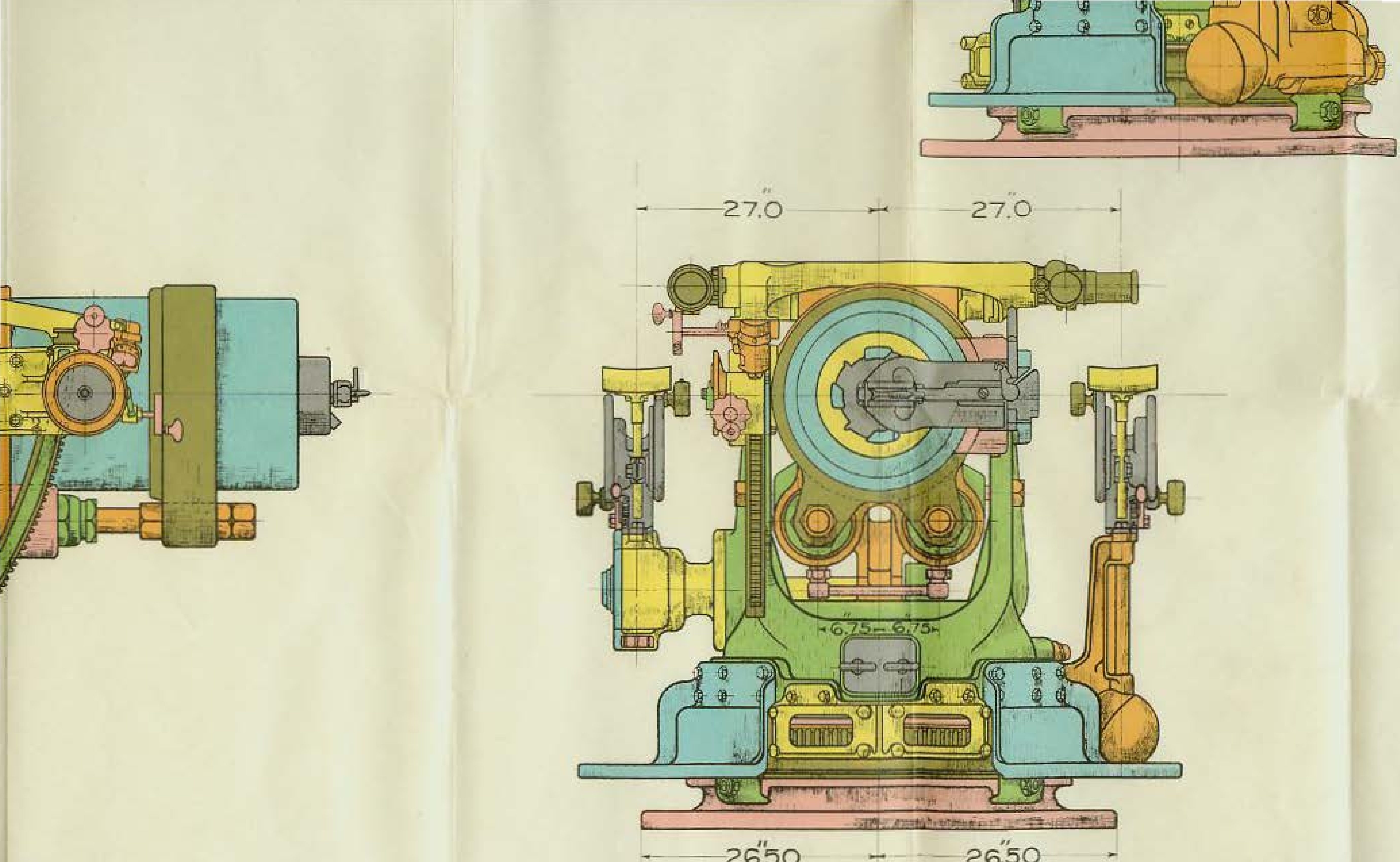
We have thus far spoken of the A-socket ring as tilted in one direction only. If it be tilted in the opposite direction, that is, with the top towards the valveplate, and the A-shaft still rotates in the same direction as before, the oil will be sucked in from the near port of the valveplate and carried across the lower land to the far side. This will, of course, cause the B-shaft to rotate opposite to its former direction, that is, in the same direction as the A-shaft.


14.0"
6.0
4.5
27.0"
27.0"


20.70"
20.70"
14.0"
10.0"
4.5"
20°
12.0"

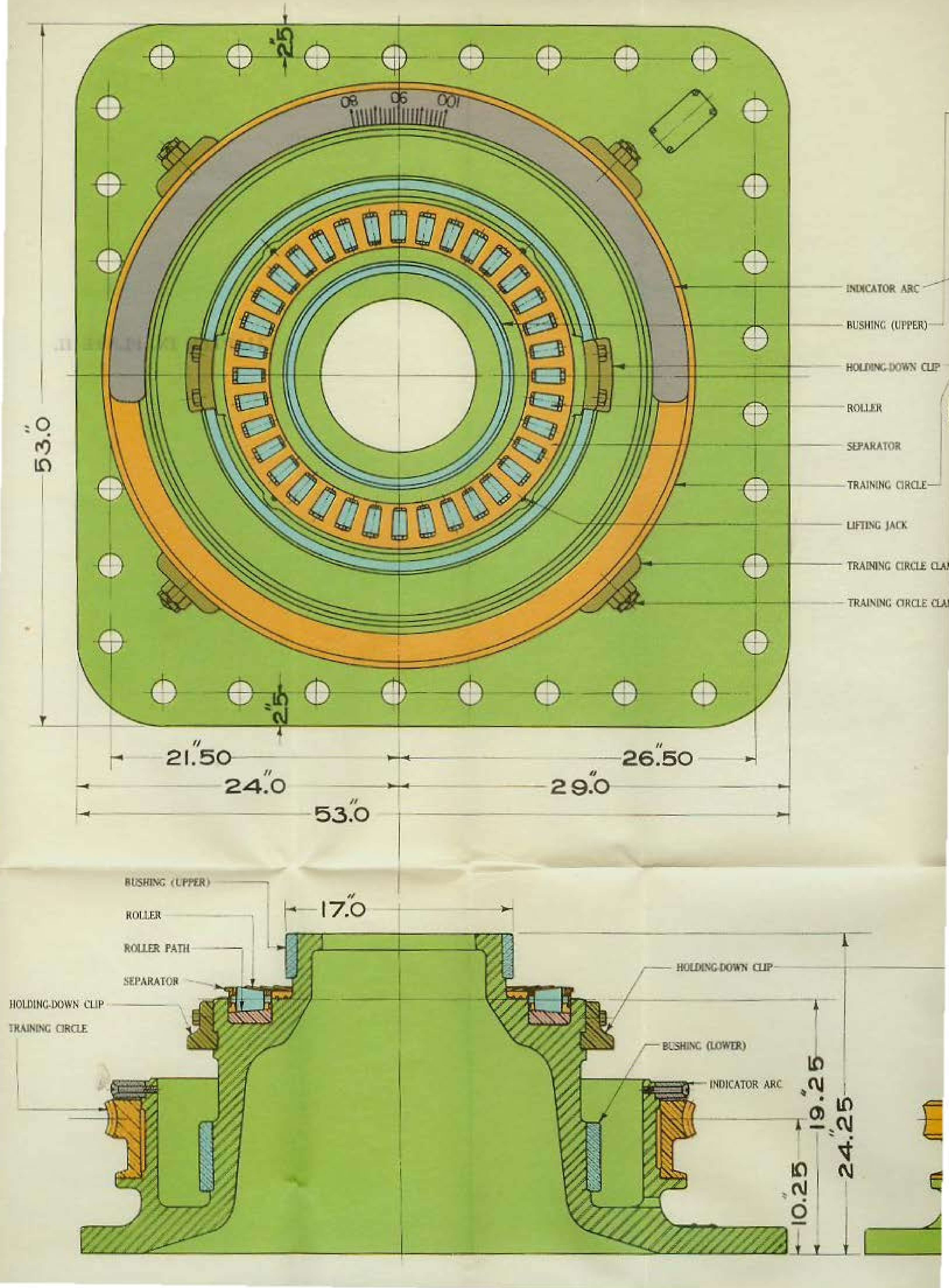


General Arrangement of the 5-inch Mount, Mark XIII, Modification 3

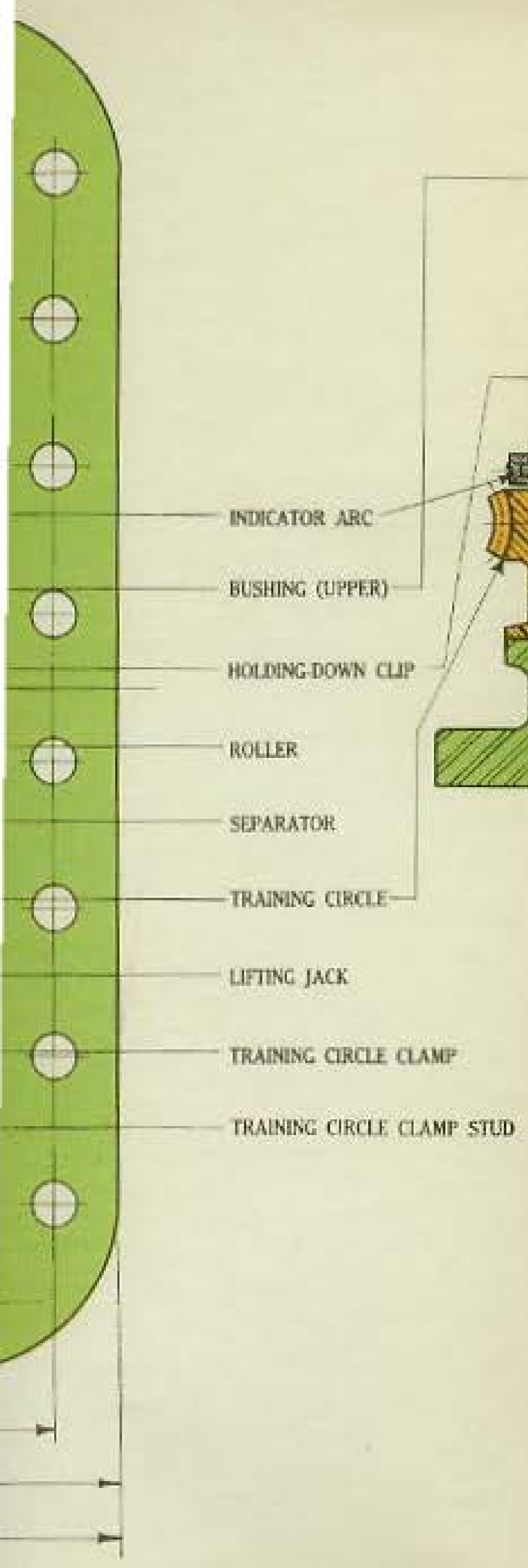


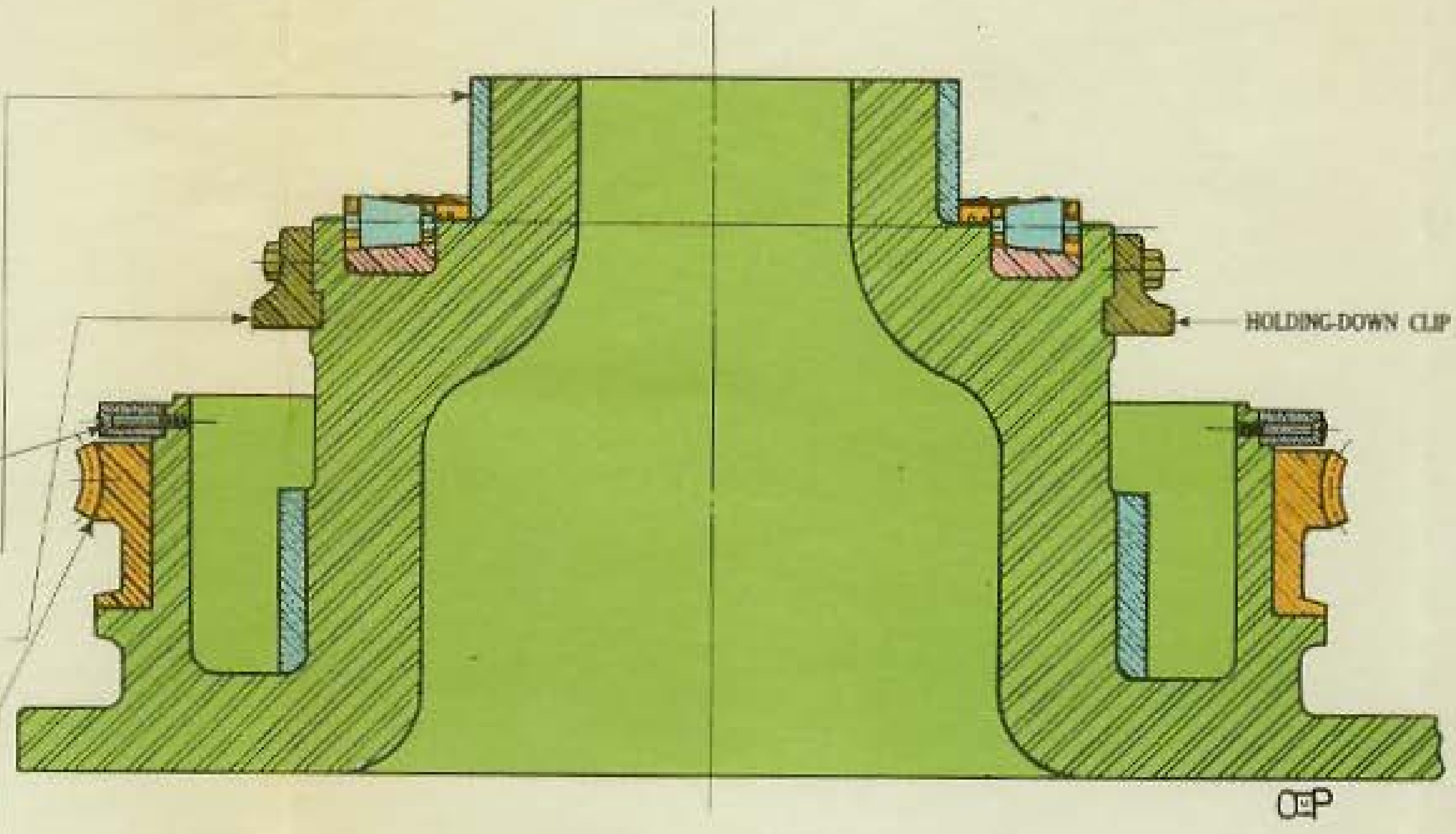
General Arrangement of the 5-inch Mount, Mark XIII, Modification 3

Litho. A. Hoen & Co., Inc.

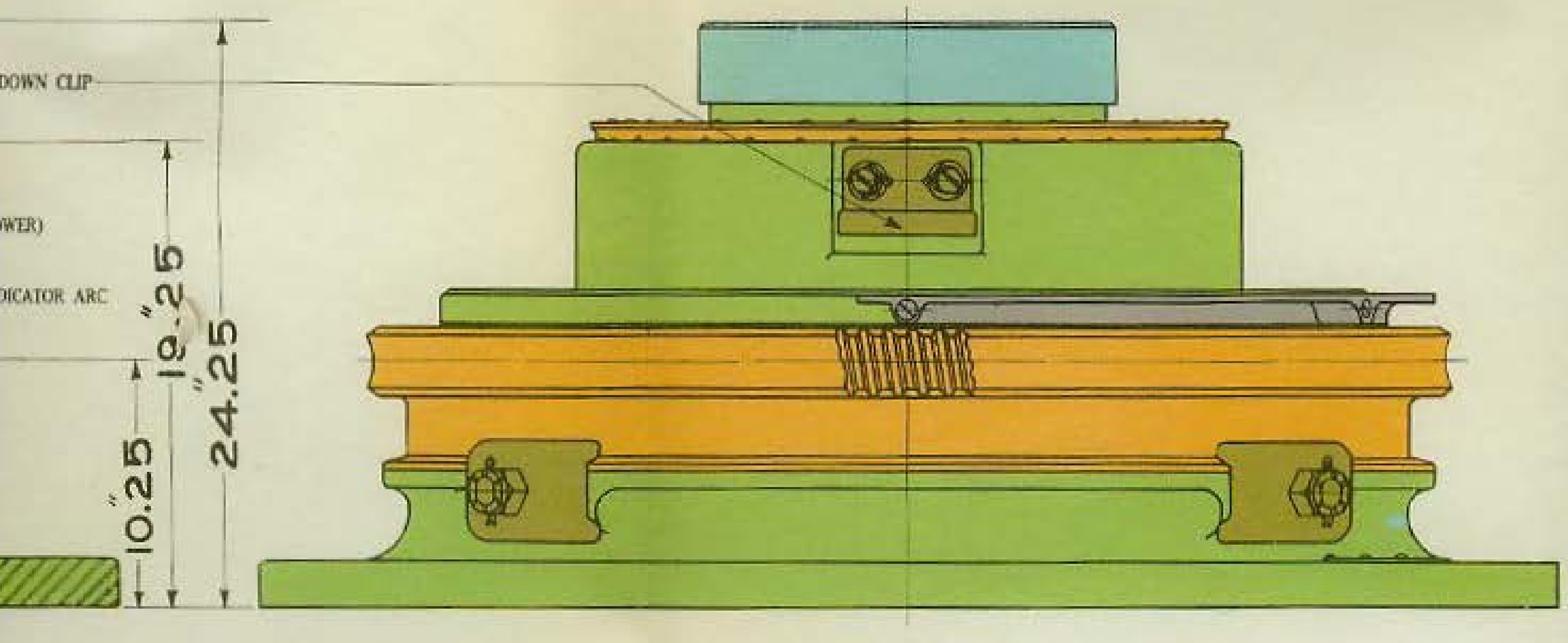


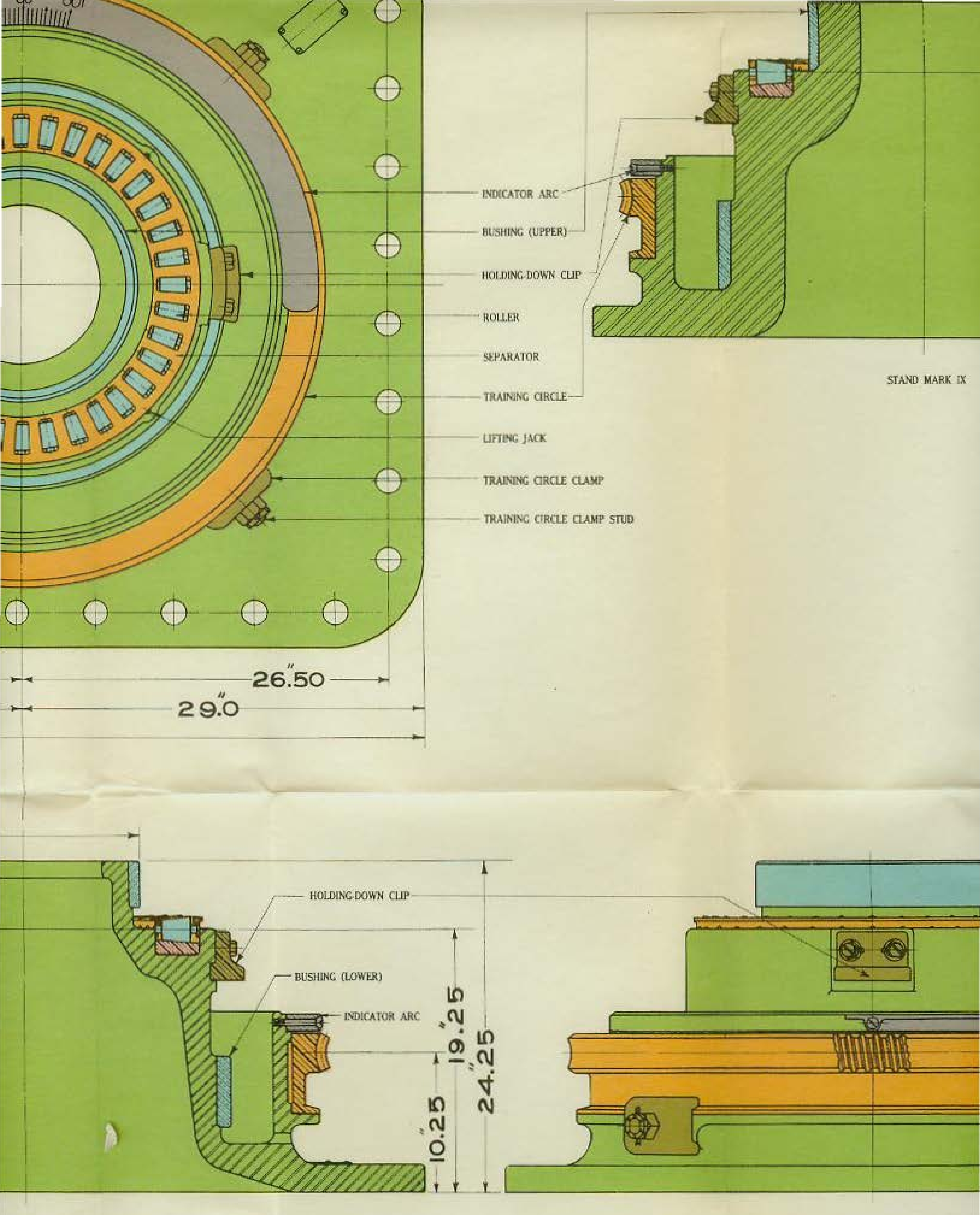
80
90
100
INDICATOR ARC
BUSHING (UPPER)
HOLDING-DOWN CLIP
ROLLER
SEPARATOR
TRAINING CIRCLE
LIFTING JACK
TRAINING CIRCLE CLA
TRAINING CIRCLE CLA
2.5"
53.0"
21.50"
26.50"
24.0"
29.0"
53.0"
BUSHING (UPPER)
ROLLER
ROLLER PATH
SEPARATOR
HOLDING-DOWN CLIP
TRAINING CIRCLE
17.0"
HOLDING-DOWN CLIP
BUSHING (LOWER)
INDICATOR ARC
19.25"
24.25"
10.25"



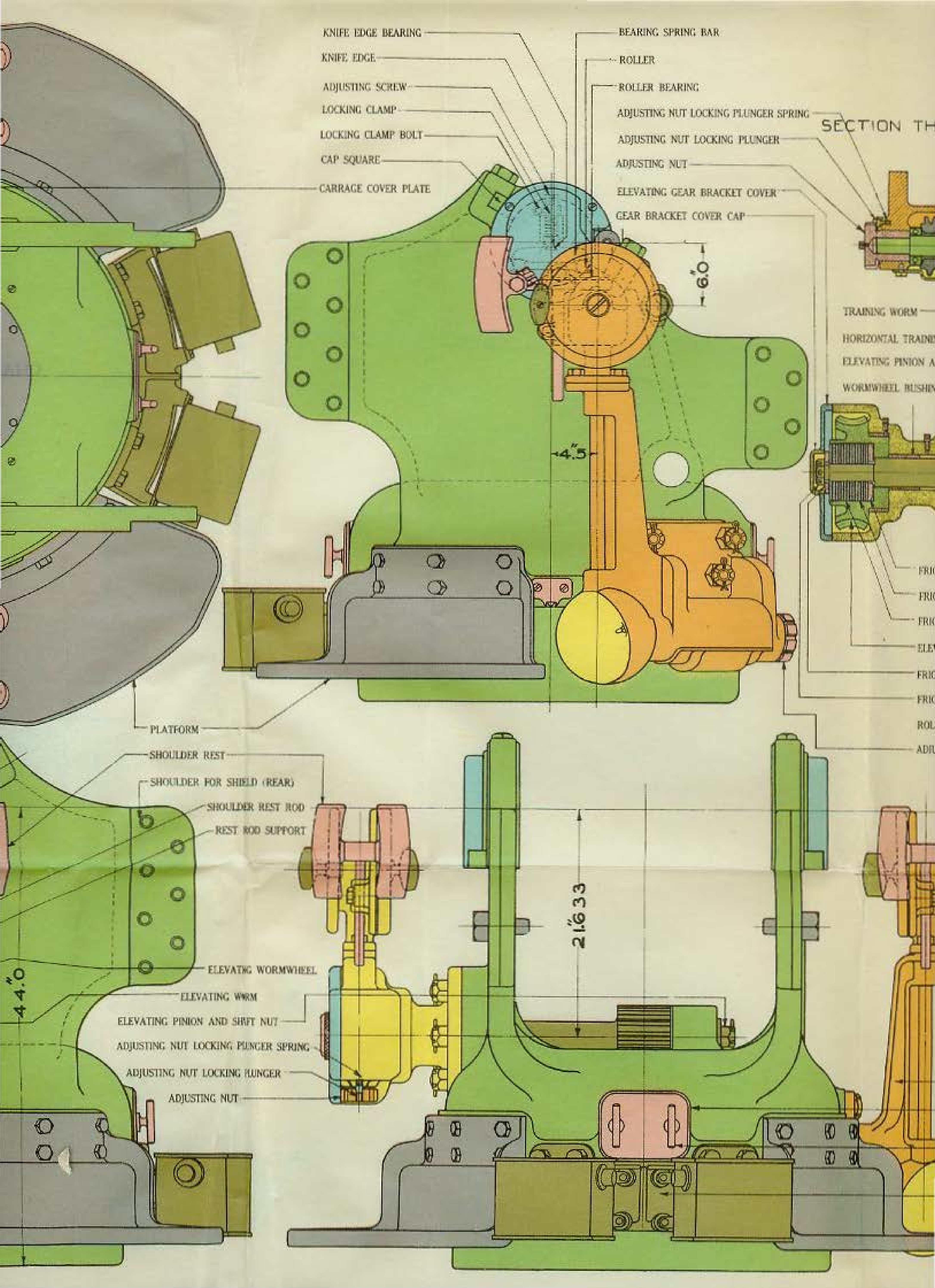


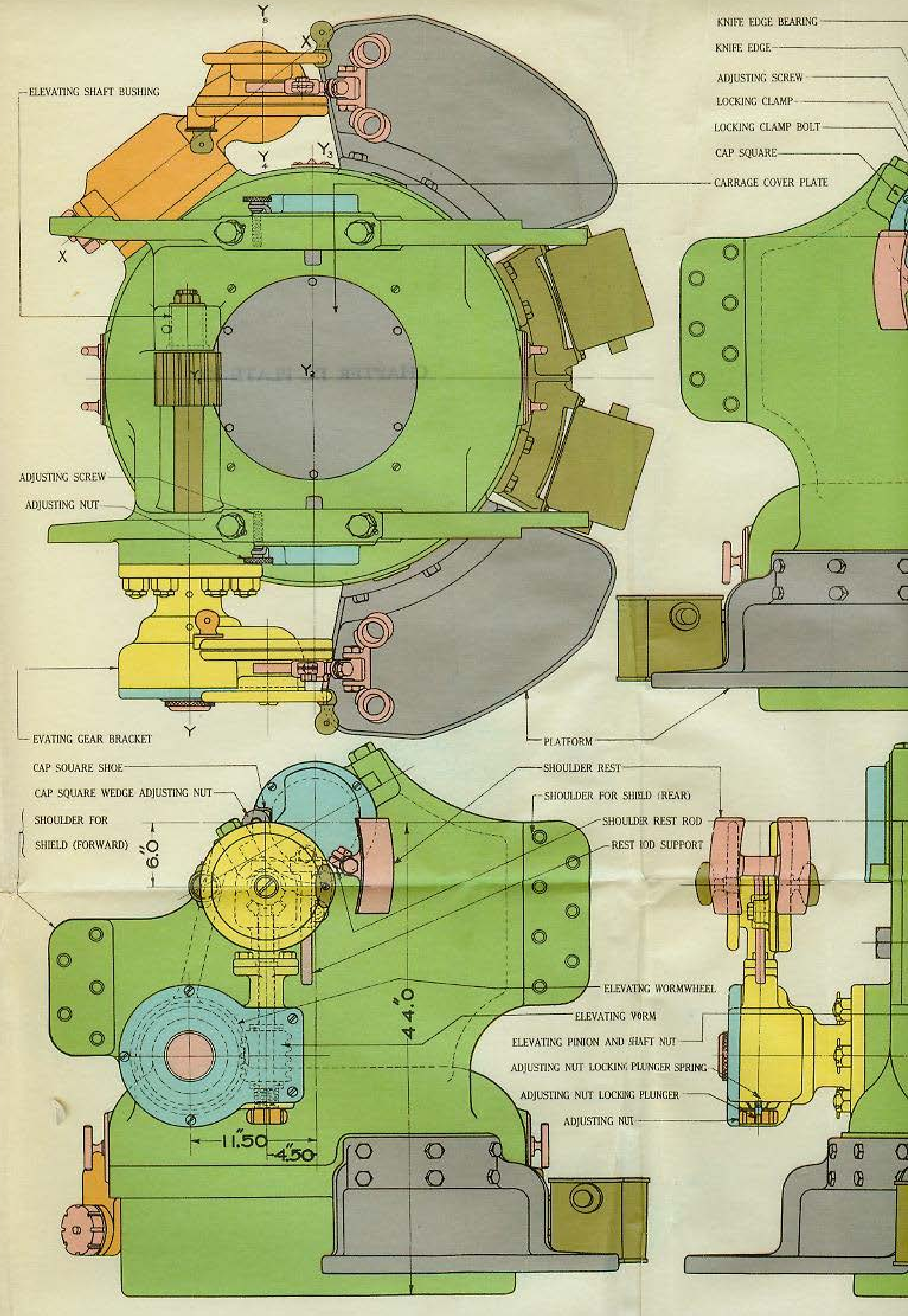
STAND MARK IX



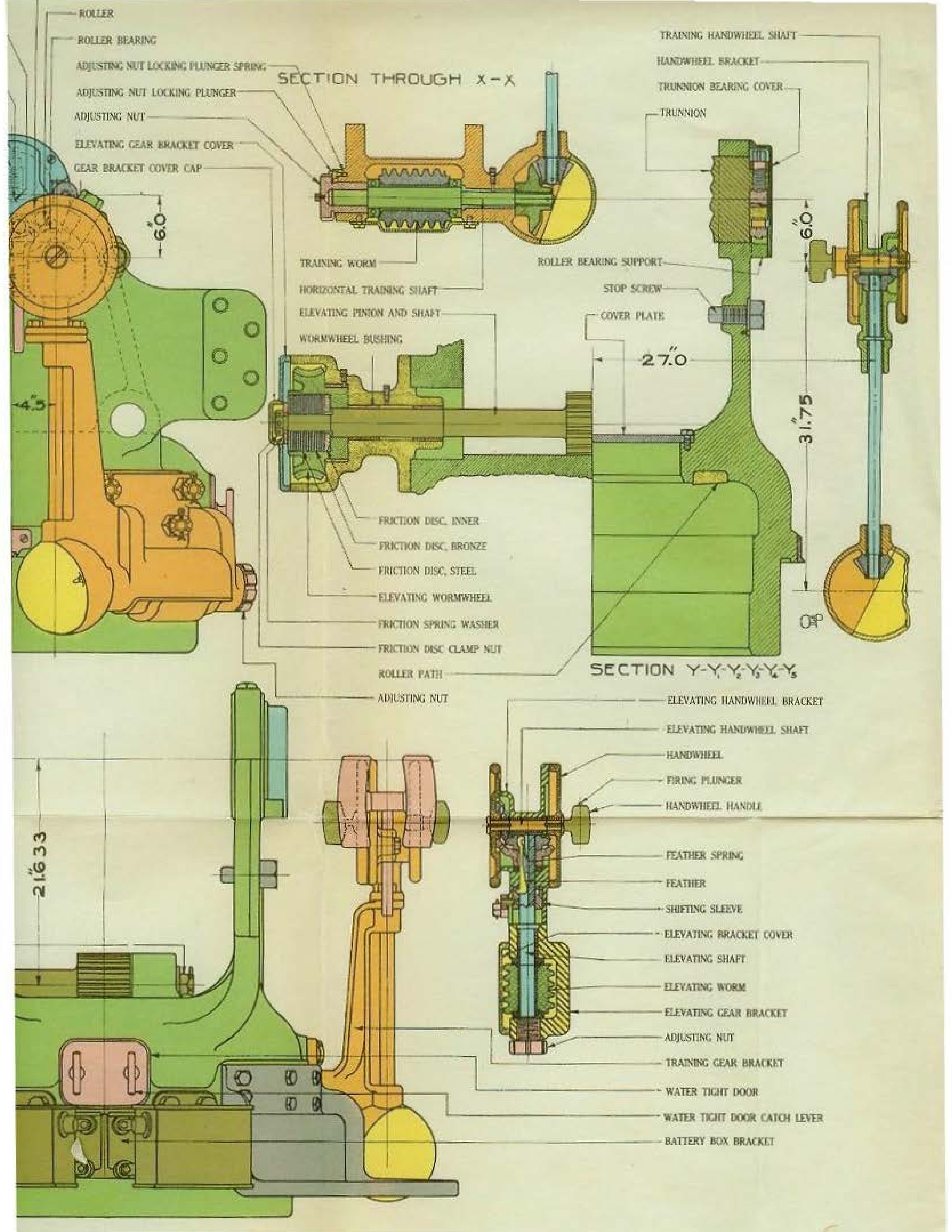


General Arrangement of the 5-inch Stand, Mark XI

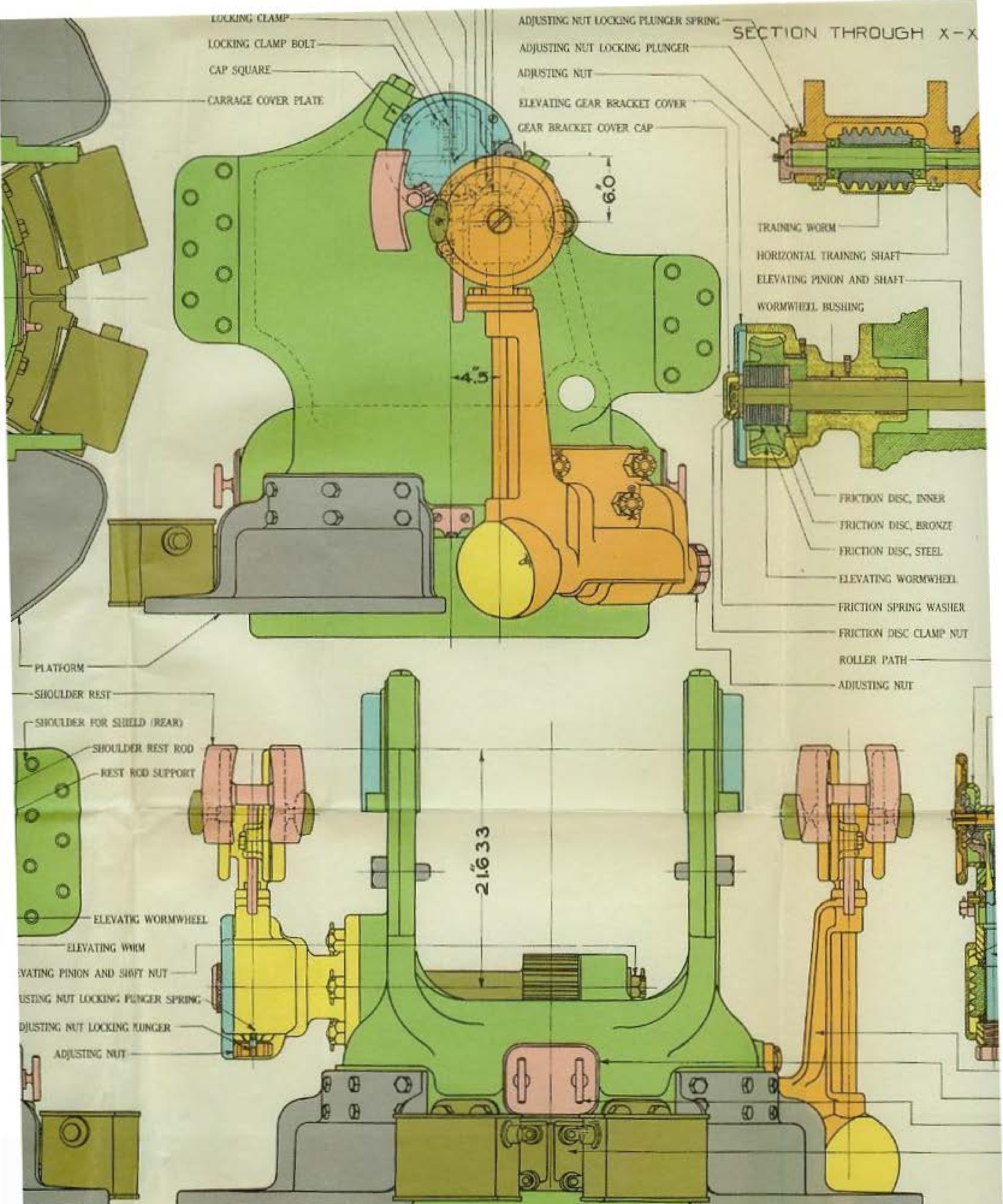

KNIFE EDGE BEARING
KNIFE EDGE
ADJUSTING SCREW
LOCKING CLAMP
LOCKING CLAMP BOLT
CAP SQUARE
CARRAGE COVER PLATE
BEARING SPRING BAR
ROLLER
ROLLER BEARING
ADJUSTING NUT LOCKING PLUNGER SPRING
ADJUSTING NUT LOCKING PLUNGER
ADJUSTING NUT
ELEVATING GEAR BRACKET COVER
GEAR BRACKET COVER CAP
6.0"
4.5"
TRAINING WORM
PLATFORM
SHOULDER REST
SHOULDER FOR SHIELD (REAR)
SHOULDER REST ROD
REST ROD SUPPORT
21.633"
44.0"
ELEVATNG WORMWHEEL
ELEVATING WORM
ELEVATING PINION AND SHFT NUT
ADJUSTING NUT LOCKING PLUNGER SPRING
ADJUSTING NUT LOCKING PLUNGER
ADJUSTING NUT



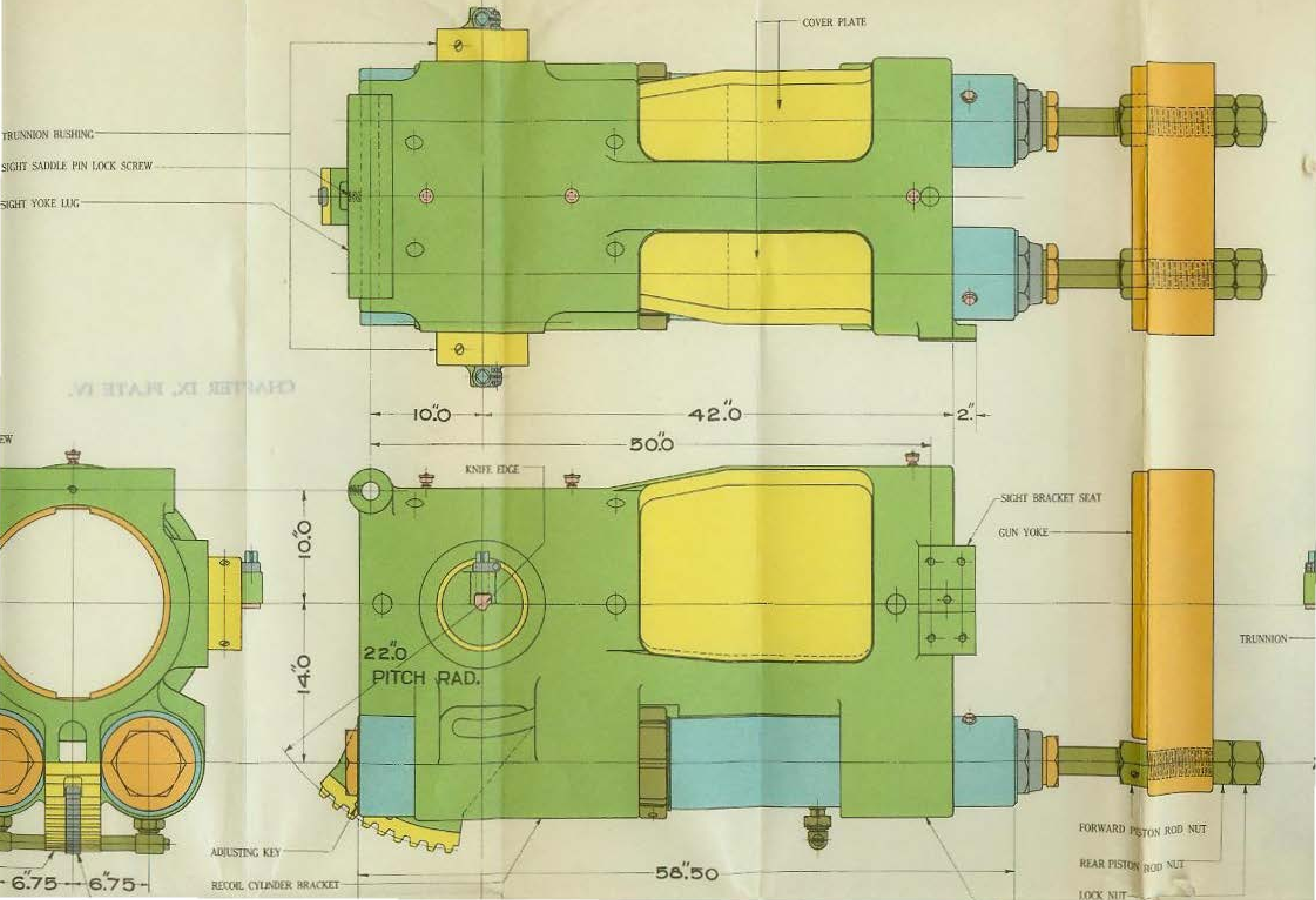
KNIFE EDGE BEARING
KNIFE EDGE
ADJUSTING SCREW
LOCKING CLAMP
LOCKING CLAMP BOLT
CAP SQUARE
CARRAGE COVER PLATE
ELEVATING SHAFT BUSHING
X
Y
Y
Y
Y
Y
X
ADJUSTING SCREW
ADJUSTING NUT
EVATING GEAR BRACKET
Y
PLATFORM
CAP SOUARE SHOE
CAP SQUARE WEDGE ADJUSTING NUT
SHOULDER FOR
SHIELD (FORWARD)
6.0"
SHOULDER REST
SHOULDER FOR SHIELD (REAR)
SHOULDER REST ROD
REST ROD SUPPORT
ELEVATNG WORMWHEEL
ELEVATING VORM
ELEVATING PINION AND SHAFT NUT
ADJUSTING NUT LOCKING PLUNGER SPRING
ADJUSTING NUT LOCKING PLUNGER
ADJUSTING NUT
4'4.0"
11.50
4.50

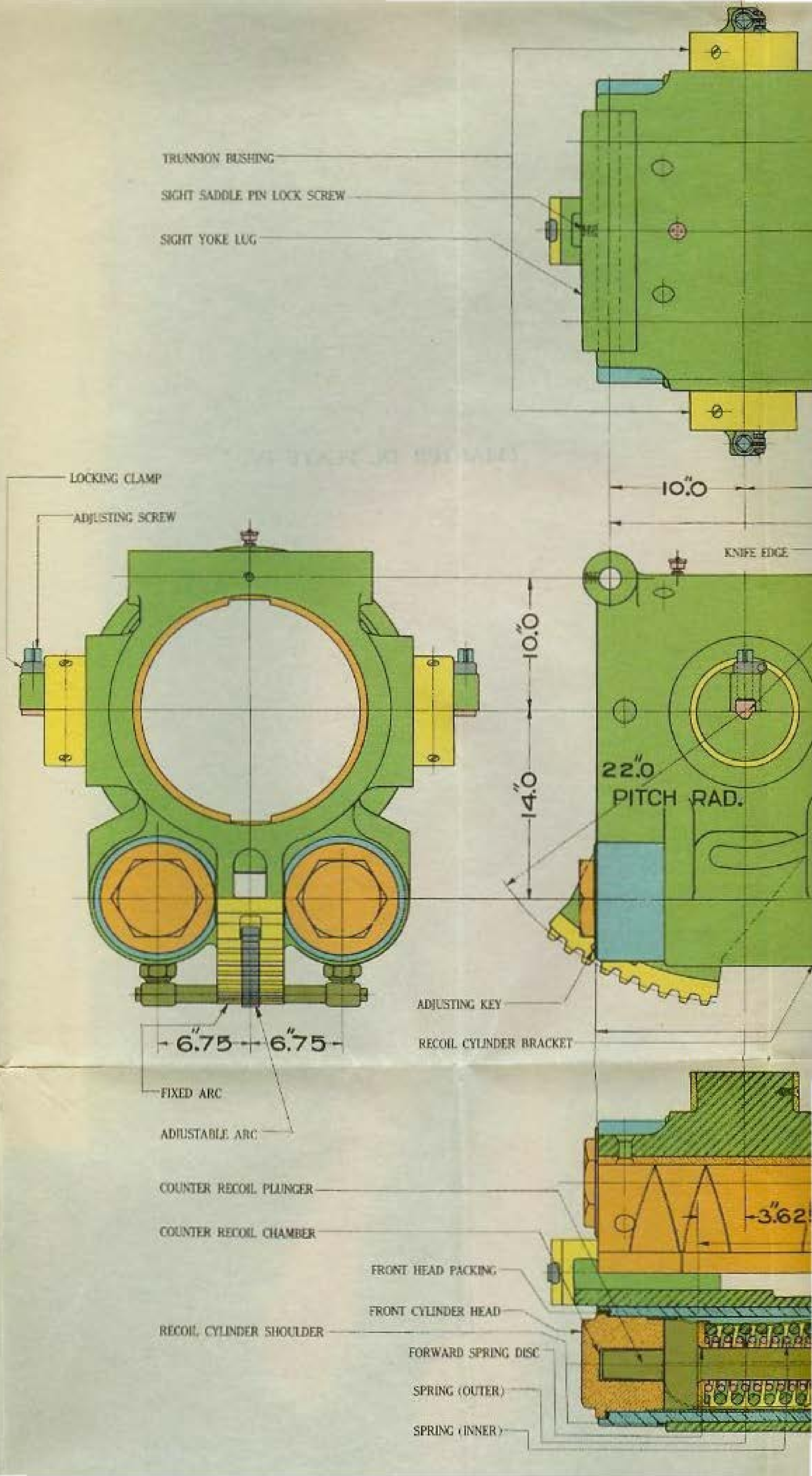


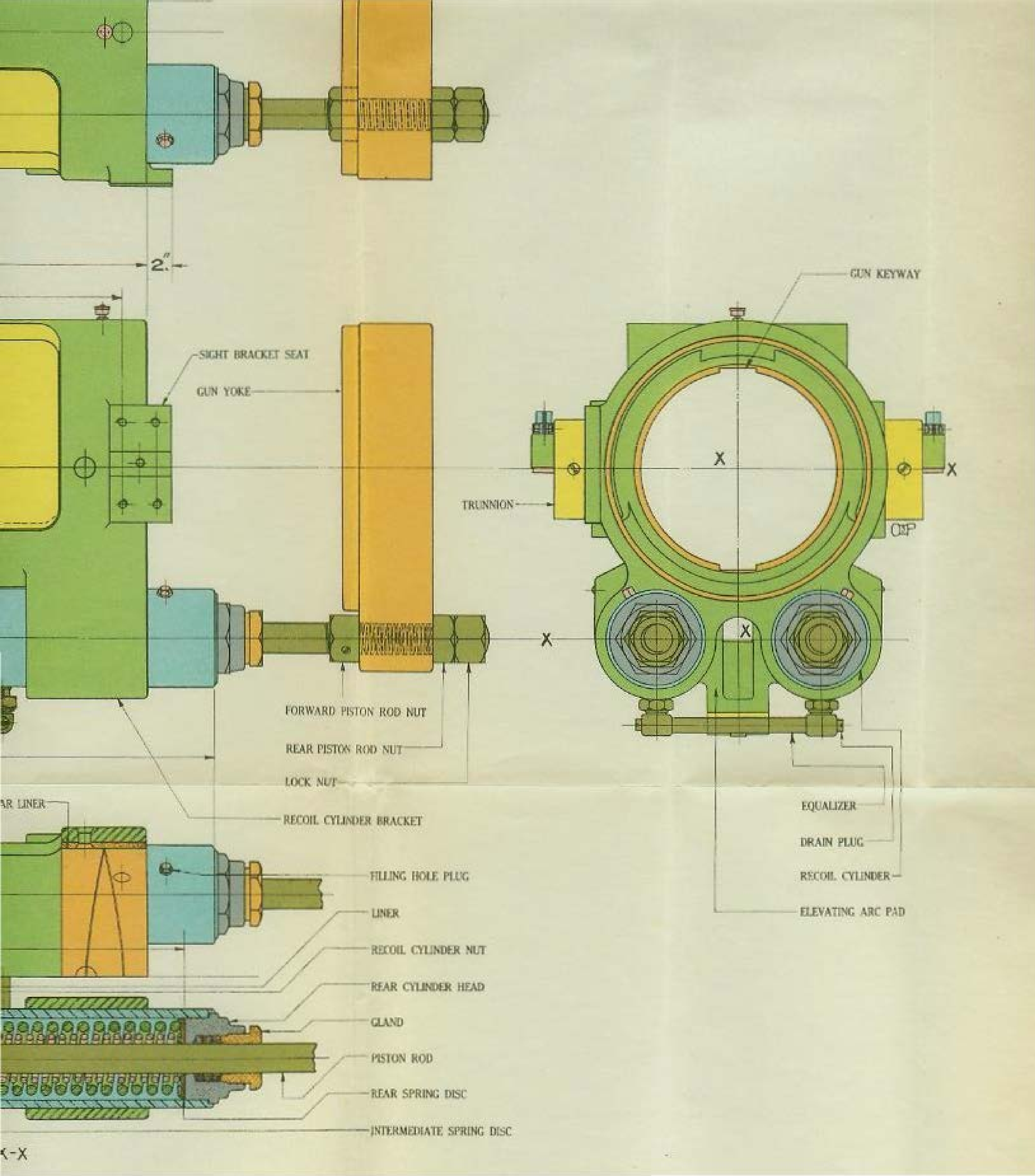
ROLLER
ROLLER BEARING
ADJUSTING NUT LOCKING PLUNGER SPRING
ADJUSTING NUT LOCKING PLUNGER
ADJUSTING NUT
ELEVATING GEAR BRACKET COVER
GEAR BRACKET COVER CAP
SECTION THROUGH X-X
TRAINING WORM
HORIZONTAL TRAINING SHAFT
ELEVATING PINION AND SHAFT
WORMWHEEL BUSHING
6.0"
4.5"
TRAINING HANDWHEEL SHAFT
HANDWHEEL BRACKET
TRUNNION BEARING COVER
TRUNNION
ROLLER BEARING SUPPORT
STOP SCREW
COVER PLATE
27.0"
6.0"
31.75"
FRICTION DISC, INNER
FRICTION DISC, BRONZE
FRICTION DISC, STEEL
ELEVATING WORMWHEEL
FRICTION SPRING WASHER
FRICTION DISC CLAMP NUT
ROLLER PATH
ADJUSTING NUT
SECTION Y-Y1-Y2-Y3-Y4-Y5
21.633"
ELEVATING HANDWHEEL BRACKET
ELEVATING HANDWHEEL SHAFT
HANDWHEEL
FIRING PLUNGER
HANDWHEEL HANDLE
FEATHER SPRING
FEATHER
SHIFTING SLEEVE
ELEVATING BRACKET COVER
ELEVATING SHAFT
ELEVATING WORM
ELEVATING GEAR BRACKET
ADJUSTING NUT
TRAINING GEAR BRACKET
WATER TIGHT DOOR
WATER TIGHT DOOR CATCH LEVER
BATTERY BOX BRACKET



General Arrangement of the 5-inch Carriage, Mark XIII

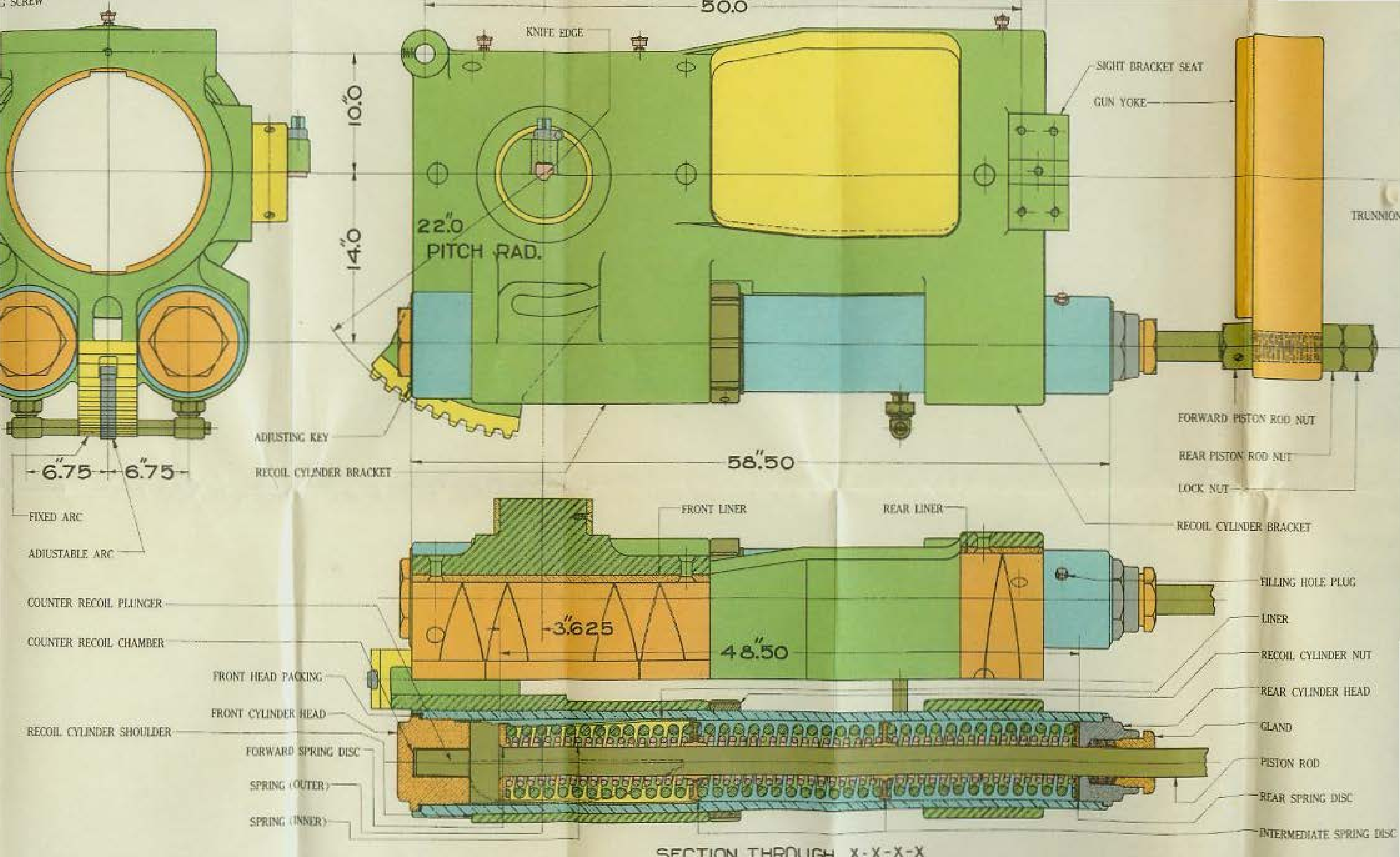

COVER PLATE
TRUNNION BUSHING
SIGHT SADDLE PIN LOCK SCREW
SIGHT YOKE LUG
10.0"
42.0"
2"
50.0"
KNIFE EDGE
SIGHT BRACKET SEAT
GUN YOKE
TRUNNION
10.0"
14.0"
22.0" PITCH RAD.
ADJUSTING KEY
RECOIL CYLINDER BRACKET
58.50"
FORWARD PISTON ROD NUT
REAR PISTON ROD NUT
LOCK NUT
6.75
6.75


TRUNNION BUSHING
SIGHT SADDLE PIN LOCK SCREW
SIGHT YOKE LUG
LOCKING CLAMP
ADJUSTING SCREW
10.0"
KNIFE EDGE
10.0"
14.0"
22.0"
PITCH RAD.
ADJUSTING KEY
RECOIL CYLINDER BRACKET
6.75"
6.75"
FIXED ARC
ADJUSTABLE ARC
COUNTER RECOIL PLUNGER
COUNTER RECOIL CHAMBER
FRONT HEAD PACKING
FRONT CYLINDER HEAD
RECOIL CYLINDER SHOULDER
FORWARD SPRING DISC
SPRING (OUTER)
SPRING (INNER)

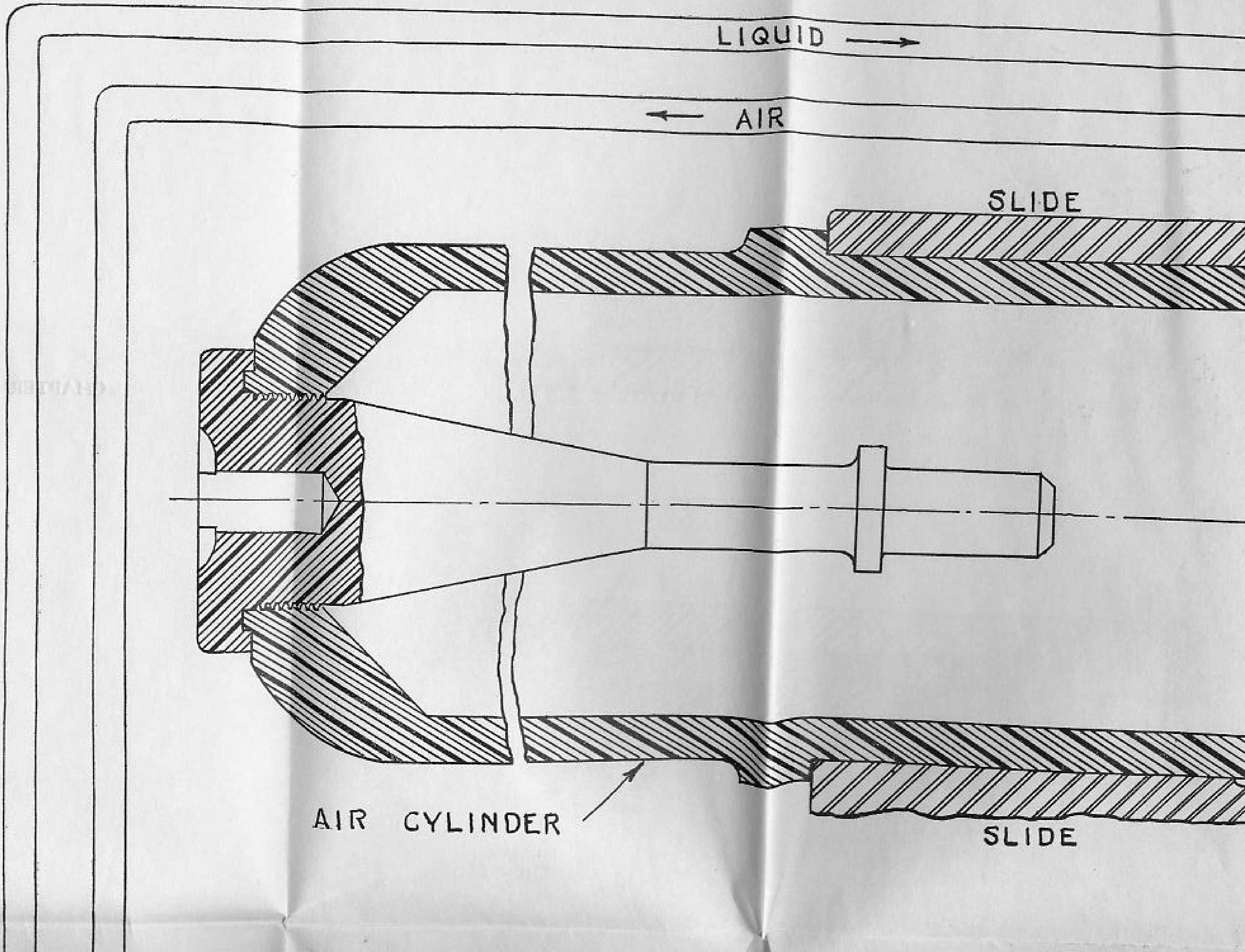


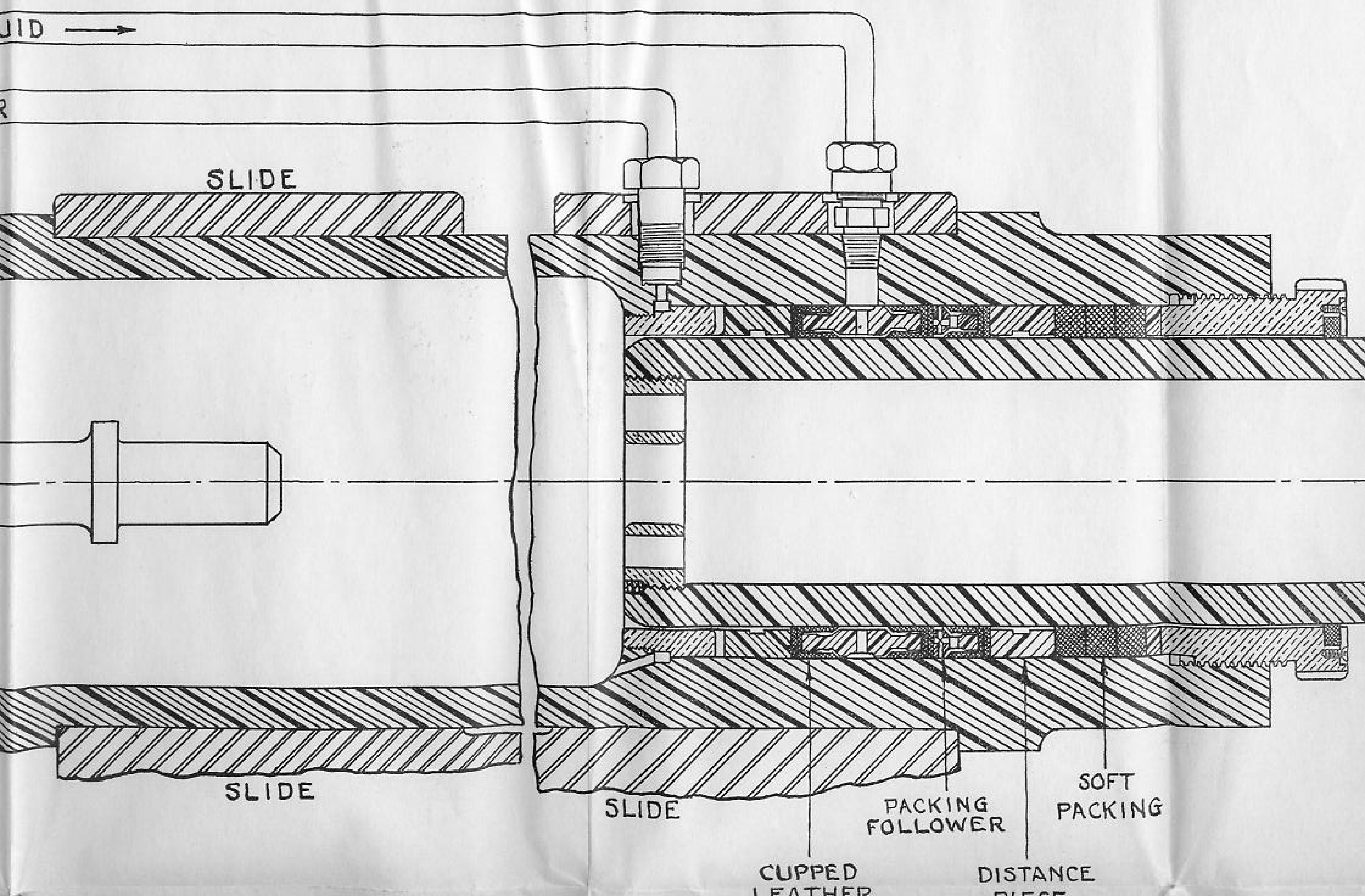
2"
GUN KEYWAY
SIGHT BRACKET SEAT
GUN YOKE
X
X
TRUNNION
X
X
FORWARD PISTON ROD NUT
REAR PISTON ROD NUT
LOCK NUT
AR LINER
RECOIL CYLINDER BRACKET
EQUALIZER
DRAIN PLUG
RECOIL CYLINDER
ELEVATING ARC PAD
FILLING HOLE PLUG
LINER
RECOIL CYLINDER NUT
REAR CYLINDER HEAD
GLAND
PISTON ROD
REAR SPRING DISC
INTERMEDIATE SPRING DISC

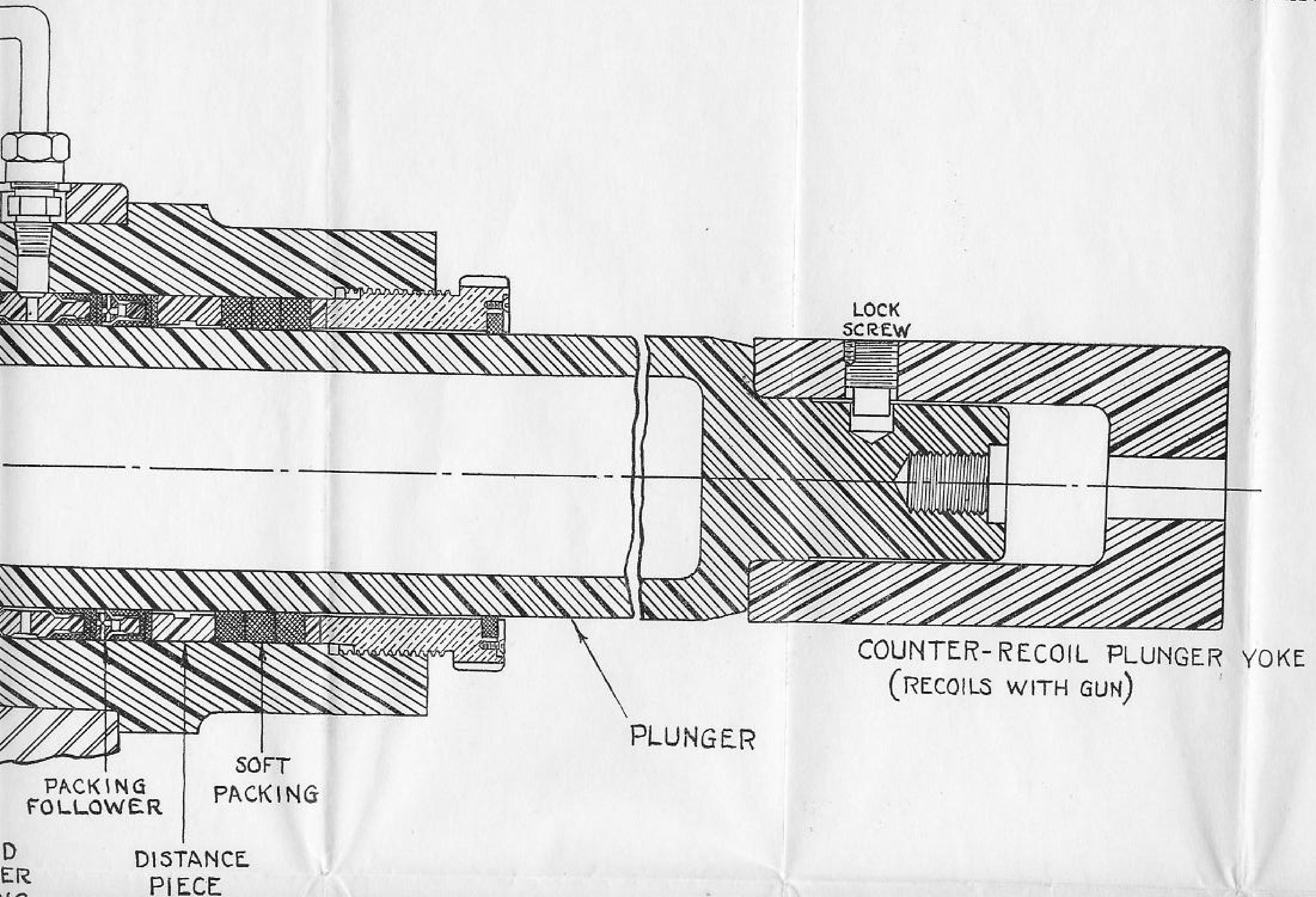
<-X

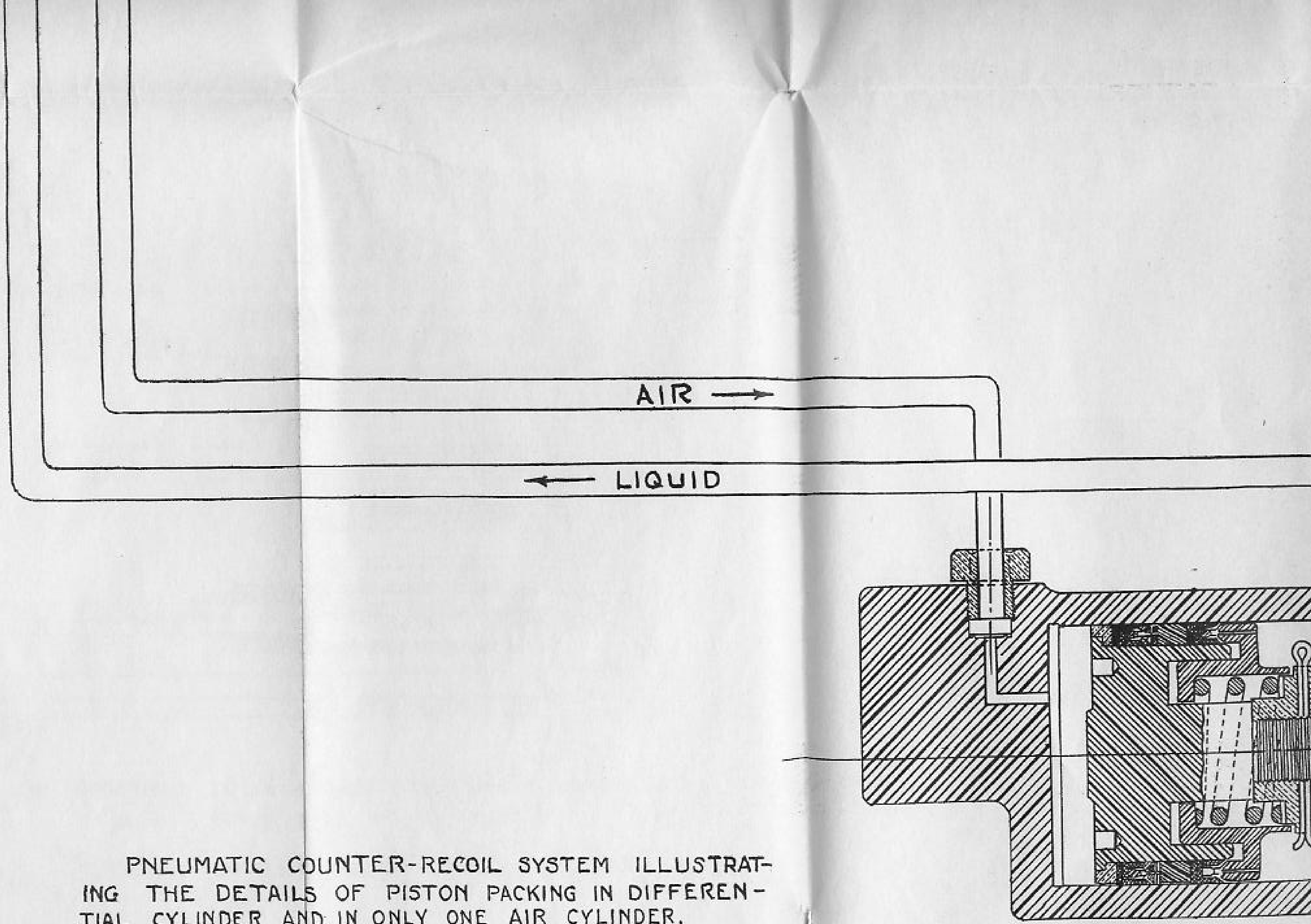


General Arrangement of the 5-inch Slide, Mark XIII


LIQUID
AIR
SLIDE
AIR CYLINDER
SLIDE


UID
R
SLIDE
SLIDE
SLIDE
PACKING
FOLLOWER
SOFT
PACKING
CUPPED
DISTANCE


LOCK
SCREW
COUNTER-RECOIL PLUNGER YOKE
(RECOILS WITH GUN)
PLUNGER
SOFT
PACKING
PACKING
FOLLOWER
DISTANCE
PIECE
D
ER



PNEUMATIC COUNTER-RECOIL SYSTEM ILLUSTRATING THE DETAILS OF PISTON PACKING IN DIFFERENTIAL CYLINDER AND IN ONLY ONE AIR CYLINDER.

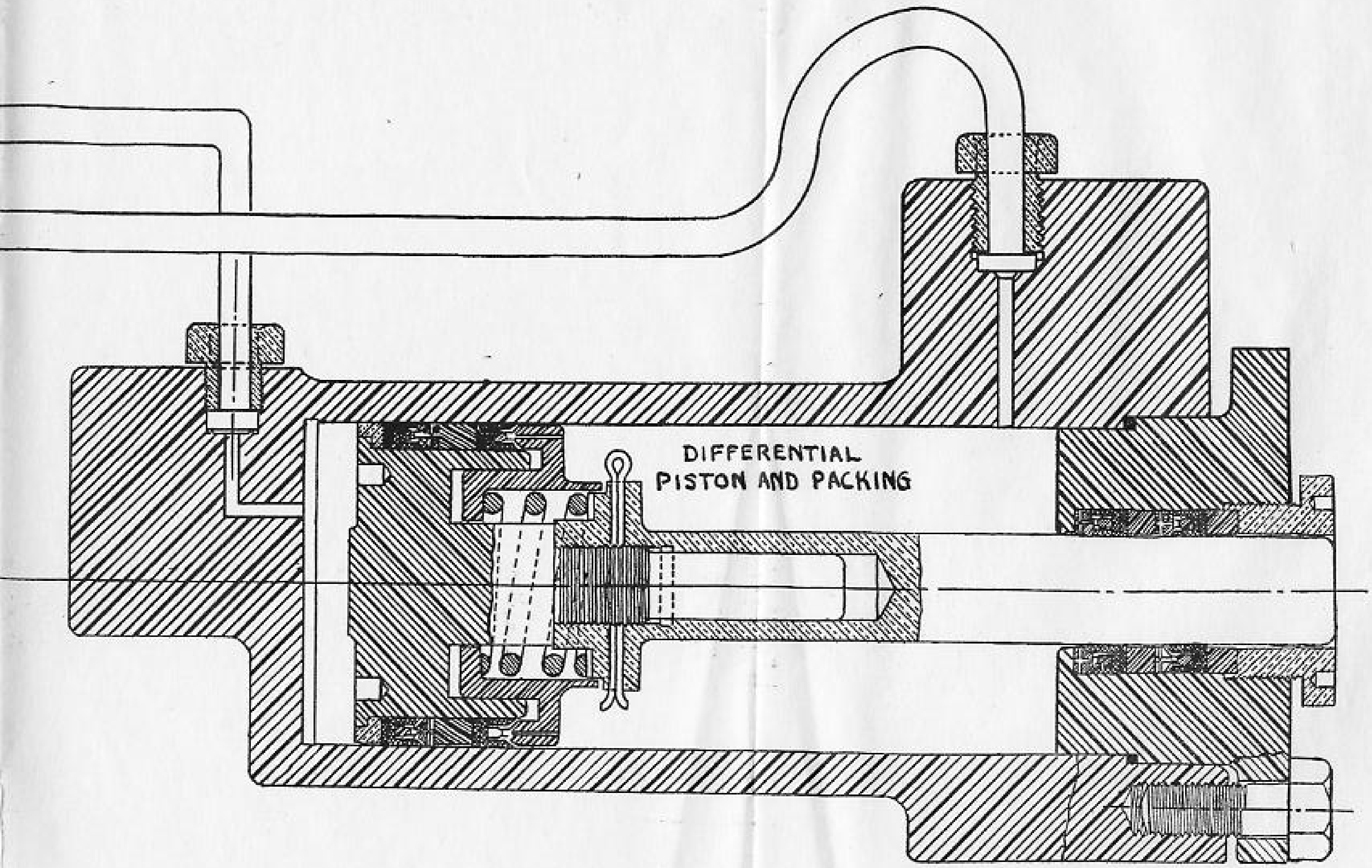
THE PIPE CONNECTIONS FOR AIR AND LIQUID BETWEEN THE TWO CYLINDERS ARE SCHEMATIC ONLY.

FILLING AND GUAGE CONNECTIONS ARE OMITTED.

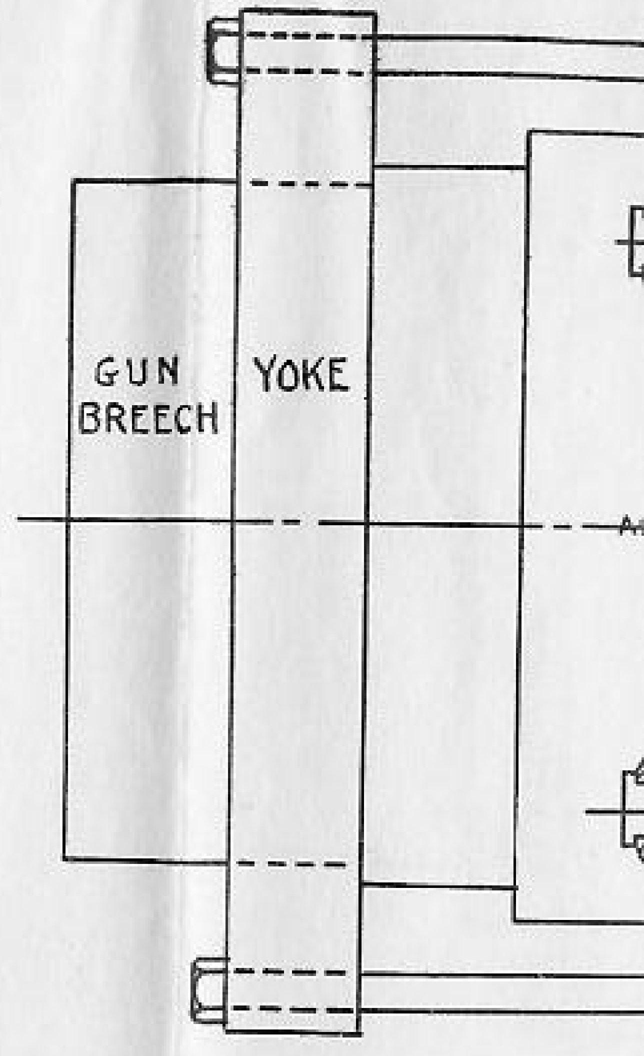
DIFFER

CUPPED LEATHER PACKING

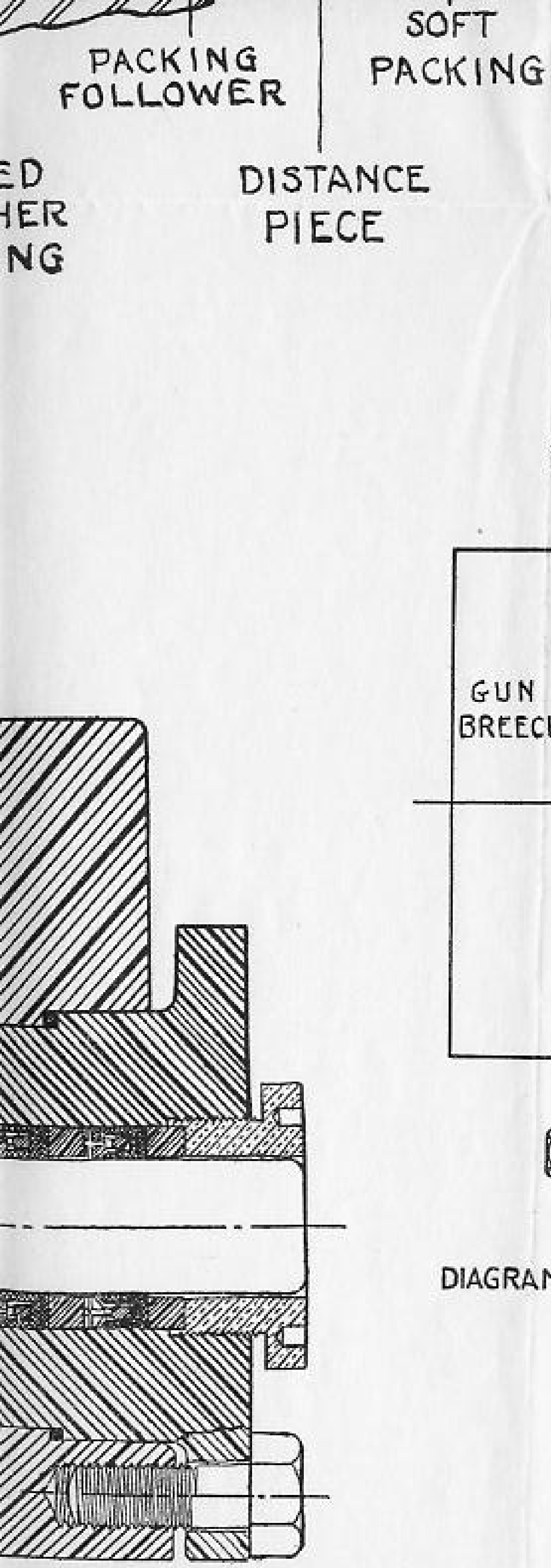
DISTANCE PIECE

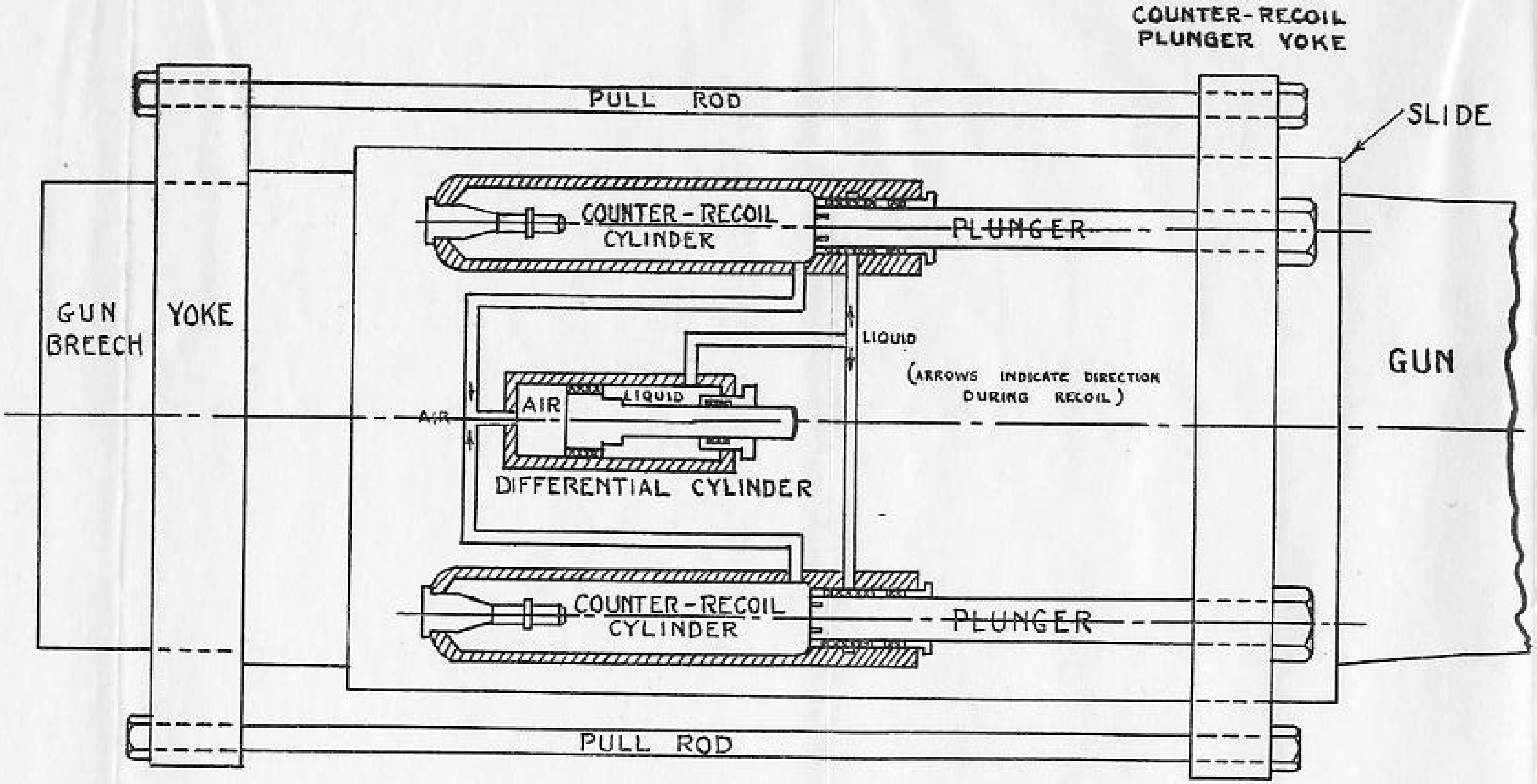


DIFFERENTIAL CYLINDER



DIAGRAMMATIC ARRANGEMEN
CYLINDER AS
GUIDE RAIL





DIAGRAMMATIC ARRANGEMENT OF PNEUMATIC COUNTER-RECOIL CYLINDERS AND DIFFERENTIAL CYLINDER AS INSTALLED ON EACH TURRET GUN

GUIDE RAIL FOR COUNTER-RECOIL YOKE IS OMITTED

CHAPTER X.

RECOIL AND RECOIL BRAKES.

Section I.—General Considerations.

1001. All modern guns recoil in their mounts when fired. The recoil movement is introduced to reduce the forces acting on the mount and ship's structure.

In the case of a gun having no recoil, the force acting on the mount, due to the firing of the gun, is the product of the area of the bore and the effective powder chamber pressure. This product amounts to several million pounds in the case of major caliber guns and is of considerable magnitude for all calibers of modern naval guns. From this it is obvious that, for a gun having no recoil, the proportions of the mount would be unreasonably large, making it cumbersome to handle and, on account of weight, unsuitable for use aboard ship.

By permitting the gun to recoil a limited distance the forces which would otherwise act on the mount are greatly reduced and can be regulated to suit the character of the vessel for which the mount is designed, thus making possible the use of larger caliber guns aboard ship than would otherwise be practicable.

The movement of the gun to the rear as a result of the work done upon the gun by the powder gases is known as the *recoil*, and the length of this movement as the *length of recoil*.

The return movement of gun to battery after firing is known as the *counter-recoil*, and is equal in amount to the recoil.

1002. Direction of recoil.—Recoil generally takes place in the direction of the axis of the gun, as in Fig. 1001. But in special cases where it is necessary to insure that the breech clear the deck of a vessel or platform of a car, as in some types of railway mounts, the recoil takes place parallel, or slightly inclined, to the deck or platform, as in Fig. 1002. Occasionally, as in the case of anti-aircraft mounts, it is necessary to vary the length of recoil to suit the elevation, as in Fig. 1003, in order to clear the deck at the higher angles of elevation.

The type of mounting and recoil represented by Fig. 1002 is not adapted to the higher angles of elevation, since the recoil serves only to reduce the component of the firing force in the direction of the recoil. As the angle of elevation increases, the component of the firing force acting in the direction of recoil decreases and approaches zero as a

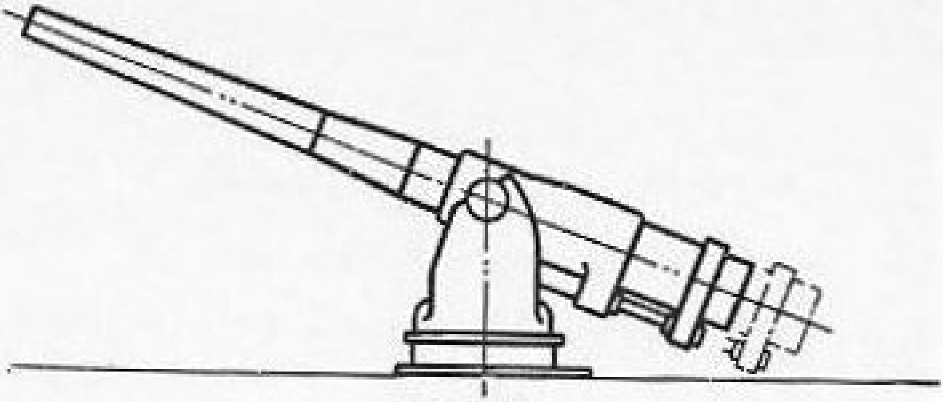


FIG. 1001.

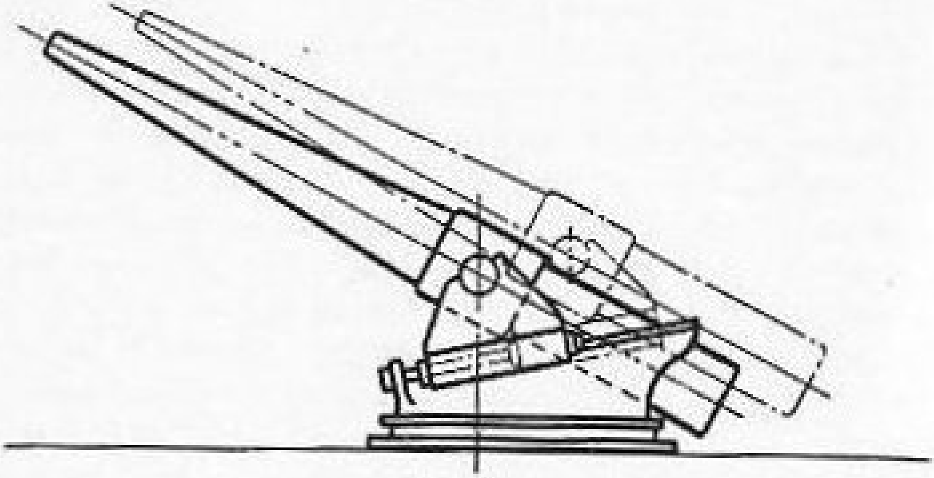


FIG. 1002.

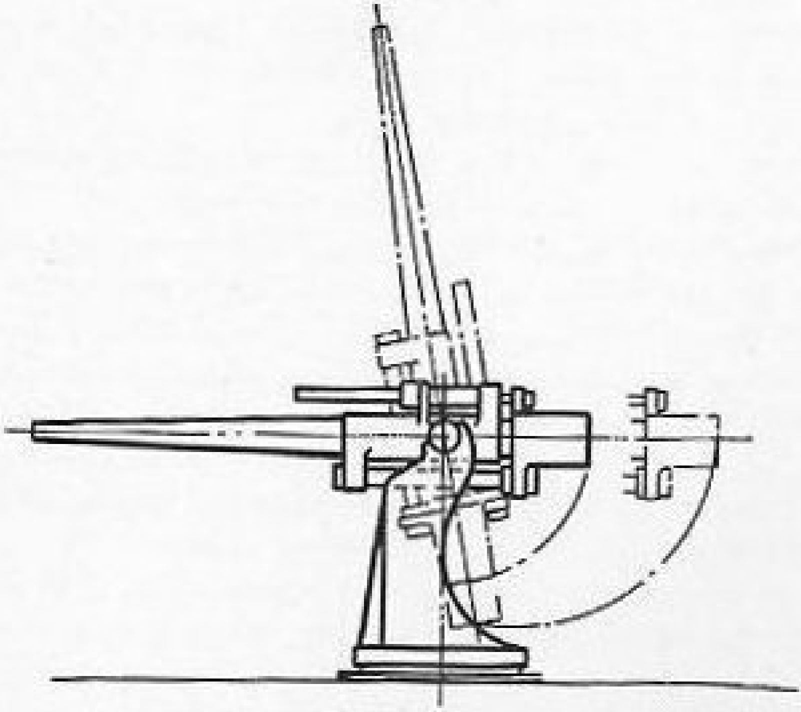


FIG. 1003.

limit, whereas the component of the firing force acting normal to the direction of recoil increases and approaches the full breech pressure as a limit. The effect of this is that for angles of elevation approaching 90° the full effect of the breech pressure is transmitted directly to the mount. Mounts of this type are built to meet special conditions where the maximum angle of elevation does not exceed 40°.

1003. Length of recoil.—Usually the length of recoil varies with the size of the gun and the type of the mount. Mounts of destroyers and small light vessels have a longer recoil than mounts for similar guns on battleships and battle cruisers, where the deck structure is more substantial and capable of sustaining greater forces.

Where the gun recoils in the mount, *the forces acting on the mount depend on the resistance offered by the mount to the recoil of the gun* rather than on the chamber pressure and the diameter of the bore. For the same gun and the same powder pressure curve, the forces acting on the mount vary inversely as the length of recoil. For major caliber guns of battleships, the length of recoil is limited to about three calibers on account of the restrictions offered by the barbette of the turret; for destroyers, where the deck structure is light and incapable of sustaining large forces, the length of recoil is considerably increased and is usually six calibers or more in length.

As a rule, it will be found there is some limitation on the length of recoil imposed by the ship's structure, and that the determination of the proper length is compromised by other conditions. In the case of turret mounts, an increase of recoil results in a larger barbette diameter and greatly increased weights as a consequence. In the case of minor caliber guns, longer recoil results in increased trunnion heights in order that the breech of the gun shall clear the deck at extreme elevation and at maximum recoil.

1004. Design of recoil brakes.—The mechanism incorporated in the mount for the purpose of checking the recoil and bringing the gun to rest within a limited distance is called a recoil brake. The allowable length of recoil having been decided on by considerations of Art. 1003 above, it becomes necessary to design a brake which will absorb the energy of recoil in the most efficient manner within the allowable distance. Such design calls into use the sciences of physics, mechanics, and mathematics. Stated in a very general way it may be said that the designer must know (1) the powder pressure in the bore and the effective area on which it acts; (2) the weight of the recoiling parts, the location of their center of gravity and the gravity components introduced at various angles of elevation; (3) the friction opposed to recoil; (4) the force exerted against recoil by the counter-recoil mechanism;

(5) the velocity that the recoiling parts would attain if the recoil were unopposed. With these items known it is possible to compute, by an extended process, the value of the resistance[1] that the brake must offer to recoil, and from this the dimensions and proportions of the piston[2] and throttling orifices[2] of the brake may be calculated.

1005. Forces acting on the gun during recoil.—It is important that the jump of the gun between the time the gun pointer "wills to fire" and the time the projectile leaves the gun shall be the least possible amount in order to avoid a change of direction of the line in which the gun is laid. On this account, it is desirable and necessary that the forces acting on the gun, including those due to the powder gases and the forces resisting recoil, be so disposed that the gun will not be lifted from its bearing in the bottom of the slide until after the projectile leaves the gun, and that the only appreciable movement of the gun before this time will be in the direction of the axis. To insure a steady mounting and to reduce the jump of the gun in the slide to a minimum, it is desirable to arrange the recoiling parts around the gun in such a way that their center of gravity is in the axis of the gun,[3] or as small a distance as possible below it. Since there are usually several cylinders containing the recoiling parts of the recoil and counter-recoil mechanisms, it is customary to put some of the cylinders on the upper side of the slide and some on the lower side. Other considerations of design may require a departure from this rule.

1006. Recoil and counter-recoil systems of new mounts are tested with the mounts at the Naval Proving Grounds. The velocity of recoil and the pressures developed in the recoil cylinders are measured, as mentioned in Arts. 1525 and 1526.

Section II.—Recoil brakes.

1007. In *all* service mounts the major portion of the energy of recoil is absorbed by the *hydraulic brake* comprising the principal part of the recoil system. The counter-recoil system and the friction of the gun in the slide contribute a small part of the resistance to recoil, whereas the gravity component of the recoiling weights exerts a varying effect as the gun is elevated.

In all forms of the hydraulic brake, including that of the recoil system of gun mounts, the brake consists of four simple elements, viz., cylinder, piston, liquid, and some form of orifice connecting the ends

[1] It is taken as an axiom that the resistance to recoil offered by the brake should be constant throughout the length of recoil.

[2] In the case of a hydraulic brake.

[3] Late designs have the center of gravity of the recoiling parts in the axis of the gun.

of the cylinder on either side of the piston. The cylinder being full of liquid, the motion of the piston within the cylinder forces the liquid through the orifice from one side of the piston to the other. The work required to force the liquid through any given orifice can be definitely determined from the laws of hydraulics and depends upon the area of the orifice, the area of the piston, the velocity of the piston, and the weight of the liquid.

The work done on the piston is equivalent to the work done on the liquid. The work done on the piston is utilized to overcome the movement of the gun during recoil, whereas the work done on the liquid during the same time is indicated by a rise of temperature of the liquid. It can be shown that the work absorbed by the hydraulic brake can be fully accounted for in the rise of temperature of the liquid. Under rapid fire conditions, the temperature rise is accumulative from shot to shot and results in a considerable rise of temperature which must be taken into account in designing the recoil system.

1008. The liquid used in the dashpots and recoil cylinders of the Navy is composed of a solution of 80 per cent glycerine and 20 per cent water, which weighs about 76 pounds per cubic foot. This liquid has a low freezing point and fairly constant viscosity within the ordinary temperature ranges, and has given satisfactory results in naval mounts for a great many years. Certain grades of buffer oil of the same weight give equally good results.

1009. The advantages of the hydraulic brake can be attributed to the large amount of energy that can be absorbed in an unreturnable form; to its simplicity and reliability; and to the facility with which the resistance offered to the movement of the gun can be regulated. The energy absorbed is converted into heat and dissipated by the mount into the atmosphere. Springs or compressed air are not suitable for checking the recoil of guns on account of the limited amount of energy that can be absorbed, and also because the energy absorbed during recoil is returned again to the mount during counter-recoil.

1010. The hydraulic brake is so proportioned that the total resistance offered by the recoil system, counter-recoil system, and friction, with a proper allowance being made for gravity forces, is constant and of sufficient magnitude to bring the gun to rest in the prescribed distance. With the resistance constant, the velocity of the gun during recoil will vary from zero at the beginning to a maximum and back again to zero at the termination of recoil. The resistance offered to recoil by the liquid at any point of recoil would be proportional to the velocity of the piston at that point *if the area of the throttling orifice were constant*. In order to obtain a constant resistance it is necessary to vary the size of the orifice so that it is proportional at any point to the velocity of the recoil at that point. For example, the area of the orifice must be greatest at the point where the velocity of recoil is greatest. This is accomplished in various ways, as illustrated in Figs. 1004, 1005, 1006, and 1007.

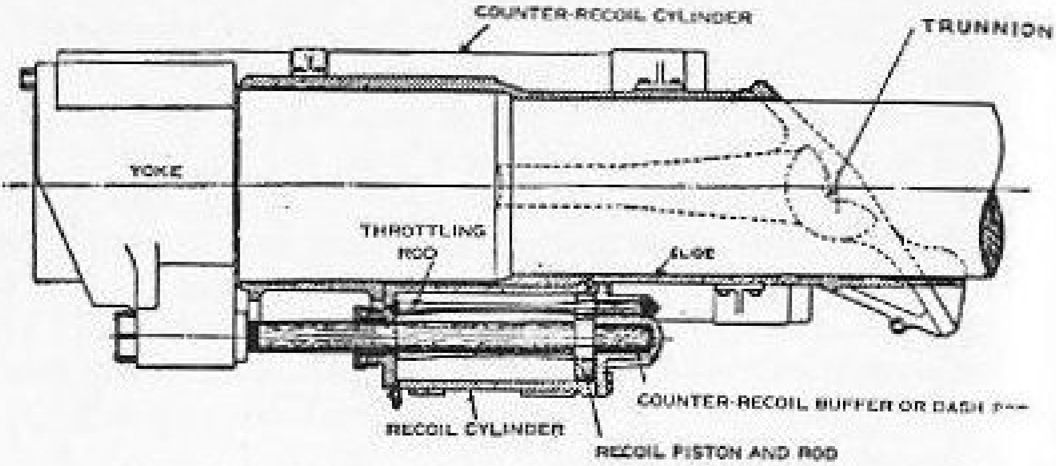


FIG. 1004.—TYPICAL RECOIL SYSTEM FOR TURRET MOUNTS.

1011. In the application of the hydraulic brake to gun mounts, the recoil cylinder is usually attached to the slide and the piston to the gun by means of the piston rod and gun yoke. Figure 1004 shows a typical installation for turret mounts, and Fig. 1005 the same recoil cylinder in a larger view.

Figure 1005 illustrates the usual method of varying the orifices in turret mounts. Two or three rods are passed through apertures in the

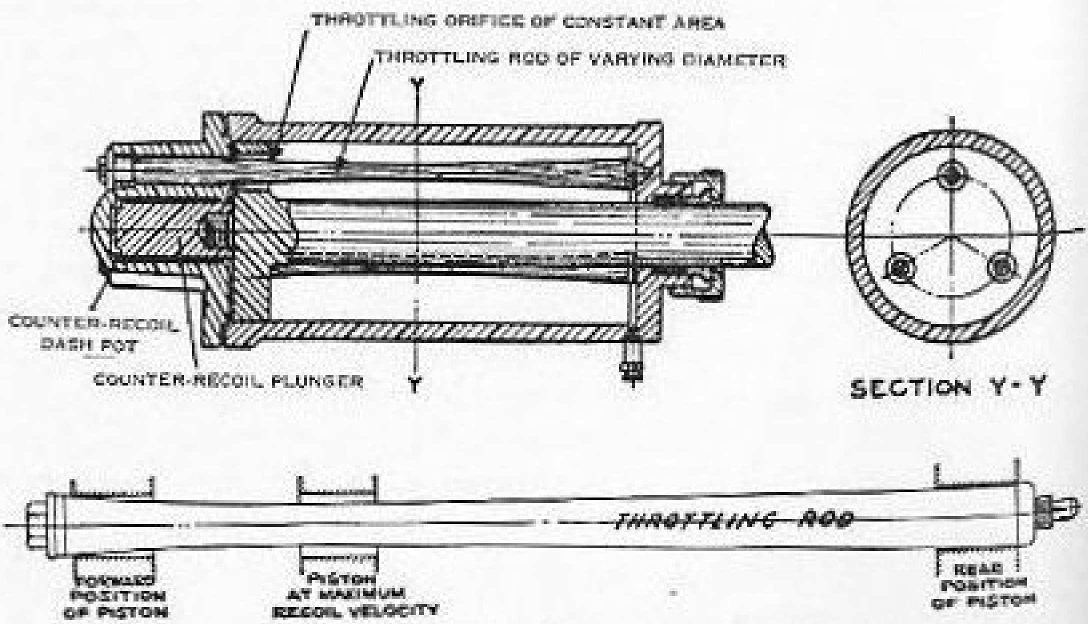


FIG. 1005.—TYPICAL MAJOR CALIBER RECOIL CYLINDER.

piston; the rods are attached to the ends of the recoil cylinders as shown. By varying the diameter of the rods, the proper variation in the area of the orifice for all points of the recoil may be obtained. Hydraulic recoil systems require that the cross-sectional area of the throttling orifices at each point of recoil be calculated and designed with great accuracy (Art. 1004). Once this orifice has been established in the form of a groove, as in Fig. 1006, no adjustment can be readily made. If the area is controlled by the use of tapered throttling rods, unsatisfactory performance during recoil can readily be corrected by the installation of a new set of rods with a different taper.

1012. Figure 1006 shows the usual method of forming the orifice in recoil cylinders of intermediate and minor caliber gun mounts. A

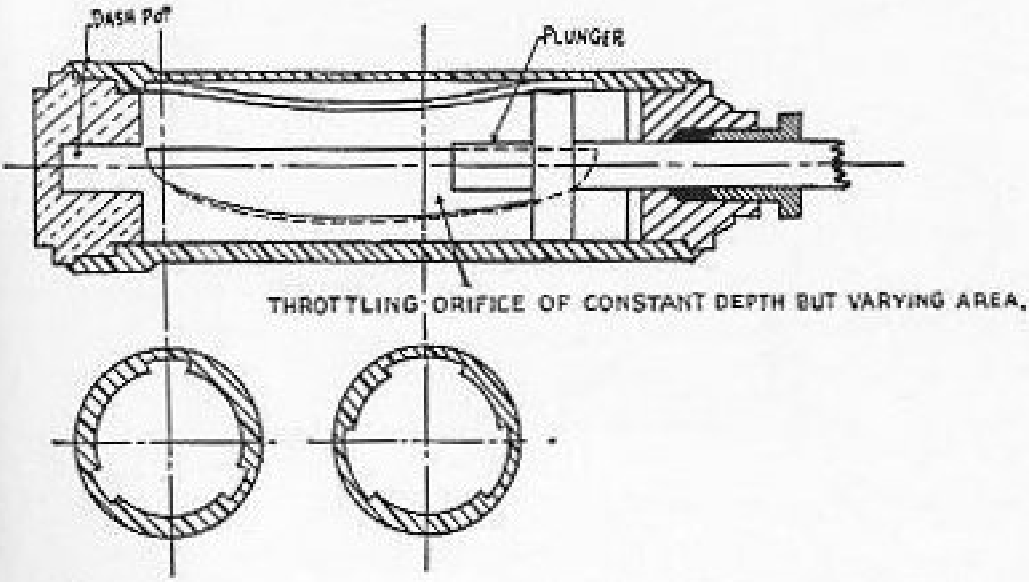


FIG. 1006.—TYPICAL MINOR CALIBER RECOIL CYLINDER (RECOILED).

groove of constant depth is cut in the wall of the recoil cylinder, the width of the groove varying to suit the velocity of recoil; two or three such grooves are arranged around the inner surface of the cylinder in a symmetrical pattern. In case two or more recoil cylinders are used, the arrangement of grooves in all cylinders is similar and the cylinders are interconnected to equalize the pressure in all cylinders.

1013. A simple form of hydraulic brake is illustrated in Fig. 1007. This form of brake is used extensively for checking the motion of heavy moving parts, and corresponds to the form of brake used in turret and broadside mounts for checking the final part of the *return* movement of the gun to battery in *counter-recoil*. In the figure, only the apparatus to the left is to be considered. The *dashpot*, or some variation of it, is always installed, in naval gun mounts, in the end of the recoil cylinder toward the muzzle of the gun. As the recoil piston moves in the recoil cylinder during the counter-recoil of the gun, the *plunger* on the head of the piston enters the *dashpot* near the end of counter-recoil. The plunger having the shape of a frustum of a right circular cone and the dashpot being cylindrical, the orifice provided for the escape of the liquid which fills the dashpot is constantly decreased as the plunger enters farther and farther into the dashpot. Constantly increased resistance is thereby offered to counter-recoil and the gun is brought to the *in battery* position without the shock or slam that would otherwise occur.

Increased gun elevation has required increased force to return the guns to battery. The force provided is far in excess of requirements when guns are in approximately horizontal position. All turret mounts

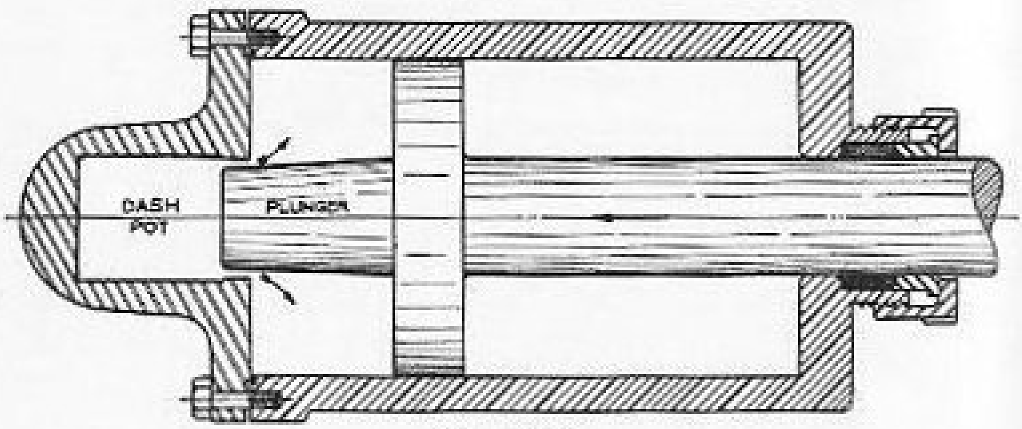


FIG. 1007.

that have been modified for increased elevation have therefore had their counter-recoil plungers in the recoil cylinders replaced with counter-recoil plungers of increased diameter so as to reduce the clearance and increase the braking effect sufficiently to bring the gun to rest at the end of counter-recoil without undue shock, at all angles of elevation.

In a variation of this counter-recoil buffer, as used in minor caliber mounts, there is a stationary plunger of circular cross section attached to the head of the recoil cylinder, inside. The recoil piston rod is hollow and near the end of counter-recoil, the plunger enters the hollow rod. Small holes of decreasing diameter are drilled through the rod to allow the escape of the liquid.

1014. Expansion chambers are used with the recoil cylinders of the larger mounts to allow for the expansion of the liquid due to heating. They consist of small closed tanks, connected to the muzzle end of the recoil cylinders by pipes. When filling the cylinders with liquid, it must be ascertained that the cylinders are full but the expansion chambers empty. In minor caliber mounts no expansion chambers are provided but after filling the cylinders a small amount (usually ½ pint) of the liquid is withdrawn in order to allow thereafter for expansion.

1015. Recoil installations on naval gun mounts of all sizes are fairly well standardized. There is usually one recoil cylinder, attached to the lower side of the slide, the piston moving with the gun. Variations will be found, however, in that (1) the counter-recoil springs are sometimes installed in the recoil cylinders[4] (Fig. 1008) in which case there are usually two or more cylinders; (2) the pistons may be attached to the slide and the cylinders move with the gun.

Variations in recoil mechanisms as used on other than naval mounts are exemplified by the mechanism of the field mount, Chapter XVI.

Section III.—Counter-Recoil Mechanisms.

1016. Counter-recoil mechanisms are incorporated in a gun mount in order to return the gun to the *in battery* position, after the recoil mechanism has brought the gun to rest at the end of recoil. Energy for this purpose is obtained from the momentum of the gun itself during recoil and is stored in a suitable medium, usually helical springs or compressed air.

The counter-recoil mechanism has two other subsidiary duties: (1) to help check the recoil, although the resistance it offers to recoil is minor as compared with the resistance exerted by the recoil mechanism; (2) to hold the gun in battery at all times except when it is fired; for this reason the springs are installed with an initial compression, or the air with an initial pressure above atmospheric.

1017. A typical counter-recoil system, as found installed on naval gun mounts, consists of a counter-recoil rod carrying a piston or plunger at one end and attached at the other end to the yoke of the gun. The piston or plunger slides within a cylinder attached to the slide, the cylinder containing either helical springs or compressed air. Upon recoil the piston or plunger moves in the cylinder in the same direction as the gun. The movement is opposed by the springs or air, which are therefore compressed. Upon the termination of recoil the energy of the springs or air, pushing back against the piston or plunger, returns the gun to battery through the medium of the counter-recoil rod.

1018. Counter-recoil systems of the hydraulic, pneumatic (air), spring, spring-pneumatic and gravity types are used for returning guns to battery. The British Navy uses the hydraulic (liquid pressure)

[4] The 3"-50 anti-aircraft mount has a single combined recoil and counter-recoil cylinder mounted on top of the slide.

system in its turret mounts. In the U. S. Navy, however, only the spring, pneumatic, and spring-pneumatic systems are used.

Formerly all counter-recoil systems were of the spring type. However the introduction of anti-aircraft guns of high elevation and the increasing of the elevation of heavy turret guns made such increased demands on the counter-recoil system that it was found necessary in many cases to replace the spring system with the pneumatic system. Satisfactory counter-recoil springs for heavy guns are very difficult to obtain and if broken while in use they are liable to put the gun out of commission. Also it requires considerable time and work to replace the springs. Counter-recoil springs in anti-aircraft guns are liable to become permanently set or have their free length shortened if the guns are normally secured or stowed in an elevated position. For these reasons it will be found that the spring system is used on minor caliber mounts and on intermediate and major caliber mounts of moderate elevation, whereas on anti-aircraft[5] mounts and on intermediate and major caliber mounts of comparatively large elevation the pneumatic system is used. A few turret mounts use the spring-pneumatic system.

1019. Spring counter-recoil system.—A spring cylinder for a minor caliber mount is shown in Fig. 1008. In the example shown there are

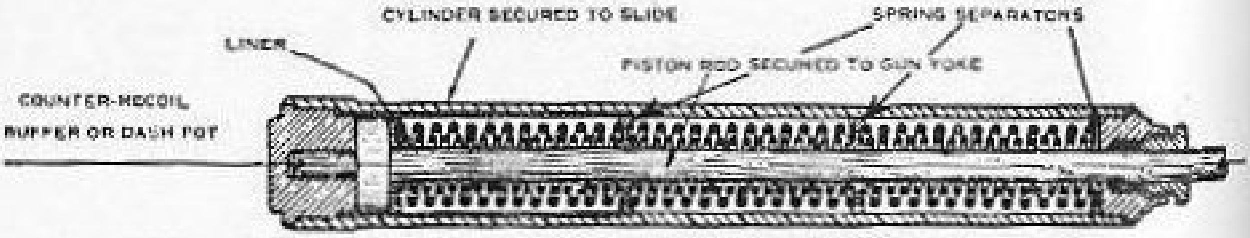


FIG. 1008.—TYPICAL SPRING COUNTER-RECOIL SYSTEM MINOR CALIBER MOUNTS INSTALLED WITHIN RECOIL CYLINDER.

six springs, three of large diameter and three of small diameter, the smaller being within the coils of the larger. The counter-recoil rod passes through the center of the coils of the smaller springs. The springs bear against the head of the cylinder at one end and against the piston at the other. Each pair of springs (one large and one small) is separated from the adjacent pair by a spring separator, which is simply a diaphragm not attached either to the rod or to the cylinder. On recoil and counter-recoil the separators slide along the cylinder and the rod slides through the separators. At full recoil, the springs are compressed to about 50 per cent of the length they have when the gun is in battery.

The cylinder shown is a combined recoil and counter-recoil cylinder,

[5] Except the 3″-50 anti-aircraft mount, which uses springs.

the springs being installed within the recoil cylinder. Such a system is used on the 6″ mounts in the Armory at the Naval Academy. Where the springs are installed in cylinders (called spring tubes) separate from the recoil system, the piston need not fit the cylinder as closely, as no liquid is present, nor is there any necessity for a gland at the cylinder end from which the rod emerges. Springs are more often installed in spring tubes separate from the recoil system, in which case there are usually two or more such tubes, depending on the size of the mount. The 4″ mounts in the Gun Shed at the Naval Academy have the separate spring tubes.

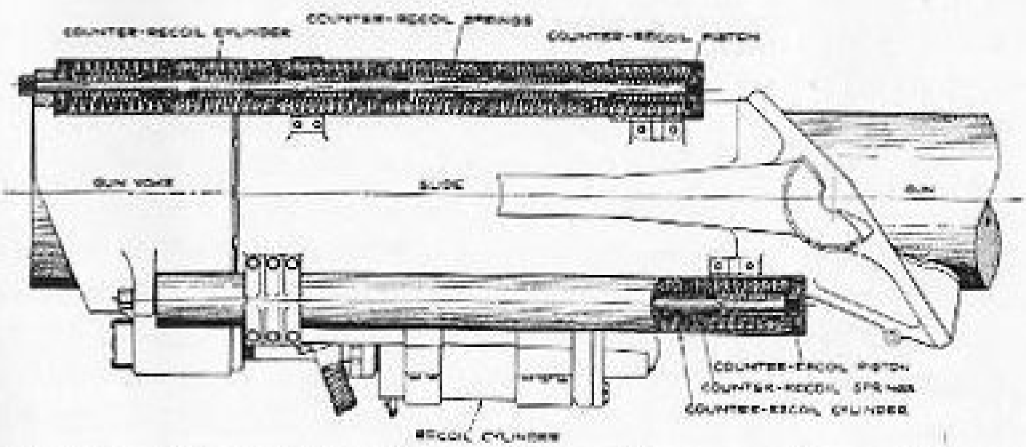


FIG. 1009.—TYPICAL SPRING COUNTER-RECOIL SYSTEM FOR TURRET MOUNTS.

Figure 1009 shows the counter-recoil spring tubes as installed in a turret mount designed for 15° elevation. There are four such tubes, two on the upper side and two on the lower side of the slide, the recoil cylinder being mounted below, between the two lower tubes. In each of these tubes are installed six pairs of springs.

Spring counter-recoil systems require that the design be very accurate and that all springs be in accordance with design specifications. Once the system is installed no adjustment can easily be made.

1020. Spring-pneumatic counter-recoil systems.—The turret mounts of the *California* and *Maryland* classes of battleships (5) are equipped with a combined spring and pneumatic type of counter-recoil system, the 14″ mounts using five spring tubes and the 16″ mounts six. These spring tubes and the contained springs are essentially the same as those shown in the turret mount of Fig. 1009 but additional counter-recoil force is provided by keeping all the tubes filled with air at a pressure of about 50 pounds per square inch. This necessitates the use of suitable packing both on the piston and in the piston rod gland, to prevent the leakage of air. On recoil, the air, as well as the springs, is further compressed and assists in returning the gun to battery.

The air is obtained from the gas-ejection system through a permanent line, as the air in the spring tubes must be frequently replenished. It has been found difficult to pack the pistons so as to prevent leakage, and the air tends also to escape through the pores of the metal of the spring tubes. For these reasons, the pneumatic system, to be described in the next article, uses in place of the piston a plunger, which is relatively easy to pack, and a forged steel rather than a cast steel cylinder. The spring-pneumatic system may be considered an intermediate step in the progress from spring to pneumatic counter-recoil systems.

1021. Pneumatic counter-recoil system.—Turret guns with 15° elevation require four to five spring tubes for housing the necessary springs. When the elevation of these mounts was increased, additional counter-recoil force was required. Space was not available for installing additional spring tubes and it became necessary to adopt some other type of counter-recoil system. The *pneumatic* system was chosen, the springs being entirely abandoned and the counter-recoil force being supplied by air alone, under comparatively high initial pressure. Plungers rather than pistons are used in the counter-recoil cylinders, the plungers being packed with special packing kept moist by liquid under pressure. For this reason the system is frequently called the *hydro-pneumatic* system.

The following description of a hydro-pneumatic counter-recoil system refers to the triple 14" mounts of the *Oklahoma*, *Pennsylvania*, and *New Mexico* classes, but is fundamentally applicable to the 8" mounts on heavy cruisers, and to 5" anti-aircraft mounts.

In this hydro-pneumatic system there are two cylinders *per gun*, secured to the top of the slide by a bracket and caps. These cylinders are large air bottles with the front end housing the elaborate cup leather cylinder packing upon which the success of the system depends. In the breech end of each cylinder is a head and mandrel that forms a bearing for the plunger when renewing the cylinder packings. (See Plate I.)

A hollow plunger fits in the front end of each air cylinder. The rear end of the plunger is surrounded by the cylinder packing, and the forward end is secured to the counter-recoil plunger yoke. The counter-recoil plunger yoke slides in recoil and counter-recoil on a guide rail which is secured to the top of the slide. Pull rods connect the counter-recoil plunger yoke to the gun yoke. When the gun recoils, the counter-recoil plunger yoke is pulled to the rear, forcing the plungers further into the cylinders. At the end of recoil, the air, further compressed in the air cylinders, forces the plungers forward and returns the gun to battery. The initial pressure of the air in the air cylinders is approximately 1,800 pounds per square inch, which is increased about 50 per cent during recoil. The general arrangement of the system, as above described, is shown at the lower right on Plate I, the sketch showing the installation for one gun only.

1022. The success of the hydro-pneumatic system depends upon the reliability of the packing which retains this air at high pressure. Two practical difficulties are experienced in packing air at high pressure. First, it is difficult to get castings of sufficient density and homogeneity to prevent leakage of air through the pores of the metal. The second difficulty is due to the tendency of cupped packing and other forms of packing to dry out and permit the escape of air. The first difficulty can be overcome to a great extent by the use of forged steel instead of castings for all parts enclosing the air. The second difficulty is overcome by introducing a liquid chamber, called the *differential cylinder*, which boosts the liquid pressure so that it is in excess of the air pressure to be retained by the packing.

The differential cylinder is mounted between the two air cylinders on top of the slide, and contains within it the floating *differential piston*, whose piston rod protrudes from the cylinder through a gland. The differential cylinder, in the portion around the piston rod (at the right, Plate I) is filled with liquid.[6] On the other side of the piston (at the left, Plate I) the cylinder is full of high pressure air, obtained from *both* counter-recoil cylinders, to which it is connected by pipes. Since the piston is free to move,[7] the pressure of the air is transmitted to the liquid. As the piston area exposed to air pressure is greater than the piston area exposed to liquid pressure, by an amount equal to the cross-sectional area of the piston rod, the unit pressure of the liquid must exceed the unit pressure of the air in like proportion. By means, then, of this differential piston the liquid is under a higher unit pressure than the air, and this holds true no matter what the air pressure may be nor at what part of recoil the gun may be.

Whereas great difficulty is experienced in packing air by the usual methods, no great difficulty is experienced in packing liquid at the same or increased pressures since the liquid keeps the packings moist. The liquid from the differential cylinder is therefore led by pipes to both counter-recoil cylinders, where it is distributed through and around the packing of the counter-recoil plunger. The liquid tends to escape through the differential piston packing to the air side of the

[6] The liquid used is the standard recoil liquid—80 parts glycerine, 20 parts water.

[7] Leakage of liquid from the system is indicated if the differential piston rod is found to be protruding farther and farther from the end of the cylinder.

differential cylinder, or through the plunger packing to the air cylinder rather than permit the compressed air to leak through in the opposite direction.

The packings consist of three leather packing rings of U-shaped cross section seated on flat leather rings. The U-shaped cup leather packing rings are supported upon a metallic packing expander which prevents the packing from collapsing even if the pressure is removed. Three rings of soft packing are also provided to form a bearing for the plunger. The liquid holds the skirt of the U-shaped leather packing against the cylinder wall and against the side of the plunger and forms an excellent air seal. The details of the packing are shown on Plate I.

The differential piston and the piston rod gland are provided with packings similar to those around the air plunger.

1023. Secured to the differential cylinder is a safety gauge which shows the *liquid* pressure on the system at all times. As this liquid pressure is a direct function of the air pressure, the pressure on the system can easily be checked. The gauge and its connection are filled with liquid. The liquid in the gauge and the liquid in the differential cylinder are separated by a flexible diaphragm which will, in case the gauge or its connection is broken, collapse against and close the small pin hole leading to the gauge connection and thus prevent both the escape of liquid from the differential cylinder and the temporary disabling of the gun.

The counter-recoil cylinder piping is made of high-pressure copper pipe. The pipe leads consist of air and liquid pipes from the differential cylinder to the air cylinder. Pipe leads are also run from the differential cylinder to valves on the side of the slide for charging with both air and liquid. The air and liquid valves on the slide are arranged so that they can be connected to the compressed air mains or liquid pump by means of portable pipes.

Since the weight of the gun is held in battery solely by compressed air, it is essential that some positive means be provided to prevent the gun from sliding out of battery when it is being elevated, in case the air pressure in the counter-recoil system is less than required. This is done by a yoke locking device. The gun yoke is connected to a bracket on the slide by a safety link and pin. This link is of sufficient strength to support the weight of the gun in battery, but would be parted without damage to gun or mount if the gun were fired with it in place. The mechanism is to be disconnected before firing, but is to be kept in place at all other times.

CHAPTER XI.

NAVAL GUN SIGHTS.

Section I.—Preliminary.

1101. The path described by a projectile fired from a rifled gun is not a plane curve; that is, it cannot be wholly included in any one plane. The curvature of the path, as seen projected on a vertical plane through the gun and target, is caused by the influence of gravity on the projectile. The curvature as seen projected on a horizontal plane through the gun, is caused by the gyroscopic properties imparted to the projectile by the rotation or spin received from the rifling of the gun.[1] In U. S. naval guns, which are all rifled with *right-hand twist*, the curvature produced on the horizontal plane is always to the right when looking from gun toward target, and this is to be understood in connection with the discussions that follow.

It is evident that, except at pointblank ranges, a projectile fired from a gun whose axis had been pointed to coincide with a straight line joining gun and target, would not hit the target. It is necessary both to elevate the axis of the gun at some vertical angle above this line, and to offset it by some horizontal angle to the left of the line, in order to compensate for the curvatures before mentioned. Both these angles are functions (but not linear functions) of the distance to the target. It is the duty of the fire control party of the ship to determine the values of these angles but in order to insure that the gun is actually elevated to and offset laterally to the exact angles as received at the gun, there are installed on the gun mount devices known as *gun sights*. It is with these that this chapter will deal.

1102. Prior to an explanation of the fundamentals of gun sights, several definitions are given. In Fig. 1101, QT is the horizontal plane and the gun is considered to be at O, the origin, slightly above the earth's surface, as is usual in the case of guns mounted on ships. The gun's axis is pointed along the line OM at the instant of firing. The projectile describes the path OST and falls on the earth's surface at T. T represents a target.

(1) The *line of position* is the straight line connecting the gun and

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[1] See *Exterior Ballistics, 1935*, by Lieutenant Commander E. E. Herrmann, U. S. Navy.

target (OT, Fig. 1101). The same line is also commonly referred to as the *line of sight*.

(2) The *angle of position*, p, is the vertical angle between the horizontal plane and the line of position; it is positive when the target is higher than the gun and negative when the target is lower than the gun.

(3) *The trajectory* is the curve traced by the projectile from the origin to the point of impact (OST, Fig. 1101).

(4) The *line of departure* is the line in which the projectile is moving at the instant it leaves the gun; it is tangent to the trajectory at the origin and practically coincides with the axis of the bore at the instant of firing (OM, Fig. 1101).

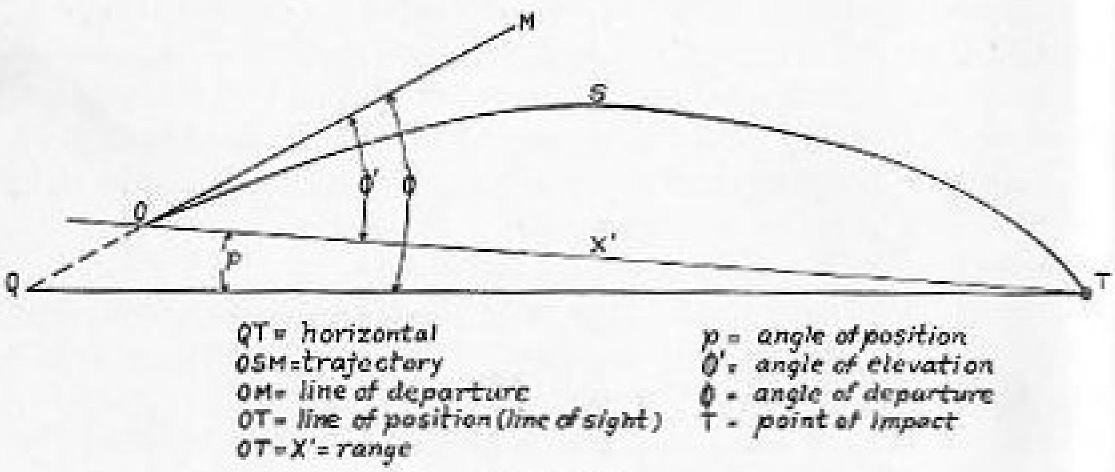


FIG. 1101.

(5) *The range* is the distance from the origin to the point of impact.

(6) The *angle of elevation*, ϕ', is the vertical angle between the line of departure and the line of position.

(7) The *angle of departure*, ϕ, is the vertical angle between the line of departure and the horizontal plane. It is equal to the algebraic sum of the angle of elevation and the angle of position.

(8) *The jump* (not illustrated). Under the shock of firing the axis of the gun may describe a vertical angle (positive if upward, negative if downward) between the time the powder charge is ignited and the time the projectile leaves the muzzle. This angle is very small in any case and may be considered an inherent part of the angle of elevation. Therefore no special symbol is given for the angle between the line of position and the axis of the bore *just prior* to firing.

(9) *The drift.* The lateral curvature of the trajectory causes the projectile to deviate from the vertical plane containing the line of departure. At any range, the linear amount of this deviation, measured

perpendicularly to the line of fire, is called the *drift* at that range [D, Fig. 1102(b)].

Section II.—Fundamental Principles of Gun Sights.

1103. If our guns were mounted on a platform ashore, we could readily lay them to the desired elevation by the use of a gunner's quadrant; the quadrant measures angles of elevation with respect to the true horizontal, and, by means of it, the gun may be laid with respect to the true horizontal. Many coast artillery guns are laid in elevation by means of some form of gunner's quadrant, but at sea such a method would be impracticable due to the motion of the ship.

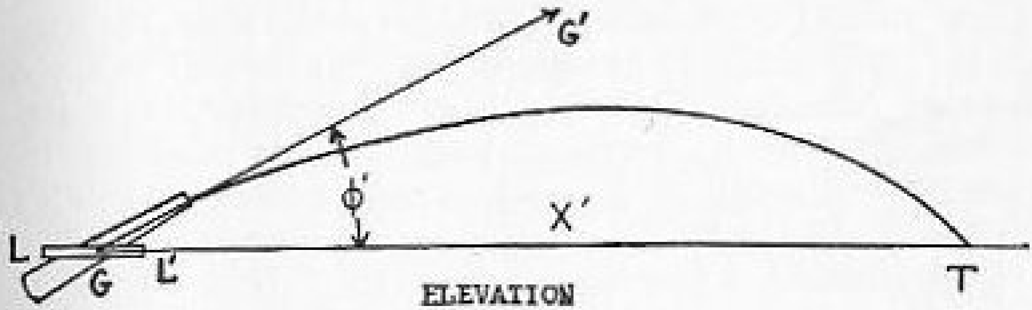


FIG. 1102(a).

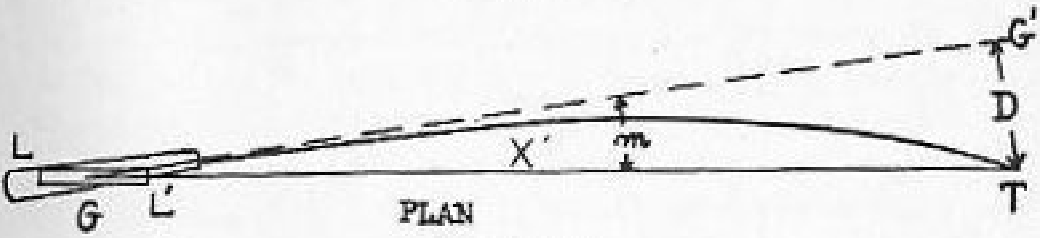


FIG. 1102(b).

At sea it is far more convenient to aim our guns by directing the line of sight at the target; we will confine ourselves to this phase of the problem.

Figures 1102(a) and 1102(b) illustrate what is meant by directing the line of sight at the target. In Fig. 1102(a) we have a gun at G and a target at T; the range to the target is X' and from the range table for this particular gun we find the angle of elevation ϕ' required for this range. A gun sight, with sighting axis LL', is shown pivoted on the gun; the gun sight is so fitted that its sighting axis LL' may be set at any desired angle (within required limits) with the axis of the bore GG', in both the vertical and horizontal planes. Now if we depress the sighting axis of the gun sight so that it makes the angle ϕ' with the bore, in the vertical plane, and, by elevating the gun while sighting along the sighting axis, direct the the axis at the target T, it will be clear that the axis of the bore will be elevated above the *line of sight* by the amount of the angle ϕ'.

The gun will, however, not be elevated above the *horizontal* by this amount unless the gun and target happen to lie in the same horizontal plane. In actual practice, guns on board ship are usually mounted well above the water line, while the targets at which they fire usually rest on the water's surface. But the height of gun above the water is always very small in comparison with the range to the target (with a gun as high as 60 feet and a range as short as 1,000 yards, the angle of position is only about 1°, while normally it rarely exceeds about 10′ of arc). We may, then, apply the principle of rigidity of the trajectory[2] under these conditions. Referring to Fig. 1102(a), this means that if the gun is elevated the angle ϕ' above the line of sight $LL'T$, it will give the range $X' = GT$, whether G and T are exactly in the same horizontal plane or not, but provided, of course, that the inclination of the line of sight to the horizontal remains within reasonable limits. Reasonable limits will not be exceeded as long as we deal with guns mounted on ships and firing at targets resting upon the water.

Figure 1102(b) is a plan view of Fig. 1102(a). We know that if the gun is laid so that the axis of its bore lies in the direction GG' in azimuth the trajectory will normally curve off to the right, due to the drift of the projectile; we will consider, for the present, that no external forces are operating to cause lateral deviation other than the normal drift. Since we may find from the range table what the amount of the drift D will be at the range X', we may direct the bore of the gun at the point G' which lies D yards to the *left* of T, and the trajectory will then terminate at the point T. The most convenient manner in which to accomplish this result is to set the gun sight so that its sighting axis makes the angle $G'GT$, or m, with the axis of the bore, and to the *right* of it, in the horizontal plane. Then if we train the gun, while sighting along the sighting axis, until the sighting axis is directed at the target, the axis of the bore will be pointed at G' and the trajectory will terminate at T, as required.

It will be clear that after we have set the sighting axis of the gun sight at the required angle ϕ' with the bore, in the vertical plane, and at the required angle m in the horizontal plane, the gun may be laid

[2] The principle of rigidity of the trajectory states that: *Provided the angle of position remains small*, a gun which obtains a certain inclined range along a line of position, when elevated a given angle above that line of position, will obtain the same range along the horizontal when elevated the same angle above the horizontal. For a more extensive explanation, see *Exterior Ballistics, 1935*, Chapter 3, by Lieutenant Commander E. E. Herrmann, U. S. N.

in the proper direction by directing the sighting axis of the gun sight at the target, regardless of the motion of the platform upon which the gun is mounted. Figure 1103 illustrates that the elevation of the gun with respect to the ship may vary greatly, while its elevation above the line of sight remains the same. The gun's elevation with respect to the ship varies with the roll of the ship, if the sighting axis of the gun sight is kept pointed at the target, but its elevation above the line of sight depends only upon the setting of the gun sight.

1104. The sighting axis of the gun sight is determined in several ways in the various types of sight mechanisms. There follows a description of an *open sight*, shown on Plate I, which will clearly illustrate the principles involved in the determination of the sighting axis and the setting of this axis at the required angles (vertically and horizontally) with the bore of the gun. The *scales*, by which these angles are measured, will be described later.

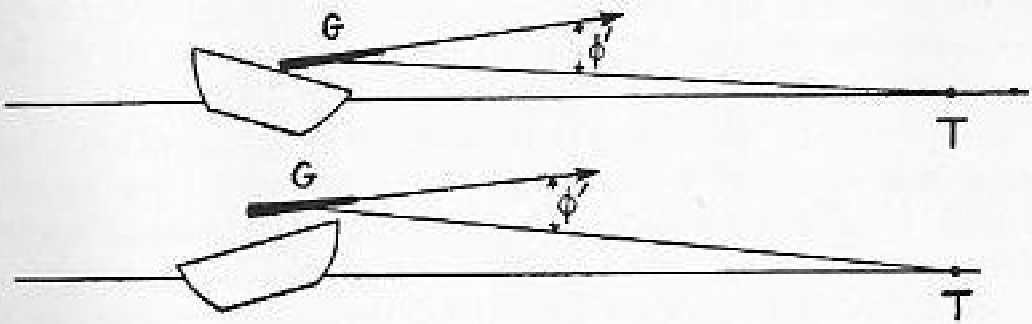


FIG. 1103.

On Plate I, the *rear sight point* is determined by the bottom of the V-shaped notch, S, and the *front sight point* by the apex of the cone S'. If the eye is placed so that the apex of the cone can just be seen in the bottom of the notch, the eye then lies in the sighting axis.

In order that the sighting axis, as determined by S and S', may be set at various angles with the axis of the bore in the vertical and horizontal planes, the two sight points are set on the *pivot bar* B, which is pivoted to swing in the horizontal plane about the vertical sight pivot vv' and in the vertical plane about the horizontal sight pivot hh'. These pivots are mounted in the *pivot block* p, which is attached to the gun slide. The rear end of the pivot bar slides in a circular groove in the *azimuth head* b, the center of curvature of the groove being in the vertical sight pivot vv'. The azimuth head is at the top of and is an integral part of the *sight bar* w, which slides vertically in the *sight bar bracket* c, attached to the gun slide. The sight bar is shaped to the arc of a circle whose center is in the horizontal sight pivot hh'.

It may be seen that if the rear end of the pivot bar is moved horizontally in the azimuth head, the sighting axis may be set to any desired angle with the axis of the bore in the horizontal plane, and if the sight bar is raised in the sight-bar bracket, the sighting axis may be set to any desired angle with the axis of the bore in the vertical plane. If we now elevate and train the gun so that the line of sight is directed at the target, the axis of the bore will be offset horizontally and elevated vertically by the amount of these angles *with reference to the line of sight*.

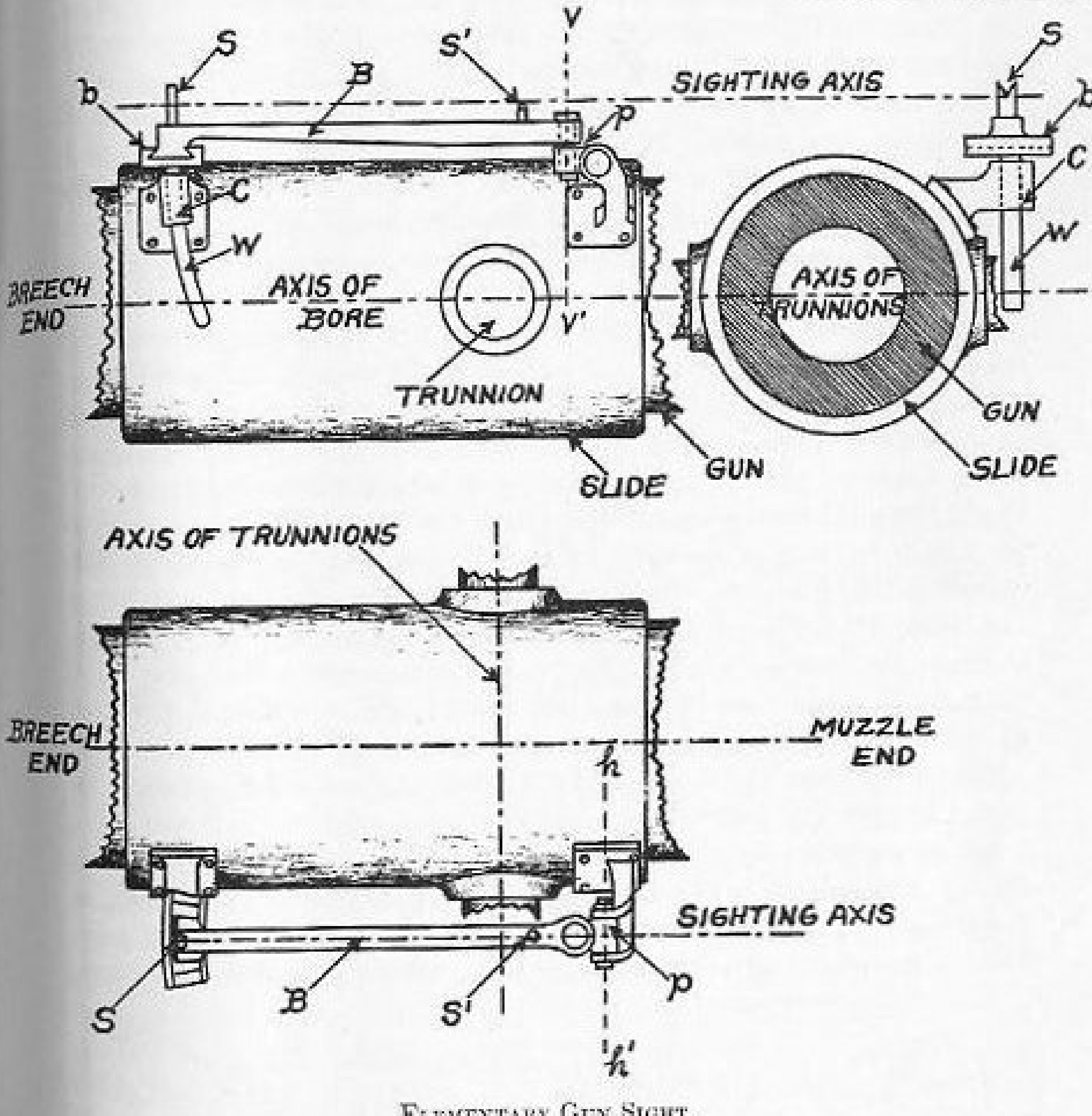
1105. The axis of trunnions is the axis about which the gun elevates. The slide's trunnions and the trunnion bearings are so constructed that this axis intersects the axis of the bore at right angles. The axis of training is the axis about which the mount or turret (gun) rotates in azimuth. The mount is so installed that when the ship is on an even keel and even trim, the axis of trunnions is horizontal and the axis of training vertical. Consider for the moment that these two axes are so horizontal and vertical. The gun sight must be so installed on the slide that when the sight bar is raised in the sight-bar bracket, the pivot bar will be moved only through a *vertical* angle with reference to the axis of the gun, no lateral (*horizontal*) component of motion being introduced; and similarly, when the pivot bar is moved laterally in the azimuth head, it will be moved only through a *horizontal* angle with reference to the gun's axis, no *vertical* component of motion being introduced. If the *sight pivots* are so installed that these requirements are met when the axes of trunnions and training are horizontal and vertical, respectively, then they are properly installed for any position which the mount may take while on a ship in motion.[2] The positions of the sight pivots necessary to fulfill the above two requirements are given in the following:

(a) The horizontal sight pivot *hh′* (Plate I) must be parallel to the axis of the gun trunnions. This is absolutely necessary in order to insure that the sighting axis makes with the axis of the gun the angles, in the horizontal and in the vertical plane, indicated by the sight scales. This is also necessary to prevent a change in sight elevation from causing an unintentional change in sight deflection.

(b) The vertical sight pivot *vv′* (Plate I) must be installed exactly at right angles to the horizontal sight pivot *hh′* and to the axis of the gun trunnions. This is absolutely necessary in order to insure that the sighting axis makes with the axis of the gun the angles, in the horizontal and vertical planes, indicated by the sight scales. This

[2] The error in the fall of shot due to "trunnion tilt" will not be discussed here; such a discussion will be found in *Exterior Ballistics, 1935*, Chapter 13.

CHAPTER XI, PLATE I.



ELEMENTARY GUN SIGHT.

is also necessary to prevent a change in sight deflection from causing an unintentional change in sight elevation.

Section III.—Methods of Establishing the Sighting Axis.

1106. The sighting axis may be defined as the line determined by the front and rear sight points. There are three principal arrangements for establishing these sight points. They are (1) the open sight, (2) the peep sight, and (3) the telescope sight.

The open sight, already described in connection with the fundamentals of sights (Plate I), was one of the earliest to be used, and and the least efficient arrangement (of the three enumerated) of the sight points. This sight is not only fatiguing to the eye because of the necessity of focusing the eye for different distances, but is inaccurate even under the most favorable conditions (namely, when both gun and target are still, and there is no difficulty in keeping the optical axis coincident with the line joining the sight points); this is because changes in the direction and intensity of the illumination on the front sight point will make an apparent change in its position and a consequent apparent change in the direction of the sighting axis. In addition to the above, there is no magnification of the target, and a considerable portion of its area is obscured by the sight points. This type of sight is now rarely found in the U. S. Navy except as a stand-by sight.

A later development of the open sight was the peep sight, familar to many because used on the service .30 caliber rifle.[4] The peep sight is an improvement on the open sight, for the reason that it is easier to align the front sight point in the center of the peep than in the notch of the open sight. Figure 1104 shows the essential parts of this type of sight. The front sight point in a peep sight is about the same as in an open sight; but instead of a notch for the rear sight point there is a circular hole in a diaphragm (*a*, Fig. 1104). The sighting axis is defined by the tip of the front sight point and the center of the peep hole. A disadvantage of this sight is that, whereas the peep should be

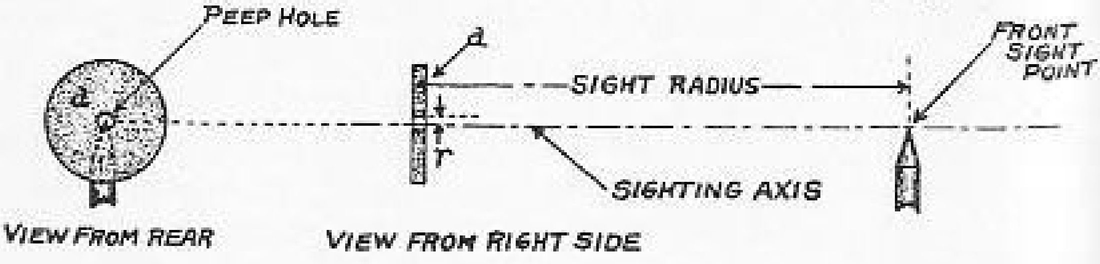


FIG. 1104.

[4] Both open and peep sights may be constructed with the sight-bar bracket tilted laterally, so that as the sight bar is raised for increased elevation the rear sight point is offset laterally to the left, thereby compensating, approximately, for drift.

made as large as the human eye pupil in order to admit the greatest amount of light (especially for night use), any such enlargement of the peep makes it difficult for the eye to align itself with the center of the peep.

1107. The telescope is the most convenient and most efficient means of establishing the sight points. It may be defined as the combination of two systems of lenses on a common axis, spaced so that the second focal plane of the first system (the objective equivalent) is coincident with the first focal plane of the second system (the eyepiece equivalent), which plane contains a pair of intersecting crosswires or etched cross lines.[5]

There are three points in the telescope that determine the sighting axis; namely, the intersection of the cross lines, and the first and second unit points[6] of the objective equivalent. The stability of the sighting axis with reference to the sight mount therefore depends on the rigidity of the point of intersection of the cross lines and all optical parts in front of it. The telescope is so attached to the gun that the sighting axis can be set at any desired angle with the axis of the gun.

Advantages of the telescope sight.—(a) The first point of superiority of the telescope as a sight is the fact that the eye is focused for only one distance, instead of successively accommodating for more than one, as with the open sight and the peep sight. This is because the eye, when the adjustment of the telescope is correct and the target is at long range, sees, through the eyepiece equivalent, the intersection of the cross lines and the image of the target in one plane. Furthermore, under the above conditions the pencils of light that emerge from the eyepiece are parallel pencils, and the accommodation muscles of the normal eye are at rest when it is receiving such pencils. With the open sight and peep sight, if the eye is moved off the sighting axis, errors in pointing will occur; but with the telescope, motion of the eye either across or along the sighting axis will not affect the accuracy of pointing, provided the telescope is properly adjusted and the target is at long range; for as long as the eye is in some position where it will receive a part of some pencil that emerges from the eyepiece after diverging from the intersection of the cross lines, it will see the intersection of the cross lines and some part of the field of view. There are limits along the axis of the eyepiece and across it within which the eye should

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[5] The entire mechanism by means of which the telescopes are set at the required angle with the bore of the gun, is called the *gun sight;* the telescopes themselves are properly called *gun-sight telescopes*.

[6] Unit points are the points of zero curvature on each face of the lens, *i.e.*, the points at which the optical axis pierces the two faces.

be placed if it is desired to utilize the full field of view and receive the maximum amount of light from the target; however, the rubber buffer fitted on the eye end of the telescope makes it easy for the eye to place itself within the proper limits.

(b) The next point of superiority of the telescope is its magnifying power. At modern battle ranges it is necessary to have an apparent enlargement of the target in order to point the gun with sufficient accuracy. Where F is the focal length of the objective equivalent, and f is the focal length of the eyepiece equivalent, the magnifying power of the instrument will be $M=\frac{F}{f}$ diameters. For instance, if F be 20 inches and f be 2.5 inches, the magnifying power will be 8 diameters. When using this telescope on a target distant 8,000 yards, we can lay the gun with as much facility as we could lay it on the same target distant 1,000 yards with a sight that has no magnifying power; but the increase of magnifying power is attended with a corresponding decrease in the field of view. Roughly, the field of view of any telescope will be 45° divided by the magnifying power. We are therefore restricted in the application of this point of advantage by the size of field of view which is large enough to permit the gun pointer to "pick up" the target.

(c) Another point of advantage in the telescope sight is the fact that the size of the emergent pencils does not affect the accuracy as does enlargement of the hole in the peep sight. When M is the magnifying power and A is the aperture of the telescope, the diameter of emergent pencils will be $\frac{A}{M}$. By making the proper relation between A and M we can utilize the full area of the dilated eye pupil at night; and so, instead of making it more difficult to pick up a target when looking through the sight than it is when looking with the naked eye, we can, with the telescopes in service, pick up and lay on a target that is so dimly illuminated as to be invisible to the naked eye.

1108. Types of telescopes.—Telescopes have almost entirely replaced open sights in naval gun sights. There are a number of types in use, on gun directors as well as in gun sights. These may be classified roughly as follows:

(a) As to path of light—the straight type, fixed prismatic type, and rotating prism type. The latter changes the sight elevation by rotating an internal prism, rather than by moving the telescope as a whole.

(b) As to magnification—the fixed power, the continuously variable power (between two limits), and the double power.

(c) As to number of eyepieces—the single eyepiece, and the double eyepiece (checksight).

(d) As to focusing—practically all telescopes in service may be focused at the eyepiece to suit the individual eye, but some older types cannot be focused.

The straight telescope is used in most broadside gun sights, but on some broadside guns and in all turrets the prismatic type is used. The purpose of the latter is to bend the incoming light through two right angles (ordinarily) so that the line reaches the eye parallel to its original direction but offset by an amount equal to the distance between the two prisms. This makes it possible to place the objective close to the axis of the gun, while the eyepiece may be placed at a position more convenient for the user. Anti-aircraft gun sights are fitted with a special type of prismatic telescope that allows the user a comfortable position of the head even when the gun is elevated at large angles.

The checking telescope is fitted with a second eyepiece so that two observers may see through the telescope simultaneously. This is attained by means of a prism inserted in the path of the rays from the objective to the primary eyepiece. One disadvantage of this scheme is that each observer gets only half the light that he would ordinarily receive. As this checking eyepiece is intended for use in training pointers, the latest telescopes are fitted so that the checking eyepiece system can be thrown out at will. Late sight mounts in many cases use a separate telescope for the checksight observer so as to obviate the necessity of installing an additional eyepiece on the pointer's telescope.

In late telescope design, the tendency has been toward simplification and ruggedness. Straight telescopes are used in lieu of prismatic telescopes wherever possible, also the magnification is fixed instead of being of variable power.

1109. Parallax, by general definition, is the apparent displacement of an object when viewed from different points. As applied to an error that may exist in a telescope, the term indicates that if the eye is placed in several positions at the eyepiece, the image of the target will be seen in several different positions with respect to the intersection of the cross lines. Such a condition is undesirable since, when the intersection of the cross lines is accurately trained on a point on the target, a small motion of the eye at the eyepiece will apparently cause the intersection to move off of the point. This error is caused by the fact that image of the target and the cross lines in the telescope do not lie in the same focal plane.

Parallax is easily detected by laying the telescope on a fixed mark, keeping it in a fixed position, and then moving the eye up and down or sideways across the eyepiece. If there is no apparent motion of the intersection of the cross lines relative to the image, they are both in the same plane; if the intersection of the cross lines appears to move over the image in an opposite direction to the motion of the eye, the image lies forward of the cross lines; if it appears to move over the image in the same direction as the motion of the eye, the image lies in rear of the intersection of the cross lines. The second condition would be due to incorrect adjustment of the telescope; the third condition would be due to incorrect adjustment if the mark selected for the test is more than a mile distant. When a telescope has an objective equivalent of a moderate focal length like that in our telescope sights, and the telescope is in correct adjustment, the image of an object distant anywhere from infinity to a mile is not perceptibly in rear of the second focal plane of the objective equivalent—the position of the cross lines.

Parallax is ordinarily removed from a telescope by unclamping the *draw tube* containing the eyepiece and crosswire lens and sliding it axially until the cross lines lie in the second focal plane of the objective equivalent. This, however, may disturb the *bore-sighting* adjustment, later to be described. When very close targets, such as dotter targets, are to be observed, an auxiliary telescope called a *focusing cap* (Fig. 1105) may be clamped to the objective end of the main telescope. By adjusting the draw tube of the focusing cap a close target may be seen without parallax through the main telescope. This makes any adjustment of the main telescope unnecessary.

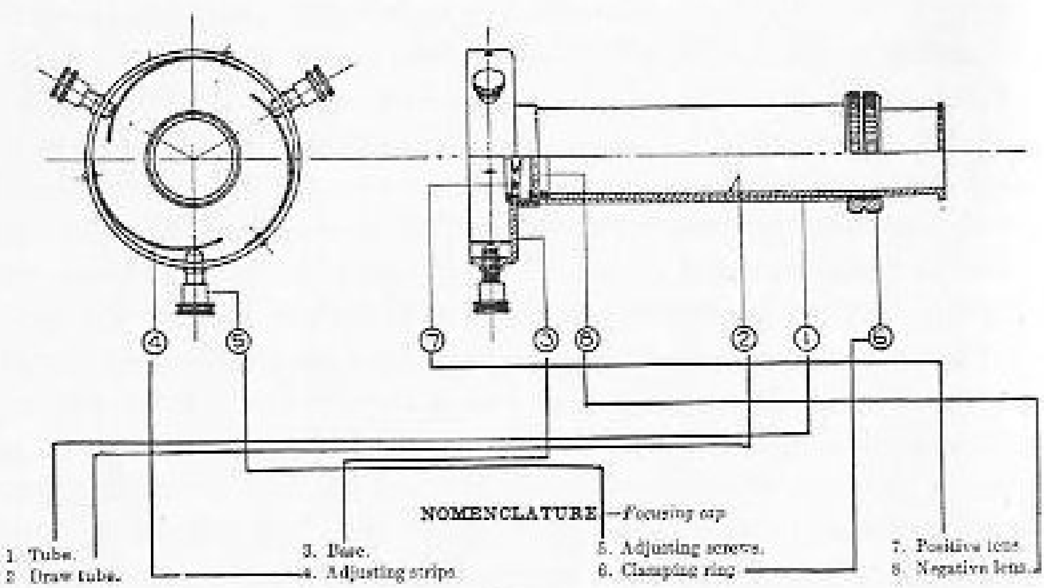


FIG. 1105.

1110. Care and handling of telescopes.—The objective lens is provided with a cover which should be kept in place at all times when the telescope is not in use; otherwise the sun will cause the balsam cement to crystallize.

When possible, telescopes should be stowed in a warm, dry place in boxes provided for them.

Telescopes should be wiped off with a dry cloth (nothing else), and the cloth should never touch the lenses.

Care should be taken that the telescope holders are kept clean and smooth. Emery should never be used for cleaning them.

Cleaning lenses.—Lenses should be wiped off only when necessary, for cleaning destroys the polish, thereby diminishing the amount of light passing through. If they are very greasy, a few drops of alcohol applied with a brush and then wiped with clean chamois skin will usually be sufficient. Dust can be removed by means of a dry camel's-hair brush.

Each pointer and trainer should have at hand a piece of lens paper, so that he may be able to wipe off the eyepiece lens in case it becomes covered with moisture, as it does sometimes. A few small holes punched in the rubber eye guard will tend to correct this trouble. In no case use waste or ordinary cloth for cleaning a lens, but only chamois skin, lens paper, or the special Selvyt cloth provided.

In cleaning the objective lens of a telescope when in place, special attention must be given that the objective lens does not rotate, as this will cause large errors in the optical axis.

Compound lenses are usually cemented together with Canadian balsam, which is soluble in alcohol; hence care must be taken that too much alcohol is not used in cleaning. In cleaning cross-line lenses, do not use alcohol, as it removes the filling-in material of the etched line.

The above remarks apply to the polished surfaces of prisms as well as of lenses.

In looking through a telescope, it is well to remember that all dirt that may be seen very clearly defined must lie in or very near to a focal plane. For this reason dirt on the cross-line lens is clear and distinct, while that on the objective and eyepiece lens will appear as a blur. However, dirt on any lens lessens the amount of light that is transmitted to the eye.

Section IV.—Sight Scales.

1111. Referring again to Plate I, there are scales installed on the sight bar and on the azimuth head for the purpose of measuring the angles in the vertical and horizontal planes at which the pivot bar is set with reference to the gun's axis. These scales are called the *sight scales*. The scale which measures the angle in the vertical plane is called the *range scale*, and that which measures the angle in the horizontal plane is called the *deflection scale*.

1112. It will be evident that the range scale must be calibrated from data contained in the range table for the particular gun to which the range scale belongs. A range table is a compilation of data giving the numerical value of each element of the trajectory for each 100-yard increment in range, including the angle of elevation and the drift. The values are calculated theoretically and actually verified by ranging at the Naval Proving Ground for each particular type of gun.

A direct-reading range scale suitable for the sight mount in Plate I is shown in Fig. 1106. The range strip, made of white metal, is normally engraved with divisions and numbers on both edges, the scale on one edge showing the elevation in minutes of arc, and the scale on the other edge showing the range in yards corresponding to the minutes graduation on the opposite edge. The scale in yards is the one normally used. The scale in minutes is sometimes employed for sight setting when using director fire. This range strip is dovetailed to fit in the *sight bar* flush with the outer side face, and is adjustable within the limits of an elongated hole for a clamp screw. (Shown as screw *a* in Fig. 1106.) Let us assume that a telescope is attached to the part marked *pivot bar*, and that the telescope is parallel to the bore in the vertical plane. The *sight-bar bracket* is rigidly secured to the gun slide and there is a reference mark *K* on it. With the telescope parallel to the bore, the gun would evidently have zero elevation with reference to the line of sight if the telescope were directed at a target. (In Fig. 1106 the sight is depressed to a reading of 600 yards opposite the reference mark *K* on the sight-bar bracket.) Hence, we may place a zero mark on the movable sight bar so that it will exactly coincide with the reference mark *K* when the telescope is in the zero position (*i.e.*, parallel to the bore in the vertical plane). The sight bar is in the form of an arc, with its center of curvature at the horizontal pivot of the pivot bar. The radius of this arc is called the sight radius. If we know, from range table data, that a range of 5,000 yards requires an angle of elevation of 2° 14′.4, and if we lay off this angle from the zero mark on the sight bar, the point so established may be marked 5,000. Then, if we move the sight bar so that the point marked 5,000 comes opposite the reference mark *K*, the pivot bar and telescope will have been set at the required angle in elevation with the bore for a range of 5,000 yards. In a similar manner points for all ranges may be located.

The range reading set on the range scale of the sight bar, called sight-bar range, represents only an angle of elevation of the gun. It does not necessarily represent the distance to which the gun will throw the projectile when the line of sight is on the target. The gun, with a sight bar range of say 10,000 yards set on its sights, will throw the projectile just 10,0000 yards only if the conditions under which the shot is fired are all equal (or equivalent) to the standard conditions on which the range tables are based and for which the sight scale was graduated. The range tables assume that the gun and target are motionless, that there is no wind, etc. When gun and target are moving,

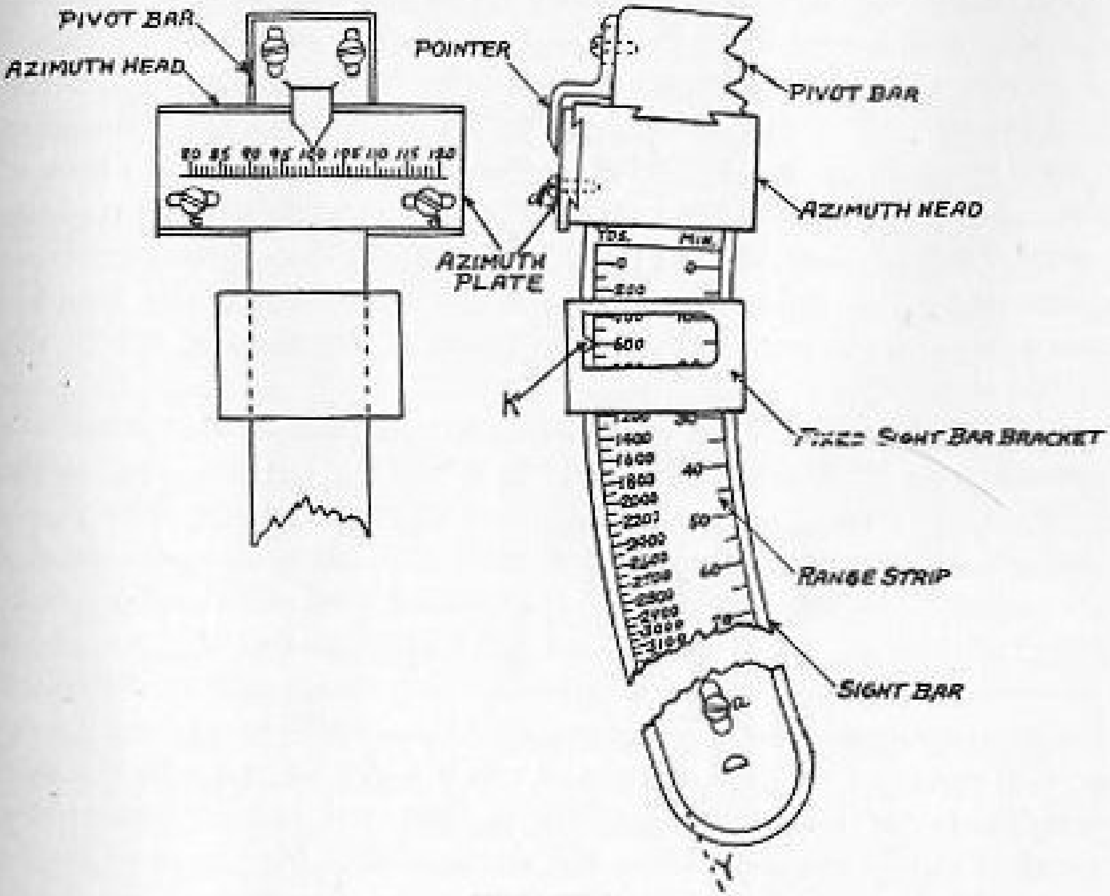


FIG. 1106.

a wind is blowing, and other conditions are nonstandard, the control party must compute corrections to compensate for these conditions, add such corrections (algebraically, in yards) to the target distance in yards, and send to the guns this corrected sight-bar range to be set on the sights. Thus, for example, a sight-bar range of 10,500 yards may be set (*i.e.*, the gun elevated at an angle equivalent to that amount) in order to cause the projectile to fall just 10,000 yards from the gun.

1113. An arrangement similar to that of the range scale is provided for setting the telescope at an angle with the bore in the horizontal plane. As shown in Fig. 1106, the pivot bar is fitted into a dovetailed groove in the azimuth head, and it may slide in this groove. The azimuth head is also in the form of an arc with its center of curvature at the vertical pivot of the pivot bar, and graduations are located on the azimuth head, and a fixed reference mark on the pivot bar, by means of which deflection settings can be made.

For setting the sight in the horizontal plane, *i.e.*, in deflection, an arbitrary scale division is used. The *arbitrary deflection scale* is one graduated in *mils*, a mil being an angle subtended by an arc of length equal to one one-thousandth of the arc's radius (*i.e.*, a mil equals .001 radian). This is equivalent to 3′.44 or 3′ 26″. The angle whose tangent is .001 so closely approximates a mil that for practical purposes the angle $\tan^{-1} .001$ is often used to represent a mil. This approximation may conveniently be used to determine the angular lateral offset of the sighting axis necessary to obtain a given lateral displacement of the point of fall at a particular range. By dividing the desired lateral displacement of the point of fall in yards by one one-thousandth of the range in yards, the necessary lateral offset of the sighting axis is obtained in mils.

Deflection scales in the U. S. Navy are marked so that when the sighting axis is parallel to the bore in a horizontal plane, *i.e.*, at the position of no deflection, the scale reads 100 (50 on some older scales and 500 on anti-aircraft scales). This convention makes unnecessary the use of the words right and left in making settings. Further, scales are graduated so that the point of fall will be moved to the right if the scale reading is numerically increased (raised) and to the left if the scale reading is numerically decreased (lowered), provided that the line of sight is kept pointed at the same object by training the gun. This leads to the following easily remembered rule: To move the point of fall to the right, raise the setting (right, raise); to move the point of fall to the left, lower the setting (left, lower). In using this rule it should be remembered, however, that we are dealing with the direction in which the correction is to be made, and not the direction in which the error is found. For instance, if the projectile falls 38 yards to the right of the desired point, its error is 38 yards right; but we must apply a correction of 38 yards left (in mils) to bring it to the desired point.

The reading set on the deflection scale includes not only the correction in mils for drift, as found in the range table for the existing range, but also corrections in mils for variations from standard conditions, as mentioned in Art. 1112. If the resulting total correction is, say, 10 mils to the right, a reading of 110 (or 60 or 510, according to the type) is set on the scale. The sighting axis is thereby offset 10 mils to the left of the bore and when the gun is trained to bring the line of sight on the target the bore is pointed, in the horizontal plane, 10 mils to the right of the line of sight. The setting on the deflection scale is called simply the *scale*. Thus, in the example above, the *scale* is 110.

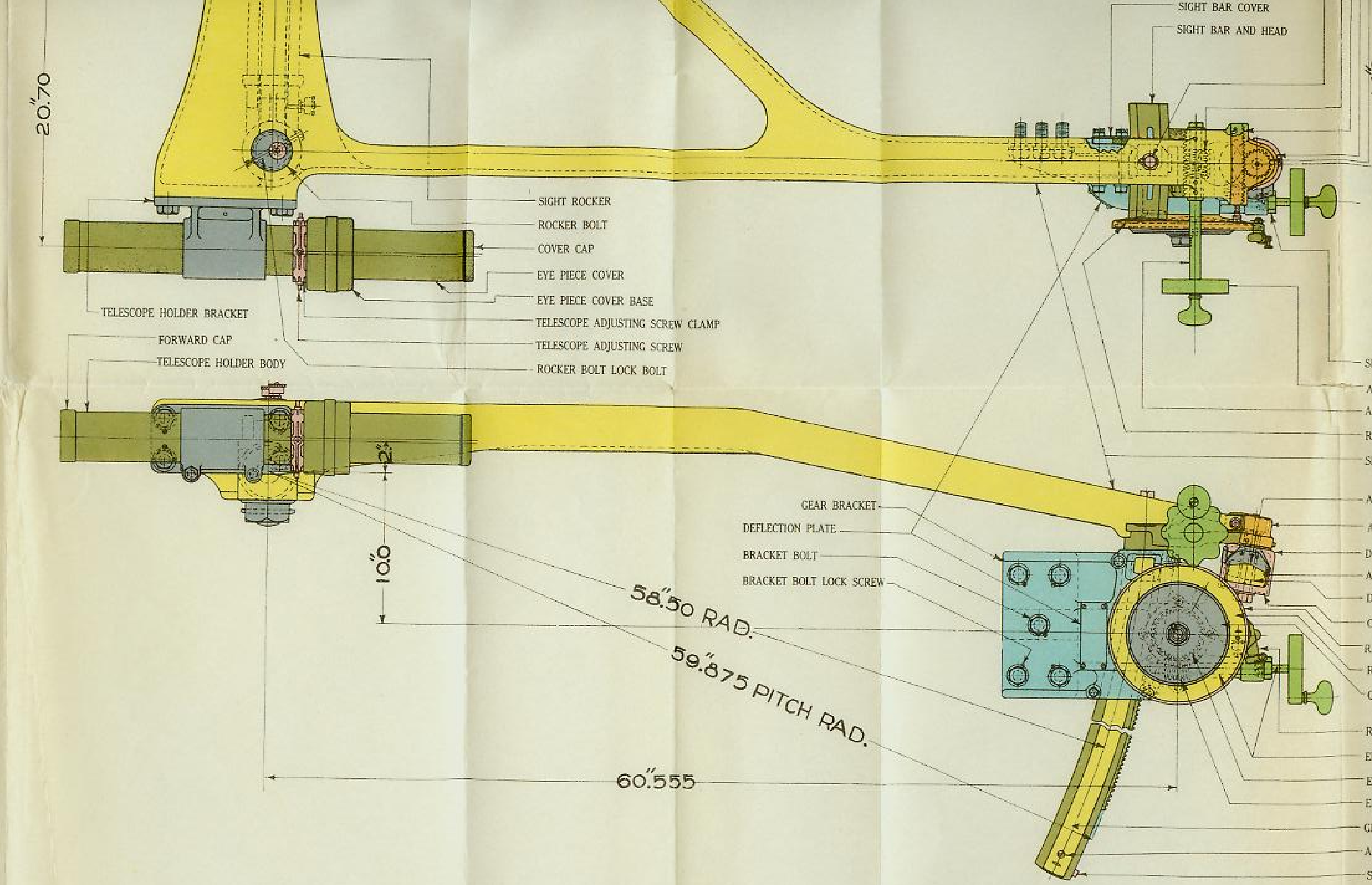
1114. Some guns use only the direct reading sight scales similar to those shown in Fig. 1106. But most of our guns are provided with *additional* scales which permit the use of larger scale divisions than can be used on the direct-reading scale. It will be evident that graduations on the sight-bar scale would have to be very close together to provide a mark for each 50 yards of range; at short ranges it would require marks at intervals of about one or two minutes of arc. In order to provide easily readable divisions, multiplying scales are used. These are merely scales attached to the gearing controlling the setting of the pivot bar in elevation or in azimuth, in such a manner that a small movement of the pivot bar will be indicated by a greater movement of the multiplying scale. The ratio between the two movements depends only on the gear ratio between them, and hence the calibration of the multiplying scale is purely a mechanical problem. (See Plate II.)[7]

Section V.—Sight Mounts.

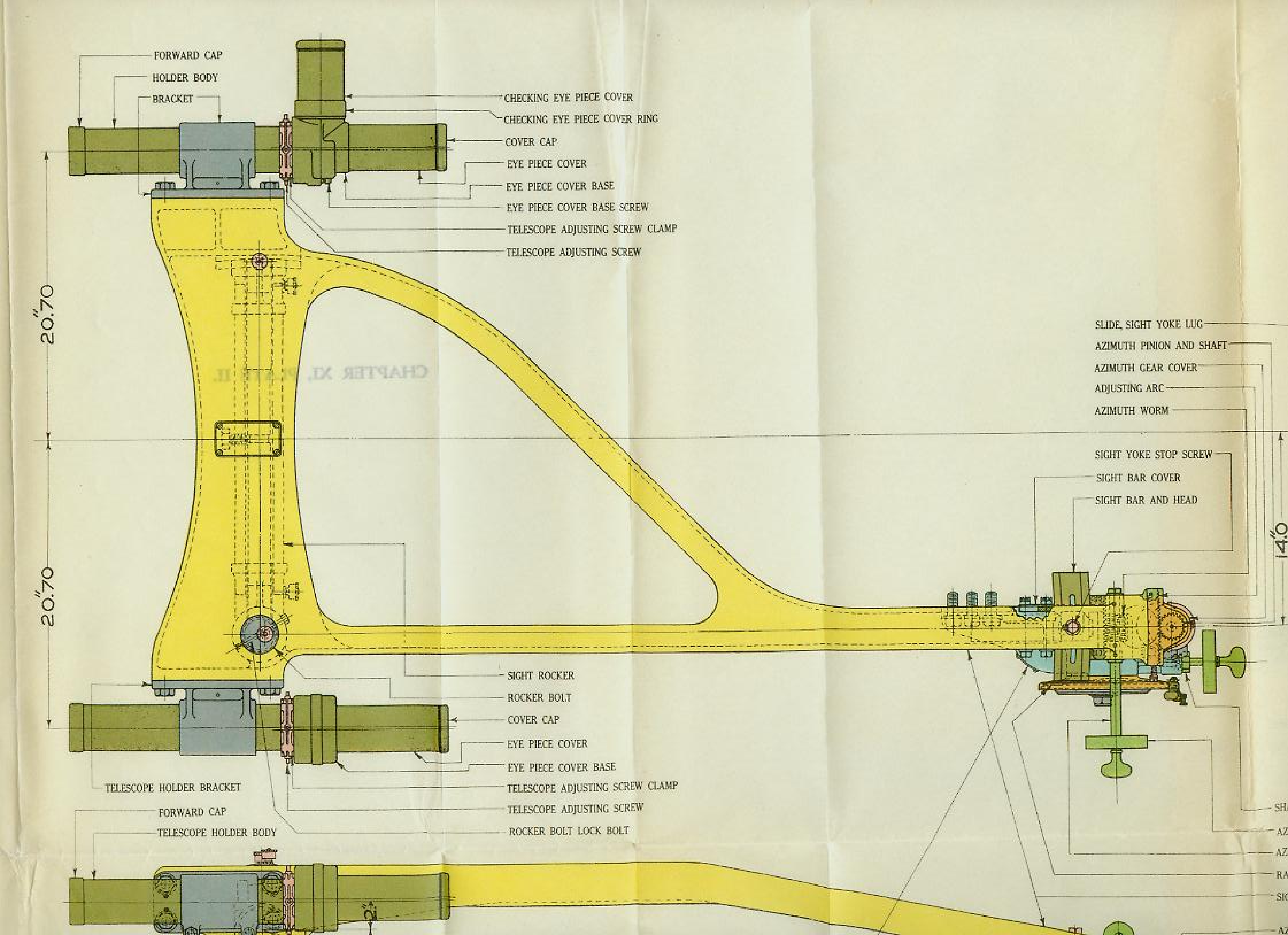
1115. Yoke sight mounts.—The yoke sight mount for broadside guns is illustrated in principle in Fig. 1107. (See Plate II, for full detail.) The two telescopes, one for the pointer and one for the trainer, are now carried on one sight mount which is a modification of the type shown in Plate I.

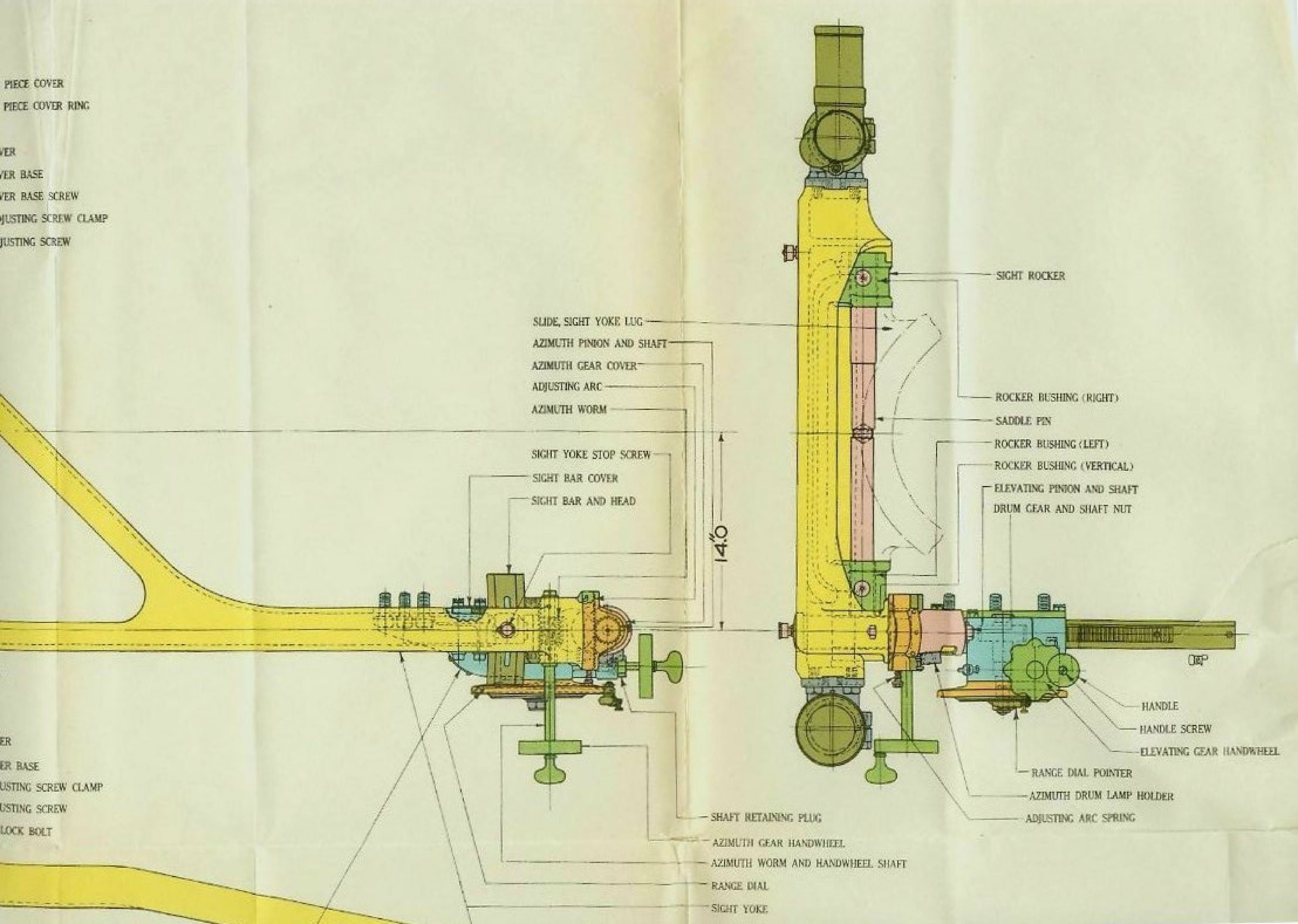
Instead of the pivot bar we have a *yoke Y* which amounts to a pivot bar spread out wide enough to carry a telescope on each side of the gun. The rear end of the yoke works in the azimuth head on the sight bar in the same manner as the rear end of the pivot bar in Plate I. The horizontal sight pivot is formed by a shaft *hh′*, called the *saddle pin*, in a casting *C* called the *saddle*, and engaging a casting *R* called the *rocker*. The vertical sight pivot is formed by the pin *vv′* which centers the yoke in the rocker. The upper and lower side edges of the rocker, *a*, *b*, *c*, *d*, are machined to arcs of circles centered in *vv′* to a working fit in the yoke; this gives stiffness at the positions *H* and *H′* where the castings called *telescope holders* are connected to the yoke. The telescopes are held in the telescope holders by semi-circular clamps secured to the telescope holders. The telescopes may be adjusted in

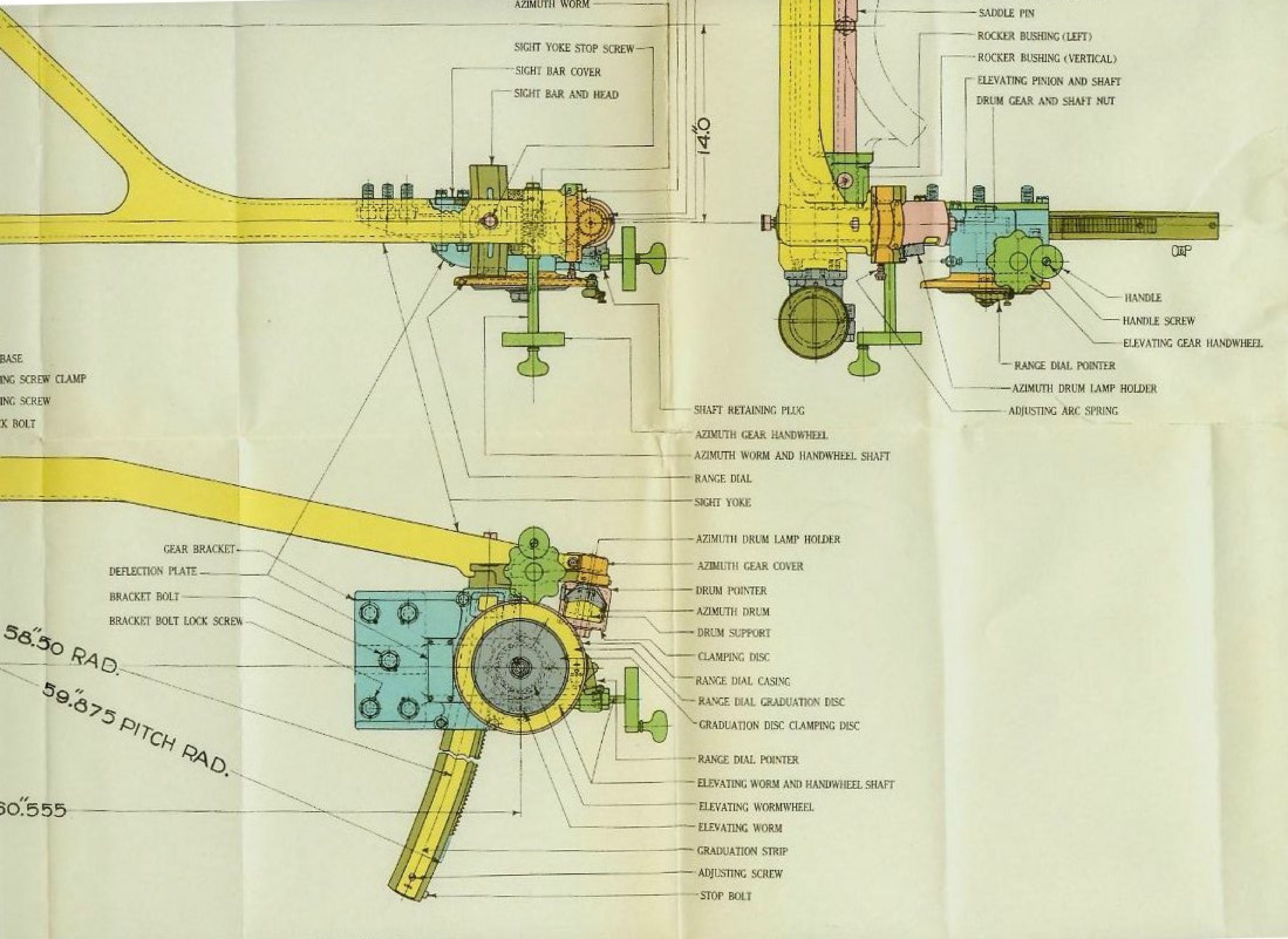
[7] The means of imparting motion to the pivot bar are, for the sake of simplicity in the drawings, omitted from Plate I and the following illustrations of sight mounts, except as shown on Plate II.



General Arrangement of the 5-inch Sight, Mark XXI, Modification 5


20.70
20.70
FORWARD CAP
HOLDER BODY
BRACKET
CHECKING EYE PIECE COVER
CHECKING EYE PIECE COVER RING
COVER CAP
EYE PIECE COVER
EYE PIECE COVER BASE
EYE PIECE COVER BASE SCREW
TELESCOPE ADJUSTING SCREW CLAMP
TELESCOPE ADJUSTING SCREW
TELESCOPE HOLDER BRACKET
FORWARD CAP
TELESCOPE HOLDER BODY
SIGHT ROCKER
ROCKER BOLT
COVER CAP
EYE PIECE COVER
EYE PIECE COVER BASE
TELESCOPE ADJUSTING SCREW CLAMP
TELESCOPE ADJUSTING SCREW
ROCKER BOLT LOCK BOLT
2"
SLIDE SIGHT YOKE LUG
AZIMUTH PINION AND SHAFT
AZIMUTH GEAR COVER
ADJUSTING ARC
AZIMUTH WORM
SIGHT YOKE STOP SCREW
SIGHT BAR COVER
SIGHT BAR AND HEAD
14.0


PIECE COVER
PIECE COVER RING
VER
VER BASE
VER BASE SCREW
DJUSTING SCREW CLAMP
JUSTING SCREW
SLIDE, SIGHT YOKE LUG
AZIMUTH PINION AND SHAFT
AZIMUTH GEAR COVER
ADJUSTING ARC
AZIMUTH WORM
SIGHT YOKE STOP SCREW
SIGHT BAR COVER
SIGHT BAR AND HEAD
14.0"
SIGHT ROCKER
ROCKER BUSHING (RIGHT)
SADDLE PIN
ROCKER BUSHING (LEFT)
ROCKER BUSHING (VERTICAL)
ELEVATING PINION AND SHAFT
DRUM GEAR AND SHAFT NUT
HANDLE
HANDLE SCREW
ELEVATING GEAR HANDWHEEL
RANGE DIAL POINTER
AZIMUTH DRUM LAMP HOLDER
ADJUSTING ARC SPRING
ER
ER BASE
USTING SCREW CLAMP
USTING SCREW
LOCK BOLT
SHAFT RETAINING PLUG
AZIMUTH GEAR HANDWHEEL
AZIMUTH WORM AND HANDWHEEL SHAFT
RANGE DIAL
SIGHT YOKE


AZIMUTH WORM
SIGHT YOKE STOP SCREW
SIGHT BAR COVER
SIGHT BAR AND HEAD
14.0"
SADDLE PIN
ROCKER BUSHING (LEFT)
ROCKER BUSHING (VERTICAL)
ELEVATING PINION AND SHAFT
DRUM GEAR AND SHAFT NUT
HANDLE
HANDLE SCREW
ELEVATING GEAR HANDWHEEL
RANGE DIAL POINTER
AZIMUTH DRUM LAMP HOLDER
ADJUSTING ARC SPRING
BASE
ING SCREW CLAMP
ING SCREW
K BOLT
SHAFT RETAINING PLUG
AZIMUTH GEAR HANDWHEEL
AZIMUTH WORM AND HANDWHEEL SHAFT
RANGE DIAL
SIGHT YOKE
GEAR BRACKET
DEFLECTION PLATE
BRACKET BOLT
BRACKET BOLT LOCK SCREW
AZIMUTH DRUM LAMP HOLDER
AZIMUTH GEAR COVER
DRUM POINTER
AZIMUTH DRUM
DRUM SUPPORT
CLAMPING DISC
RANGE DIAL CASING
RANGE DIAL GRADUATION DISC
GRADUATION DISC CLAMPING DISC
58.50" RAD.
59.875" PITCH RAD.
60.555"
RANGE DIAL POINTER
ELEVATING WORM AND HANDWHEEL SHAFT
ELEVATING WORMWHEEL
ELEVATING WORM
GRADUATION STRIP
ADJUSTING SCREW
STOP BOLT

position, independently of the yoke, in various ways as enumerated in Art. 1121(8).

The sight bar and sight-bar bracket as well as the multiplying scales, are shown on Plate II.

When a deflection setting is made on this sight mount, the end of the yoke moves laterally in the azimuth head, and the yoke rotates about vertical pivot *vv'*, sliding at points *a*, *d*, *c*, and *b* on the rocker *R*, which remains stationary. When range is set, the sight bar, azimuth head and end of the yoke rise together, and the yoke and rocker, as a unit, rotate about the horizontal pivot *hh'*.

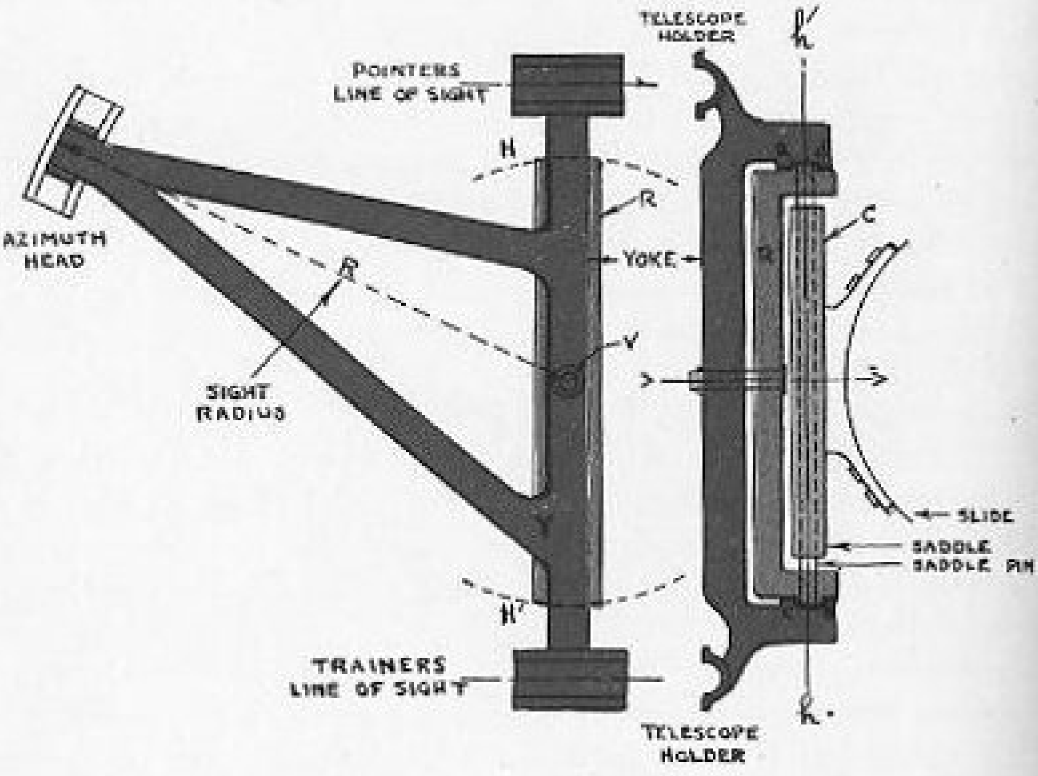


FIG. 1107.—YOKE SIGHT MOUNT.

1116. Periscopic sights for broadside guns.—With the sight mount shown in Fig. 1107, the wide distance between the two lines of sight makes the opening in the gun shield very large, or the effective arc of train of the gun is considerably less than the actual arc that the gun covers in moving from one edge of the port to the other; the pointer's line of sight will be masked when the gun is at extreme left train, and the trainer's line of sight will be masked when the gun is at extreme right train. These two faults may be corrected by using *prism telescopes* in which the line of sight, in effect, is turned through two right angles, as shown in Fig. 1108. The sight mount for these telescopes is practically the same as the mount shown in Fig. 1107, so it will be sufficient in Fig. 1108 to show a portion of the yoke, with the telescope holders, and the positions of telescopes relative to the gun when the sight bar is set at zero. The inherent weakness and other disadvantages of this type of telescope and mounting have caused a reversion to the earlier type employing straight telescopes (see Fig. 1107 and Plate II). Periscopic sights for broadside guns are still in use on a few of our oldest battleships, but straight telescopes are used on all recent construction

1117. Sight mounts for A.A. guns.—The sight for the 3″–50 caliber A.A. gun, shown in Chapter IX, Plate VI, is of the yoke type.

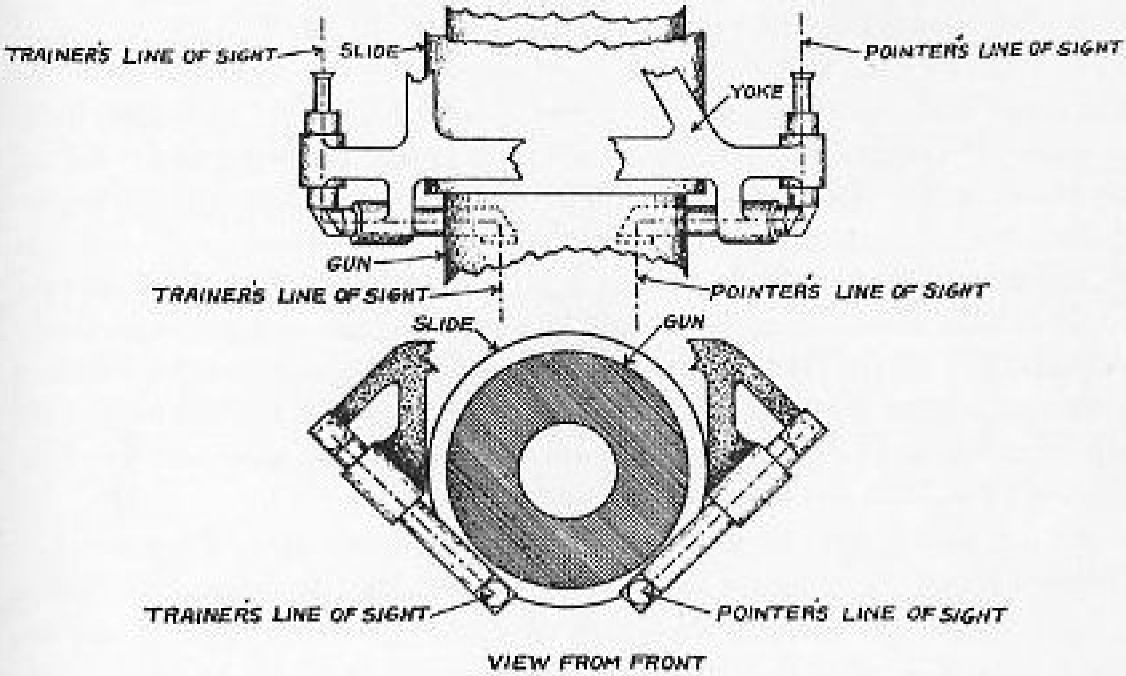


FIG. 1108.

The sight for the 5″–25 caliber A.A. gun, shown in Chapter IX, Plate VII, is not of the usual yoke type as two azimuth pivots are used instead of one. These azimuth pivots are on the center line of the telescopes and near the eyepieces so that there will be minimum lateral displacement of the eyepiece. This double azimuth pivot arrangement is desirable as this sight has a large movement in deflection which, with a yoke sight mount, would cause excessive movement of the eyepieces. The sight-setting handwheels and scales are mounted on the right side of the gun, and the sight on the right side is connected to the sight on the left side by means of two shafts, one for elevation and one for deflection, by means of which the sights on the two sides of the gun are always moved the same angle in elevation and deflection.

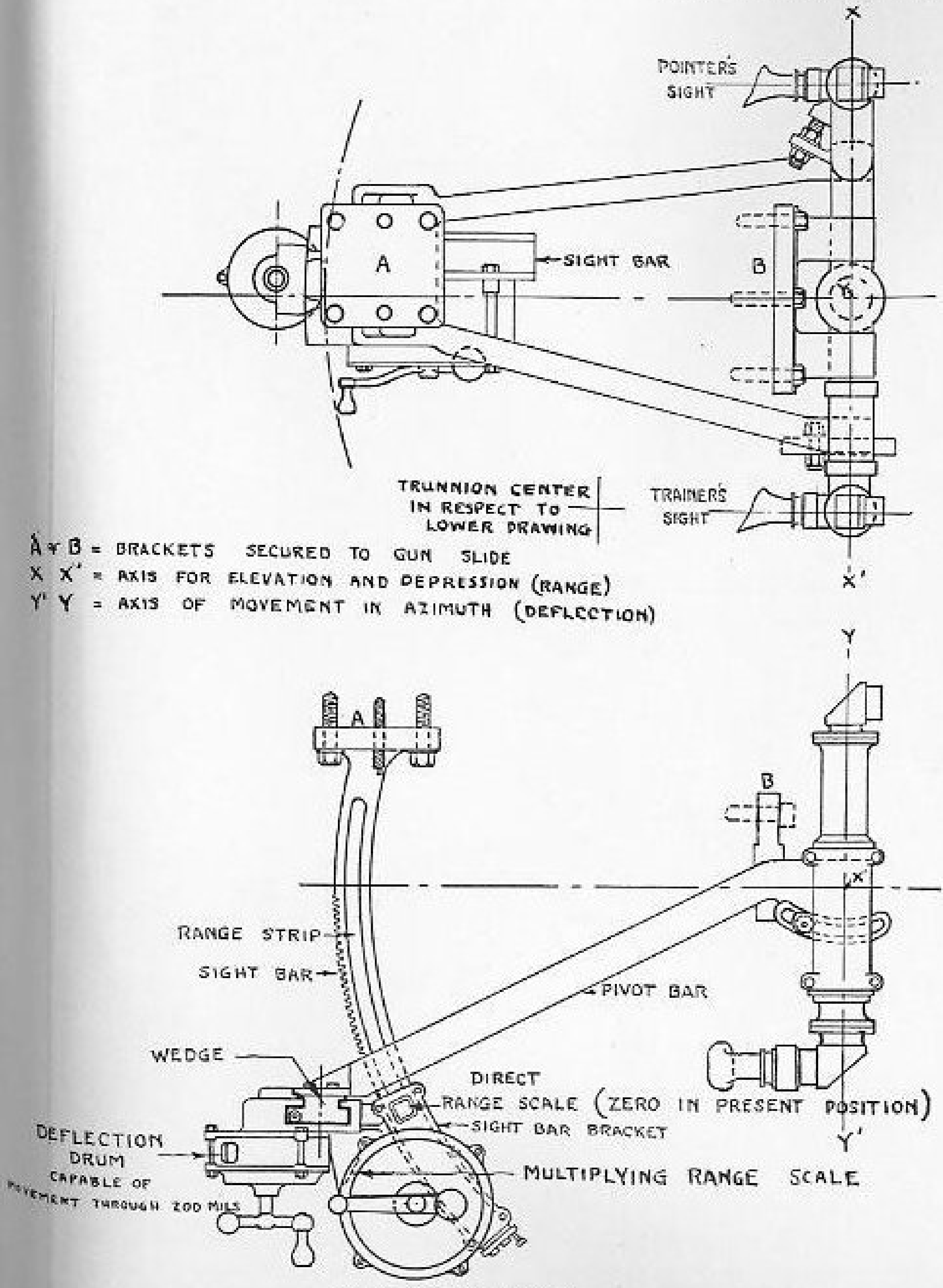
1118. Late turret sight mounts.—On the latest 14- and 16-inch turret guns, a yoke sight mount is installed, similar to those used on broadside guns, but instead of being pivoted to the top of the slide it is pivoted underneath. It is fitted with periscopic (prismatic) telescopes, the line of sight being bent through two right angles, so that while the user sits at the eyepiece in the gun pit, the line of sight emerges from the objective in the turret gun port just beneath the gun. The guns are fitted with shields which give the splinter protection made necessary by the slightly larger port openings in the face plate of the turret. Plate III illustrates the 14-inch sight mount Mark V and Plates IV and V the 14-inch sight mount Mark I. It will be noted that the Mark I sight mount is attached to the slide exactly as in the case of a broadside yoke sight mount. In the Mark V sight mount it will be noted that the sight bar itself is attached to the slide and the pivot bar and sight-bar bracket move in elevation over the fixed sight bar. In both sights the trainer's telescope is free to swing in a vertical plane, to allow the trainer to keep the target in view during heavy rolling.

The twin 6-inch mounts on the 7,500-ton cruisers and the twin and triple 8-inch mounts on the 10,000-ton cruisers use straight telescopes in their gun sights, the pointer and trainer being stationed outboard of the guns, and the telescopes look through holes cut in the face plates of the mounts. Plates VI and VII show such a sight assembled on the slide of an 8-inch triple mount.

With a gun mount capable of 40° elevation, the sights illustrated in Plates VI and VII require excessively large port openings in the front face plates of the turrets. To avoid this sacrifice of strength and protection, it is probable that heavy cruisers now building and those built in the future will be equipped with periscopic telescopes installed on a rugged form of parallel motion mechanism actuated from the trunnions of the slide; the telescopes will be mounted in a horizontal position, the objective ends to protrude through holes in the side of the turret.

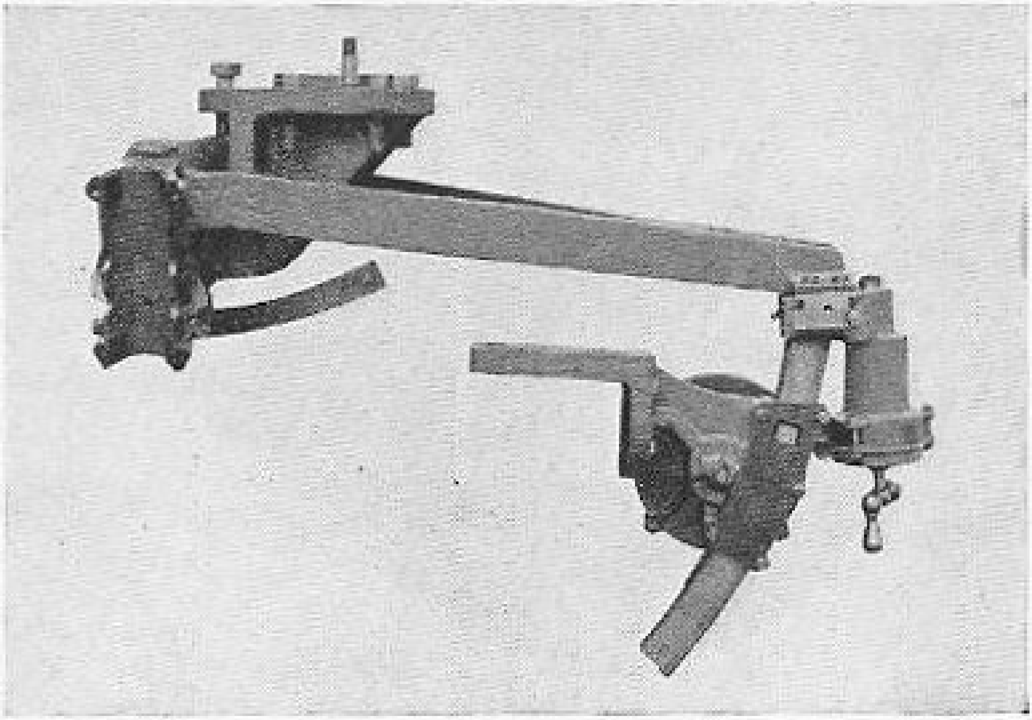
A parallel motion mechanism may be used in a sight mount to reduce the translational movement of the telescopes when the gun is elevated. Where the telescopes are installed about at the axis of trunnions such translational movement is small but where they are mounted on the slide in front of or in the rear of the trunnions, the gun, as it is elevated, imparts to them not only the rotational motion of elevation but also a translational movement (rise or fall) which necessitates a large sight port (gun port) to avoid blocking off the line of sight. The parallel motion mechanism transmits to the telescopes

CHAPTER XI, PLATE III.

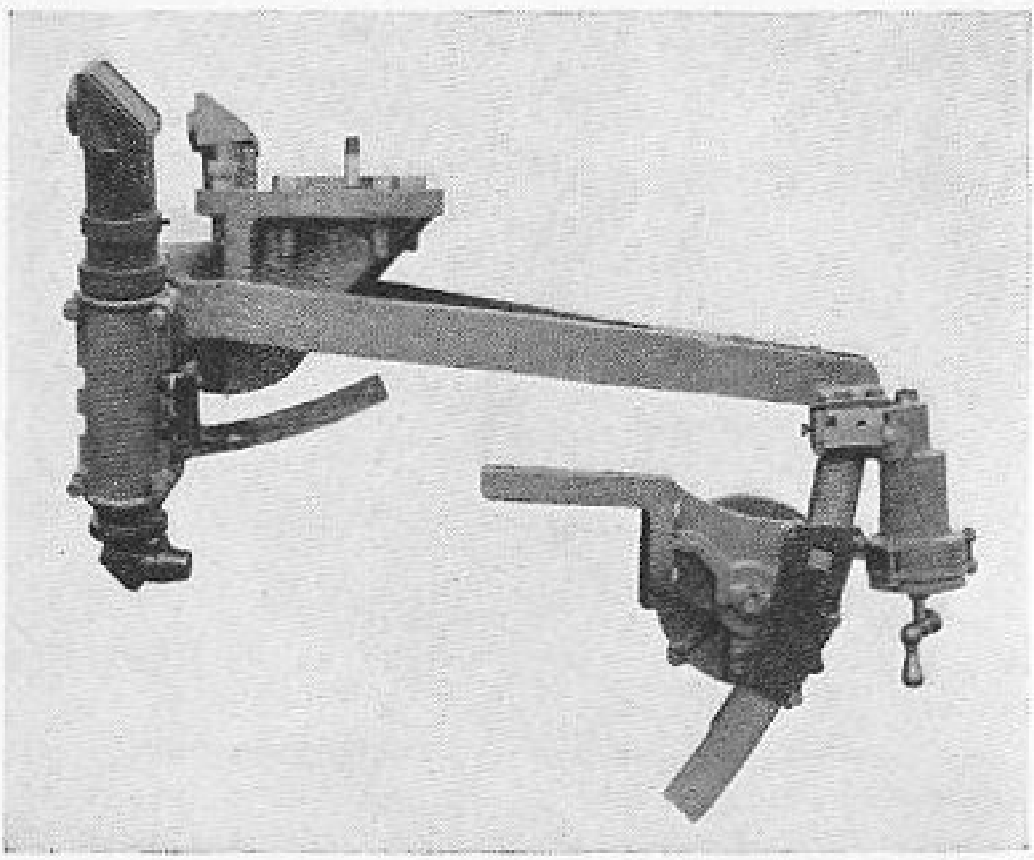


14-Inch Sight, Mark V.

CHAPTER XI, PLATE IV.

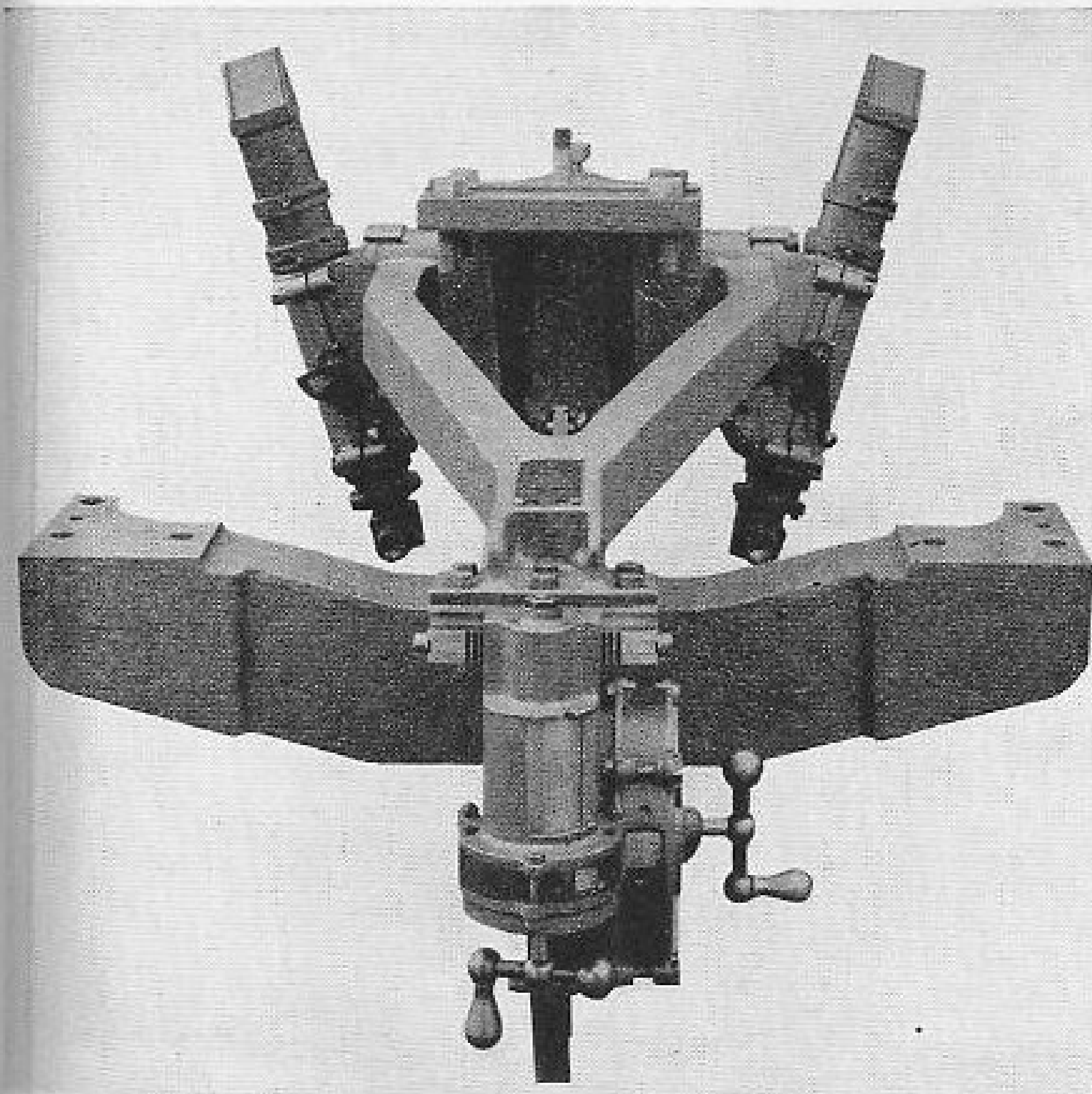


14-INCH SIGHT, MARK I, LEFT SIDE VIEW WITH TELESCOPE REMOVED.

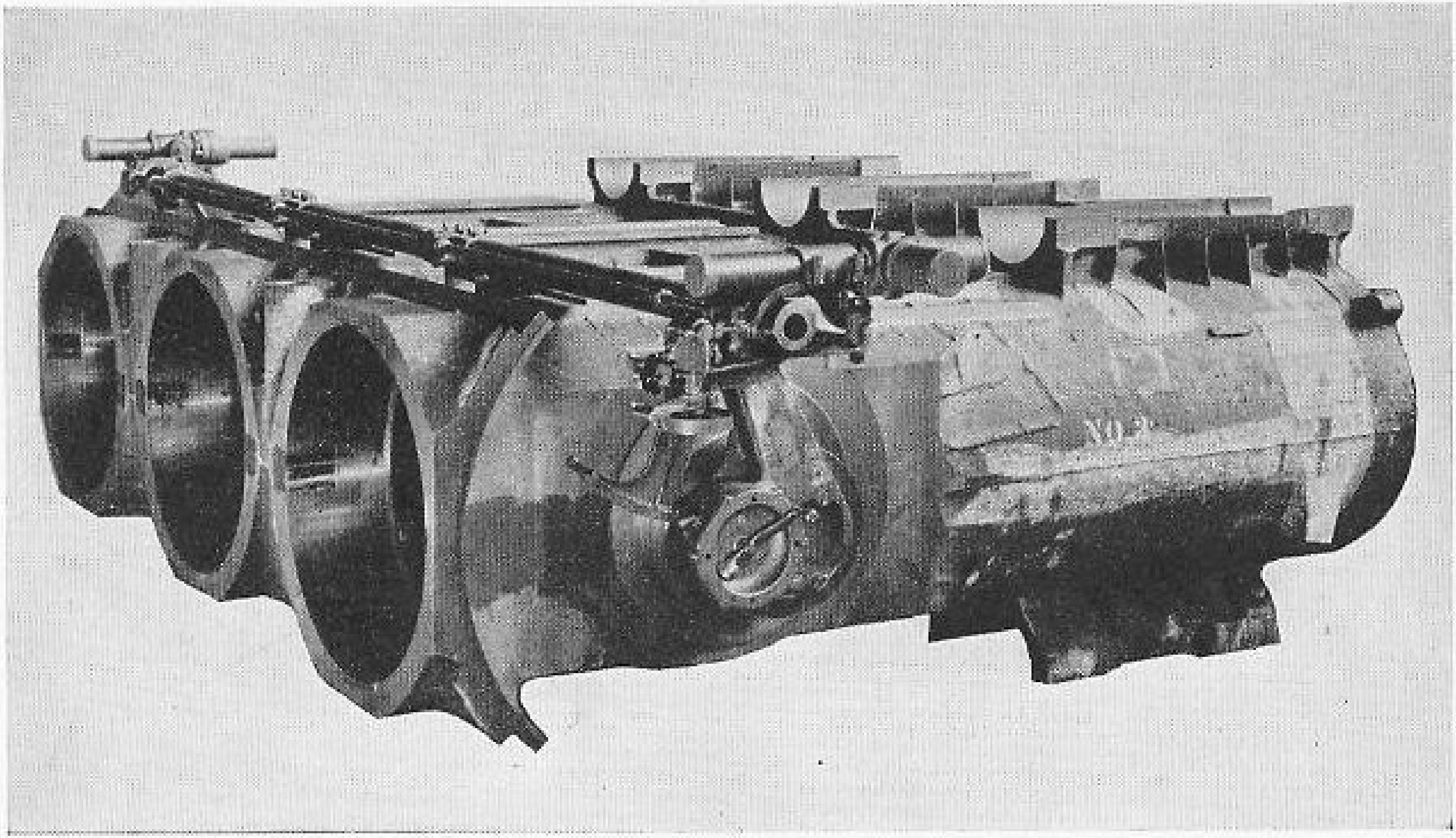


14-INCH, SIGHT, MARK I, LEFT SIDE VIEW WITH TELESCOPE MOUNTED.

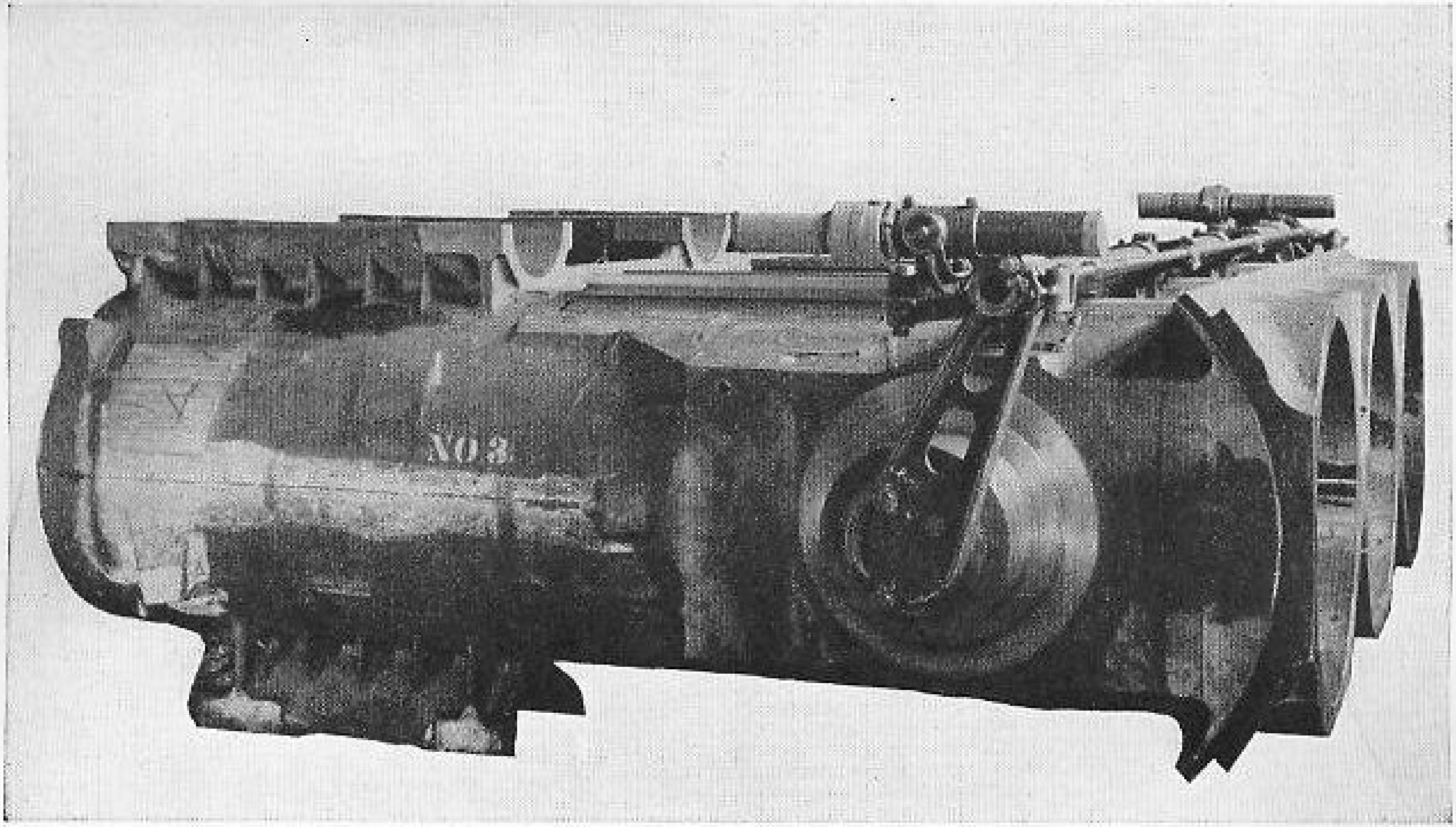
CHAPTER XI, PLATE V.



14-Inch Sight, Mark I, Rear View.



8-Inch Sight, Mark XXVII, Mod. I, Assembled on Slide Mark XV, Showing Pointer's Side.



8-INCH SIGHT, MARK XXVI, MOD. 1, ASSEMBLED ON SLIDE MARK XV, SHOWING TRAINER'S SIDE.

the rotational motion unchanged but removes the translational movement.

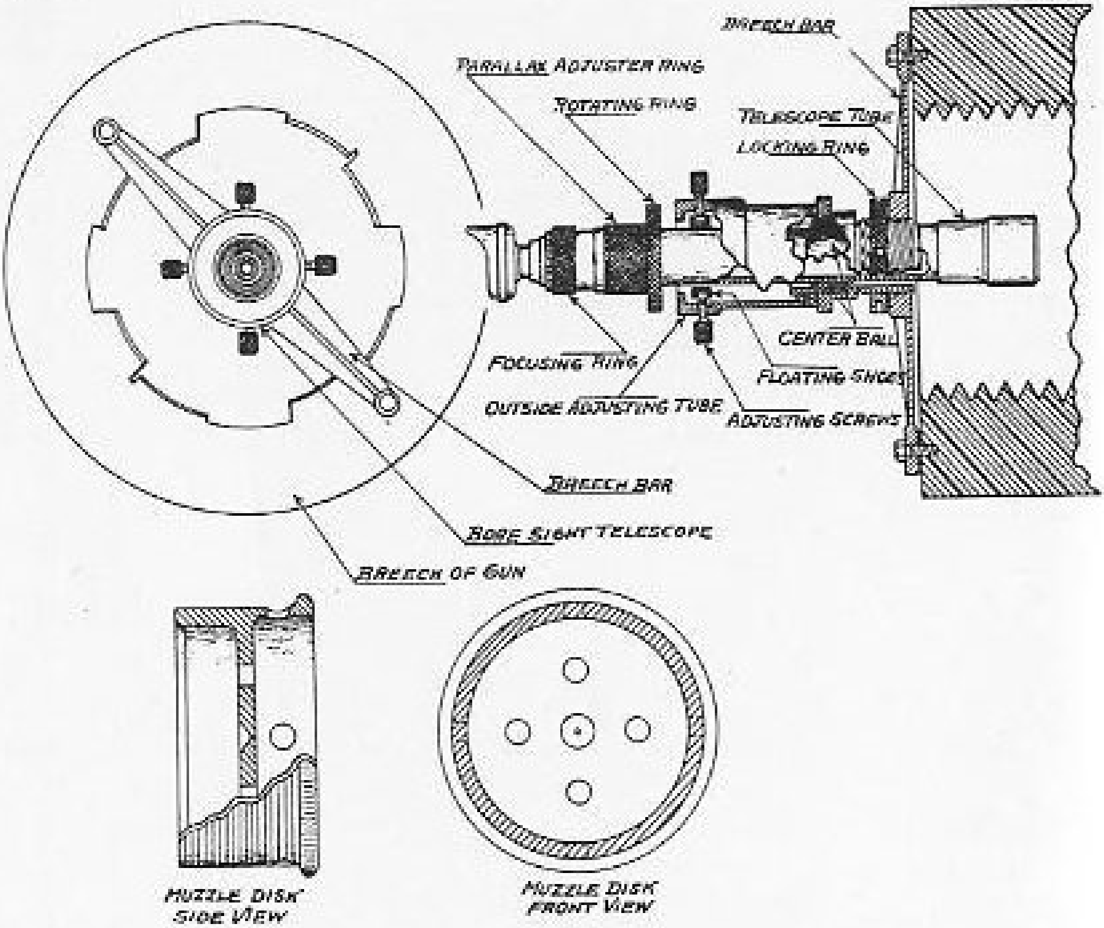


FIG. 1109.

Section VI.—Bore Sighting.

1119. A bore sight[8] is a telescope sight which may be mounted in the breech of a gun, as shown in Fig. 1109. A breech bar, accurately made so that the center of its threaded hole will lie in the axis of the bore, is screwed to the face of the breech by two screws. The outside adjusting tube of the telescope is screwed into the breech bar and clamped by the locking ring. The telescope tube proper is permanently mounted within the outside adjusting tube in a spherical bearing, there being a corresponding spherical surface (labeled *center ball* in Fig. 1109) on the outside of the telescope tube proper. The center of both the ball and its bearing must lie in the geometrical longitudinal axis of the telescope tube. By means of the four adjusting screws shown, the telescope tube can be rotated in the spherical bearing (made to

[8] The term *bore sight* includes all the apparatus used, *i.e.*, the breech bar, muzzle disk and telescope. The telescope alone is properly called "the bore-sight telescope."

take any direction within limits) and clamped in position. By this means the axis of the telescope is caused to coincide with the axis of the bore.

The use to which this telescope is put requires that its optical and geometrical axes coincide. This is difficult to accomplish in manufacture. The telescope tube is therefore provided with four additional screws (not shown) by which the position of the cross-line lens can be changed so that the intersection of the cross lines lies in the geometrical axis. This adjustment is made by the manufacturer and need not be made on board ship unless a derangement occurs.

The telescope has a focusing ring for focusing the eyepiece to the individual eye, and a parallax adjuster ring by means of which the optical system can be adjusted, so that the telescope may, without parallax, view objects at any distance required in its use. There is also a rotating ring, by which the telescope tube may be rotated (about its axis) within the outside adjusting tube.

The final part of the bore sight is the muzzle disk. This is a circular casting machined to fit snugly in the muzzle of the gun, the size of the disk corresponding to the caliber of the gun. Drilled through the disk in its exact center is a small hole. In addition there are four larger holes, arranged as shown in Fig. 1109. The larger holes serve as circles of light by reference to which the telescope may be rotated (by the rotating ring) until the cross lines are horizontal and vertical, respectively; they also admit additional necessary light to the bore.

With the muzzle disk properly shipped in the gun's muzzle the central hole lies in the axis of the bore. With the telescope properly shipped in the breech bar at the breech of the gun, the telescope also lies in the axis of the bore. If now, by means of the four adjusting screws, the telescope is adjusted in its outside adjusting tube so that the intersection of its crosswires coincides with the central hole of the muzzle disk, the optical (and geometrical) axis of the telescope lies in the geometrical axis of the bore. The muzzle disk may be removed and an observer, looking through the telescope, has his line of sight directed exactly along the axis of the bore. This is the purpose of the telescope.

1120. The object of bore-sighting is to cause the sighting axes of pointer's and trainer's telescopes and of bore sight (axis of gun) to converge at a specified range, with all parts of the sight rigidly secured in place and the sight scales *reading zero range and zero deflection* (50, 100, or 500 whichever is used to indicate no deflection). With a gun bore-sighted as above it is assured that the angular offsets of the sighting axes, as represented by range and deflection scale settings, will be properly oriented with respect to the axis of the bore.

The target used in bore-sighting is often an especially prepared screen on which are painted vertical and horizontal lines. This screen is mounted on the beach at the proper range or is mounted in a boat which is anchored at the desired range. However, any object or landmark at the proper range may be used as a target for bore-sighting and ships are often anchored so as to make such targets available for bore-sighting at the desired range.

1121. To bore-sight a gun.—(1) Preliminary to bore-sighting a gun check the following:

(a) Examine the pointer's and trainer's telescopes to see that they are clean, properly focused, free from parallax, and that the cross-wires are clearly visible and vertical and horizontal. Unsatisfactory telescopes should be replaced with spare telescopes.

(b) Run the sight through its full arc in elevation and azimuth to see that it works freely, is free from excessive lost motion, and that parts are properly lubricated. Set the sight scales at zero range and at the middle of the deflection scale (*i.e.*, at 50, 100, or 500, depending on the type of scale).

(2) Open the breech plug and lash it open, so as to prevent its swinging and injuring the bore sight.

(3) Secure the breech bar across the face of the breech by means of the bolts as shown in Fig. 1109.

(4) Enter and screw the telescope holder in the threaded hole in the breech bar. Before setting up tight on the locking ring, see that the two pairs of thumb screws are respectively vertical and horizontal. See that the cross lines are in sharp focus.

(5) Ship the muzzle disk and see that the lip or a line on its periphery touches the muzzle face all the way around.

(6) Adjust the telescope for condition of no parallax on the image of the muzzle disk. Center the cross-line intersection on the central hole in the muzzle disk by means of the telescope adjusting screws. Grasp the rotating ring and rotate the telescope through 360°. At the same time observe whether or not the cross-line intersection remains centered on the central hole in the muzzle disk for each 90° position. If it does not shift, the cross-line intersection is truly central. If the cross lines shift while the telescope is being rotated, unship the telescope and use a spare telescope that does not require cross-line adjustment. With reference to the large holes in the muzzle disk, bring the cross lines to horizontal and vertical positions, respectively, by rotating the telescope in the outside adjusting tube, using the rotating ring.

Telescopes that require cross-line adjustment are adjusted as follows:

Center the cross-line intersection on the central hole in the muzzle disk by means of the telescope adjusting screws. Rotate the telescope 180°. Move the vertical cross line half the distance of the error toward the center by the cross-line adjusting screws and the remaining half by means of the telescope adjusting screws. Do likewise with the horizontal cross line. Recheck and repeat the operation until the telescope is perfectly centered. In connection with the above we must differentiate between the telescope adjusting screws and the cross-line adjusting screws.

(7) Remove the muzzle disk and focus the telescope on a target as required, readjusting for no parallax on the target.

(8) Man stations at the pointer's, trainer's, and bore-sight telescopes. Normally the division officers take station at the bore-sight telescopes with the regular pointer and trainer at their stations. First one set of wires (horizontal or vertical) is made to converge on the target, then the other set, and as a final check, the intersections of both wires are checked on the target. The officer or man at the bore-sight telescope calls out "mark" and the wires in the gun-sight telescope are adjusted to agree with those in the bore-sight telescope. The manner of making this adjustment depends upon the type of gun sight. A careful examination of the sight will show the method to be employed. The following methods of adjustment may be found on the different gun sights now in use:

(a) Move entire sight in range and deflection. (This will adjust only one telescope on any yoke sight.)

(b) Adjust cross-line lens in telescope.

(c) Adjust telescope holder.

(d) Adjust telescope in tube. (These telescopes are mounted in a tube with ball joint on forward end of telescope and tube and adjusting screws on after end of tube.)

(9) Having made the adjustment to converge both telescopes with the bore sight, maintain this condition and slip the sight scales to read zero range and zero deflection provided they have been moved off zero by method 8(a) above. While maintaining this condition, secure the sight scales. Then make another check on the target to verify the boresighting. Having done this, the checking personnel should change stations, each checking at each telescope in order to insure that all telescopes are being checked on the correct target.

(10) Run the sights up and down, to right and to left, then set them again on zero range and zero deflection, and recheck the cross lines on the target.

(11) Test for looseness of parts and lost motion. Shake telescopes,

telescope holders, etc. See if the adjusting screws and sight scales are rigidly secured and again check the cross lines.

(12) Put muzzle disk in again and see if the bore-sight line of sight is still coincident with the axis of the bore.

1122. To bore-sight a turret, the procedure is the same, in regard to the pointer's sights, as for a broadside gun; that is, each pointer's horizontal wire is put on with his respective bore sight. All vertical wires, however, must converge at a point midway between the points on which the bores of the two guns are directed in case of a two-gun turret, and with the middle gun in the case of a three-gun turret. For a two-gun turret, a special target must be used, having two vertical lines spaced at a distance equal to the distance between the bores. The respective bore sights are directed at these lines rather than at a single line.

The detail of bringing the cross lines "on," shifting the scales, etc., are not given since they vary somewhat with each type of turret; the principle, however, is the same in all cases and if this principle and the object of bore-sighting are clearly understood, the details will present no serious difficulties.

Section VII.—Testing Sight Installations.

1123. Lost motion.—In all sights care must be taken to keep lost motion out of the mechanism, since it may cause sightsetting errors in both range and deflection. Such lost motion may be due to excessive clearances or play between moving parts, or, conversely, to binding, which may cause bending or springing of parts that should be rigid. A simple test will show the presence of lost motion, as follows:

(1) Keep the gun stationary. By setting the scales, direct the telescope at a fixed mark. If the ship is in dry dock, a mark outside the ship may be used, but if afloat, a mark on the ship should be used. The gun must be stationary with reference to the mark.

(2) Note the reading on the sight scales. Set a higher range and deflection reading, then return to the original readings. Since the scales have returned to the original readings, the telescopes should have returned to the stationary mark. If they do not there is lost motion in the range or the deflection setting mechanism, according to whether the horizontal or vertical wire fails to return to the mark.

(3) Repeat by setting a lower range and deflection reading, then returning to the original readings.

For a mark on board the ship, some means of removing telescope parallax must be used, such as a focusing cap. If no suitable shipboard mark is available, the test can be made afloat by keeping the bore directed at an external mark, using the boresight telescope for this purpose.[9]

1124. Parallelism of guns and sights.—It was pointed out in Art. 1105 that the horizontal sight pivot should be installed on the slide parallel to the trunnion axis so that when range is set on the range scale of the sight, the sighting axis will be moved only through a vertical angle with respect to the gun's axis, no horizontal component of motion being introduced. Another way of saying this is that as the gun and the sighting axis elevate and depress independently of each other in separate planes, the gun plane and the sight plane should both be perpendicular to a third plane. As a special case, for example, if the gun elevates and depresses in a vertical plane the sighting axis should also elevate and depress in a vertical plane, the two planes both being perpendicular to the horizontal plane. If the sighting axis is set at the point of no deflection the two perpendicular planes will also be parallel; if not, they will intersect.

With the ship in dry dock, the proper installation of the horizontal sight pivot may easily be checked as follows:

(1) Set the sight scales at zero range and any convenient deflection setting.

(2) Train the gun until the telescope vertical wire bears on a distant fixed mark, then take steps to prevent the gun from being trained during the remainder of the check.

(3) Elevate the gun to maximum elevation.

(4) By setting range on the sight depress the telescope until the horizontal wire comes down to the fixed mark. If the vertical wire is not on the mark, the horizontal sight pivot is not properly installed parallel to the trunnion axis. The amount of the error for maximum elevation may be obtained by setting deflection until the vertical wire comes on the mark and noting the number of mils movement necessary to bring it on.

Where two or more guns are mounted in one slide, the alignment of any gun relative to the other guns in the same slide is fixed. Some of the mounts of this type are equipped with one sight and some are equipped with two sights. Twin mounts and turrets of this type have only one pair of deck lugs and one set of trunnions. Whether equipped with one sight or two sights, the manner of checking is identical with

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[9] With modern yoke sight installations it is not considered necessary to check the accuracy of the range scale, *i.e.*, to check that, when the sight bar is moved through a given angle as read from the range scale, the sighting axis actually is moved through the same angle. This can be done however, when in dry dock, by use of a gunner's quadrant and a fixed mark.

that described above for single gun mounts. However, where any of these turrets are equipped with two sights, the sights should be checked with each other as well as checked with the guns.

Where two or more guns, each mounted in its own individual slide, are installed in a turret, each of these guns has its own individual sight. Each sight is checked with its own gun in the same manner as described above for single guns. In turret mounts of this type, it is well to check the guns with each other prior to checking the sights with each other.

1125. Batten method.—Parallelism of guns and sights may be checked by a method different from that given in Art. 1124. This is the batten method. Many navy yards have available the necessary battens, which are merely flat boards about 20′ high, mounted on a framework. The framework is placed on deck before the turrets so that the plane of the battens is parallel to a vertical plane through the guns' trunnions.

The turret is secured in train, the guns accurately leveled, all bore sights installed and adjusted, and sight scales set at zero range and no deflection. Now points are spotted on the battens where the lines of sight of the bore-sight telescopes and the gun-sight telescopes intersect the plane of the battens. Next the guns are elevated and points are spotted near the top of the battens for the bore sight (gun) axes only. The upper and lower points for each gun determine the elevation line of each gun, and fine piano wire is run between these pairs of points to represent the lines. Now sight lines are erected (with wire) through each of the lower gun-sight points and *parallel* to the gun lines. With the guns elevated near the top of the battens, the vertical wires of the telescopes should, when range is set on the sights, move along their respective sight lines on the battens. If they do not, the sights and guns do not elevate in parallel planes.

CHAPTER XIV.

AMMUNITION.

Section I.—Types of Ammunition.

1401. In the Navy the term *ammunition* is applied to all the component parts and substances which, when assembled, form a charge for any type of weapon. The weapon may be cannon, small arms, or any type of projector or releasing device. Ammunition thus includes warheads, mines, bombs, depth charges, demolition charges, fuzes, detonators, projectiles, explosives, signaling and illuminating pyrotechnic materials, and chemical warfare materials.

1402. Types of ammunition.—Ammunition is divided in the Navy into the following types:

(1) Separate loading, for guns.
(2) Semifixed, for guns.
(3) Fixed, for guns.
(4) Small arms.
(5) Trench warfare.
(6) Chemical.
(7) Pyrotechnic.
(8) Bomb.
(9) Impulse.
(10) Blank.
(11) Dummy drill.

It is further divided into three classes depending upon the purpose for which it is prepared:

(1) Service.—Ammunition which is supplied for use in battle.
(2) Special.—Ammunition which is supplied for gunnery exercises. This class was formerly termed "target."
(3) Drill.—Ammunition which is designated for drill purposes; usually "dummy."

1403. Separate loading ammunition.—Separate loading ammunition is that in which the primer, propelling charge, and projectile are loaded into a gun in two or more parts. All major caliber guns and some broadside guns in the Navy use separate loading ammunition. Separate loading ammunition is of two types: (a) for bag guns, and (b) for case guns. The latter is also known as semi-fixed ammunition.

Bag ammunition is that made up with the powder contained in one or more silk cloth bags with an ignition charge in the base of each bag. The primer is held in a firing lock secured on the end of the mushroom stem. This type is made up in two ways, loose and stacked. In the former the powder is dumped loosely into the bag and the bag is then rolled and laced tightly to make a compact unit. In the latter, the powder grains are stacked in serried rows, each grain in a layer on end, each layer placed successively in the bag and the bag sewed up and laced tightly. Stacked charges give a more compact, stiffer unit, easy to handle, occupying less space and eliminating a serious drawback in loosely packed bags, namely the cutting of the cloth by the sharp edges of the grains. Powder for service weights of charge for 8-inch guns and above is always stacked.

1404. Semi-fixed and fixed ammunition.—Fixed ammunition is that in which the projectile and primer are firmly secured in a cartridge case containing the propelling charge, so that the gun is loaded in one operation. Fixed ammunition was formerly termed *case* ammunition.

Semi-fixed ammunition is that in which the primer and propelling charge are firmly fixed in the cartridge case, but in which the projectile is separate or fits loosely in the cartridge case. The projectile and case are loaded separately. Semi-fixed ammunition was formerly called *separate case.*

In both of these types of ammunition the propellent charges and primers are prepared in cartridge cases, usually of brass. The propellent charges are generally held firmly in the cartridge cases by means of wads and distance pieces. As a rule, the cases are not designed to be entirely filled with the powder charge, since this would result in too high a density of loading. With fixed ammunition, the wads and distance pieces are held firmly in place by the projectiles, which also serve to form the air-tight seals for the powder charges. Usually the circumference of the projectiles in rear of the bands are given light coats of shellac to insure perfect air-tight seals. With semi-fixed ammunition air-tightness is secured by sealing wads or plugs inserted in the mouths of the cartridge cases.

All guns of 4-inch caliber or less and the 5-inch 25 caliber anti-aircraft gun use fixed ammunition. The cartridge of the latter is practically the limit of weight that can be handled readily by one man. The 5-inch 38-caliber anti-aircraft gun and the latest 6-inch guns use semi-fixed ammunition.

Advantages of fixed ammunition.—The advantages of using fixed ammunition are:

(a) Greater rapidity of fire.
(b) Easier to handle, to assemble, and to load.
(c) Safer, both from flarebacks and from sparks.
(d) Less chance of an error in loading.
(e) A better flame seal and gas check is provided at the breech.

The disadvantages are:

(a) Greater weight.
(b) Danger from blow-backs or split cases.
(c) The space in the vicinity of the gun becomes cluttered with empty cartridge cases.
(d) In case of misfire in action, if it becomes necessary to unload, the projectile may pull out of the case and stick in the gun.
(e) A deformed case may cause the case to jam in the gun before the cartridge is seated, thus preventing firing and making extraction difficult.

1405. Small-arms ammunition.—All cartridges of caliber less than one inch are classified as small arms ammunition. Ammunition for the standard small arms is obtained from the Ordnance Department of the War Department; but a few special types are purchased from commercial firms.

Small-arms ammunition include cartridges of the following calibers: .22, .30, .45, and .50. The projectiles may be ball, armor-piercing, tracer, blank, or dummy. It also includes 10- and 12-gauge shot gun shells for use in sporting and riot guns, and blank shells for use in miniature aircraft practice bombs and with trench mortar projectiles.

Small-arms ammunition is specified by class, such as A-1, B-2, C-1, depending upon the purpose for which it is used, namely, rifle, machine gun, aircraft. It is also graded periodically after ballistic and surveillance tests into several grades; such as Grade 1, capable of storage for several years without deterioration; Grade 2, comparable to Grade 1 in ballistic qualities, but surveillance tests indicate that it will deteriorate rapidly; Grade 3, unfit for use.

1406. Trench-warfare ammunition.—This type consists of trench-mortar ammunition, rifle grenades, and hand grenades. It is issued only to vessels on special service, to the Marine Corps, and sometimes to naval landing forces.

The 3-inch Stokes trench-mortar[1] is the only caliber in the naval service, but the Army has developed both a 4-inch and 6-inch. High explo-

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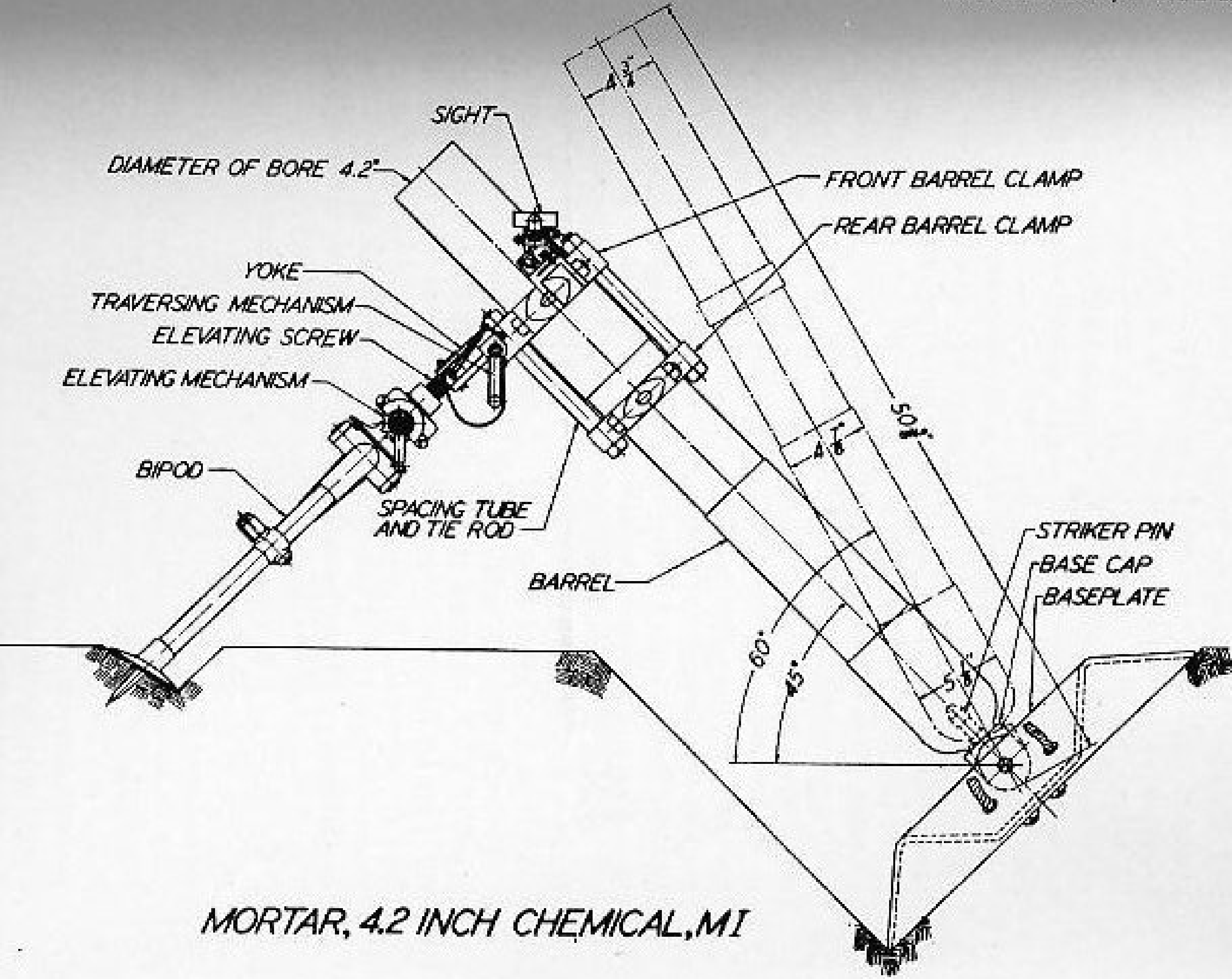
[1] The 81-mm. Stokes-Brandt mortar has recently been adopted to replace the 3-inch mortar.



MORTAR, 4.2 INCH CHEMICAL, M1

sive, chemical, and practice projectiles are employed. The shell capacity of the 3-inch, especially for dispersing chemical agents is deficient. Throughout our participation in the World War, the 4-inch mortar was used by the Army, but even it was deficient as a smoke weapon. The 4-inch Stokes mortar has been modified and will be superseded by the 4.2-inch chemical mortar. A diagram of the latter is shown in Plate I.

The trench or chemical mortar is a smooth bore, muzzle loading, high angle fire weapon, capable of firing 15–20 rounds per minute. The range may be varied between about 200 and 1,000 yards.

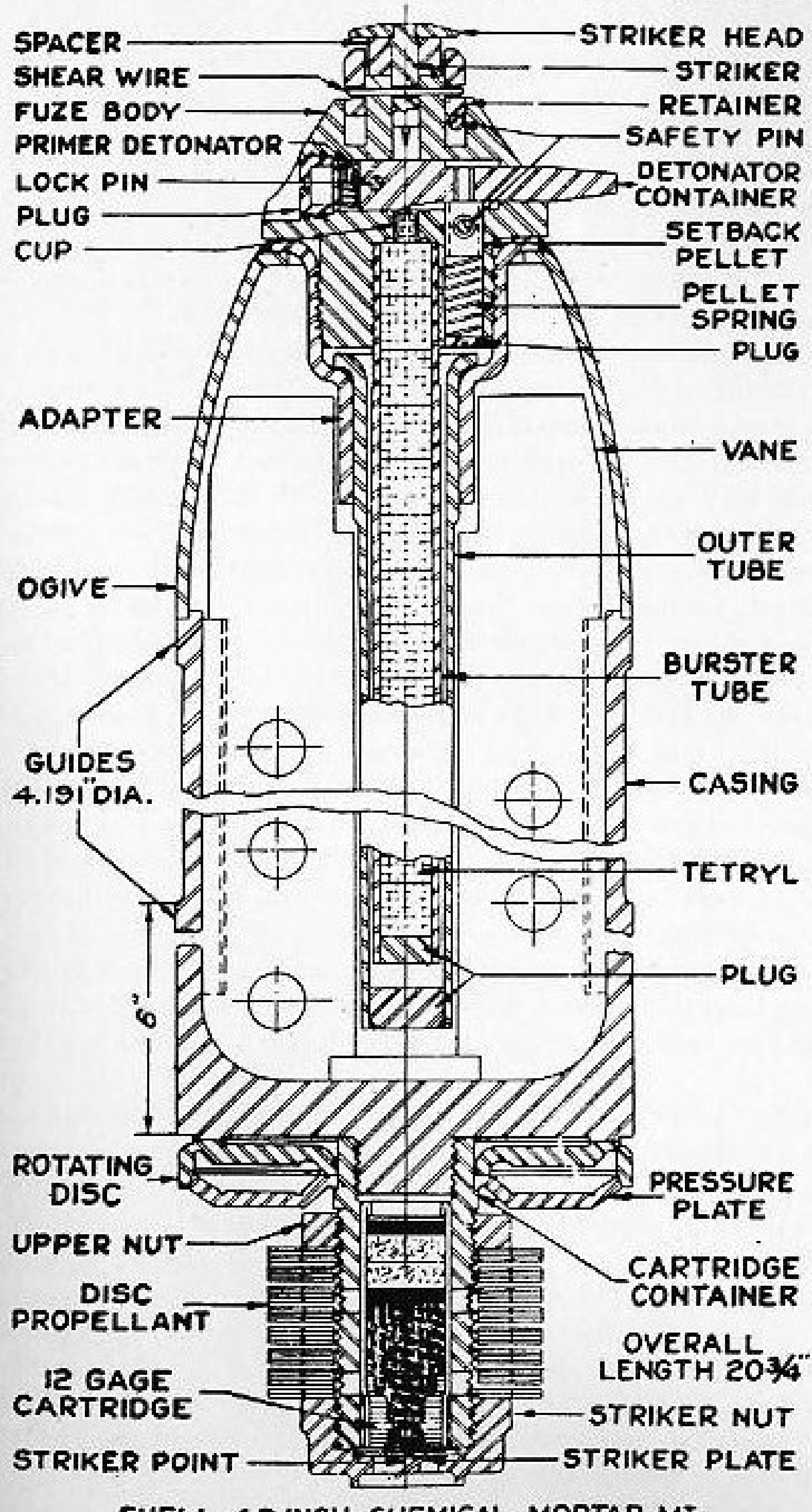
The trench-mortar projectile differs from other projectiles in that it contains, when ready for firing, the propelling charge and a shotgun shell, in addition to the fuze and burster charge. As shown in Plate II, a 12-gauge blank shotgun shell fits into a cartridge container attached to the projectile. Outside and around this container ballistite rings may be fitted, the container being perforated to permit ignition of the rings by the black powder of the shell. The range of the projectile may be controlled by firing with the shotgun shell alone as a propellant, or by adding one, two, or three ballistite rings. The projectile, after assembly, is fired by dropping it down the barrel of the trench-mortar, at the bottom of which the primer cap of the shotgun shell is caused to explode by a striker or firing pin.

The high explosive trench-mortar projectile is usually loaded with granular TNT, although some projectiles may be found to contain explosive D. The practice projectile is sand-loaded. The standard fillings for chemical projectiles include white phosphorus, phosgene, chloracetophenone, and mustard gas; the use of lethal gas projectiles, of course, is prohibited by international agreement by many nations. Trench mortar ammunition is obtained from the Army.

Grenades may be used in operations by the landing force and by the Marine Corps. Their principal application is to clear shelters, to screen, or to demoralize. Chemical grenades are of great value in peacetime training in simulating gas and smoke situations. They are extemely effective when employed in connection with civil disturbances.

The *rifle grenade* is superior to the hand grenade by reason of its greater range, approximately 250 yards. The grenade consists of five parts: the body, the fuze, the filling, the rifle rod, and the cartridge. The grenade is mounted on a rifle rod about 15 inches long, which is inserted in the muzzle of the rifle. The propellant is a special blank cartridge. The filling depends upon the class of grenade: *fragmentation*, *chemical*, or *practice*. Fragmentation grenades are loaded with TNT; chemical grenades with white phosphorus (for making smoke) or a

CHAPTER XIV, PLATE II.



SHELL, 4.2 INCH CHEMICAL MORTAR M1

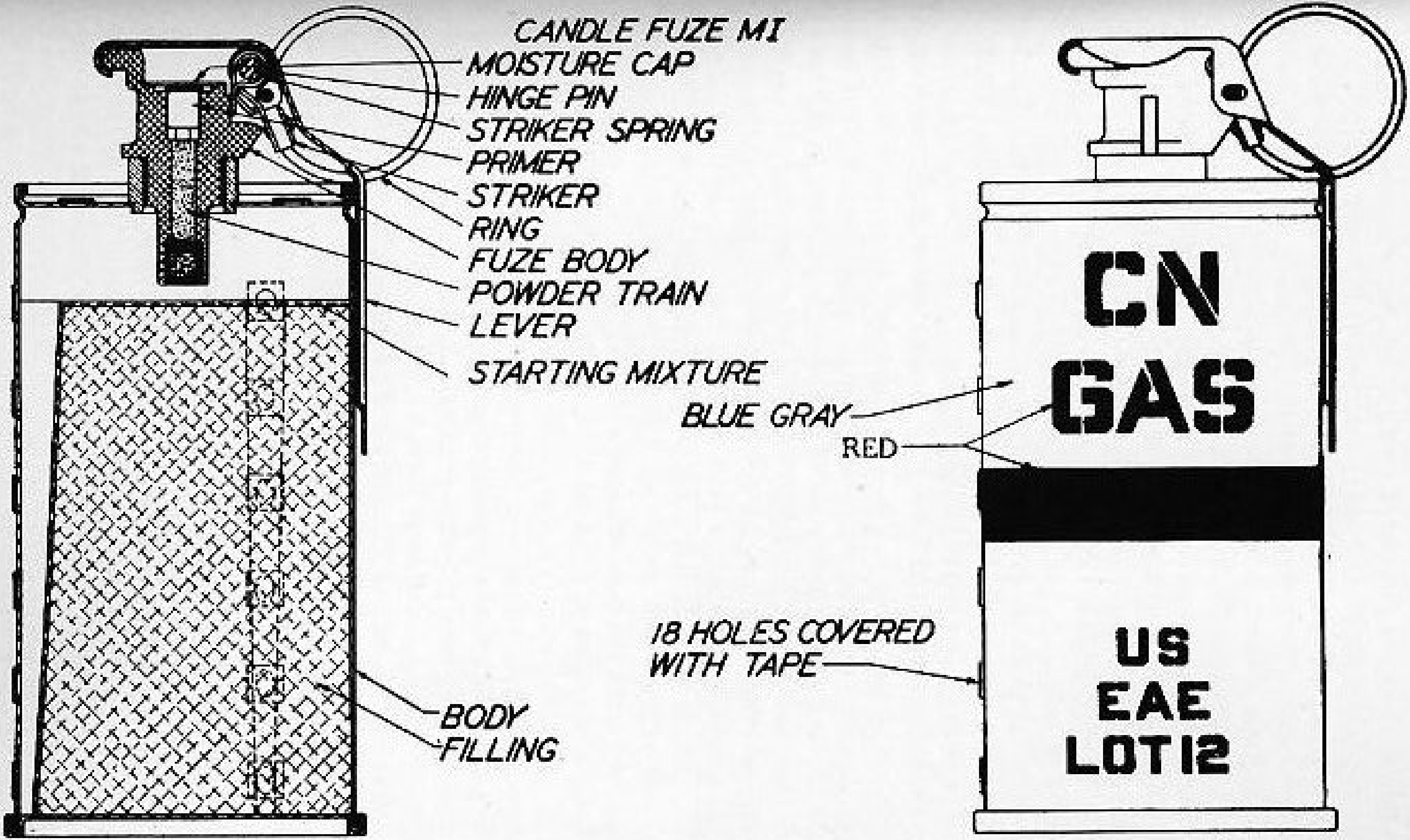
lachrymator and a powder bursting charge. When the safety pin and cover have been removed and the piece has been discharged, the forward movement of the grenade and the inertia of the striker cause the retaining wire to be sheared and the striker to explode the fulminate of mercury primer. The flash from the latter ignites a time fuze, which after about 8 seconds ignites a match-head of black powder. The latter, in turn, in the chemical grenade, ignites a layer of meal powder. The combustion of the smokeless powder charge of the filling mixture produces a pressure which forces the adhesive tape from the emission holes and carries off the vapors of the chemical agent.

Hand grenades, depending upon the ability of the individual, have a maximum range of about 35 yards. The operation of a chemical grenade is as follows (Plate III): When the safety pin has been pulled, the lever, held by the palm of the hand, acts as a deterrent to prevent contact between the striker and primer. As the grenade leaves the hand, the striker, actuated by its spring, throws the lever clear and strikes the primer. The primer ignites the powder delay train which in about two seconds ignites the starting mixture. The latter generates the heat required to start the chemical reaction of the chemical agent. The pressure resulting from the combustion forces the adhesive tape from the small emission holes and the agent from the container. Chemical grenades may have a smoke, tear gas, or irritant gas mixture filling.

1407. Chemical ammunition.—All projectiles, bombs, projectors, candles, and grenades, containing gas, smoke-making, and incendiary materials, and all gas, smoke, and incendiary materials employed from aircraft supply tanks, projectors, and sprayers, are classified as chemical ammunition.

Chemical projectiles and grenades have previously been briefly described, this article, hence, will be limited to a brief discussion of chemical candles, cylinders, projectors, and spraying and sprinkling apparatus.

Candles were developed as the result of a demand for a small smoke producer which could be employed by individuals for screening purposes. The several smoke candles which were produced during the World War were superseded by others, including both lachrymatory and irritant smoke candles. Their successful use is dependent upon favorable wind, weather, and terrain conditions. In addition to screening, they may also be used, for instance, to simulate attacks, to divert fire, and to cover withdrawals. They, furthermore, are effectively employed in civil disturbances and in peace-time training. On board ship they are extensively employed to simulate the explosion of gas projectiles and bombs in damage control problems.



GRENADE, HAND, TEAR (CN) M-7

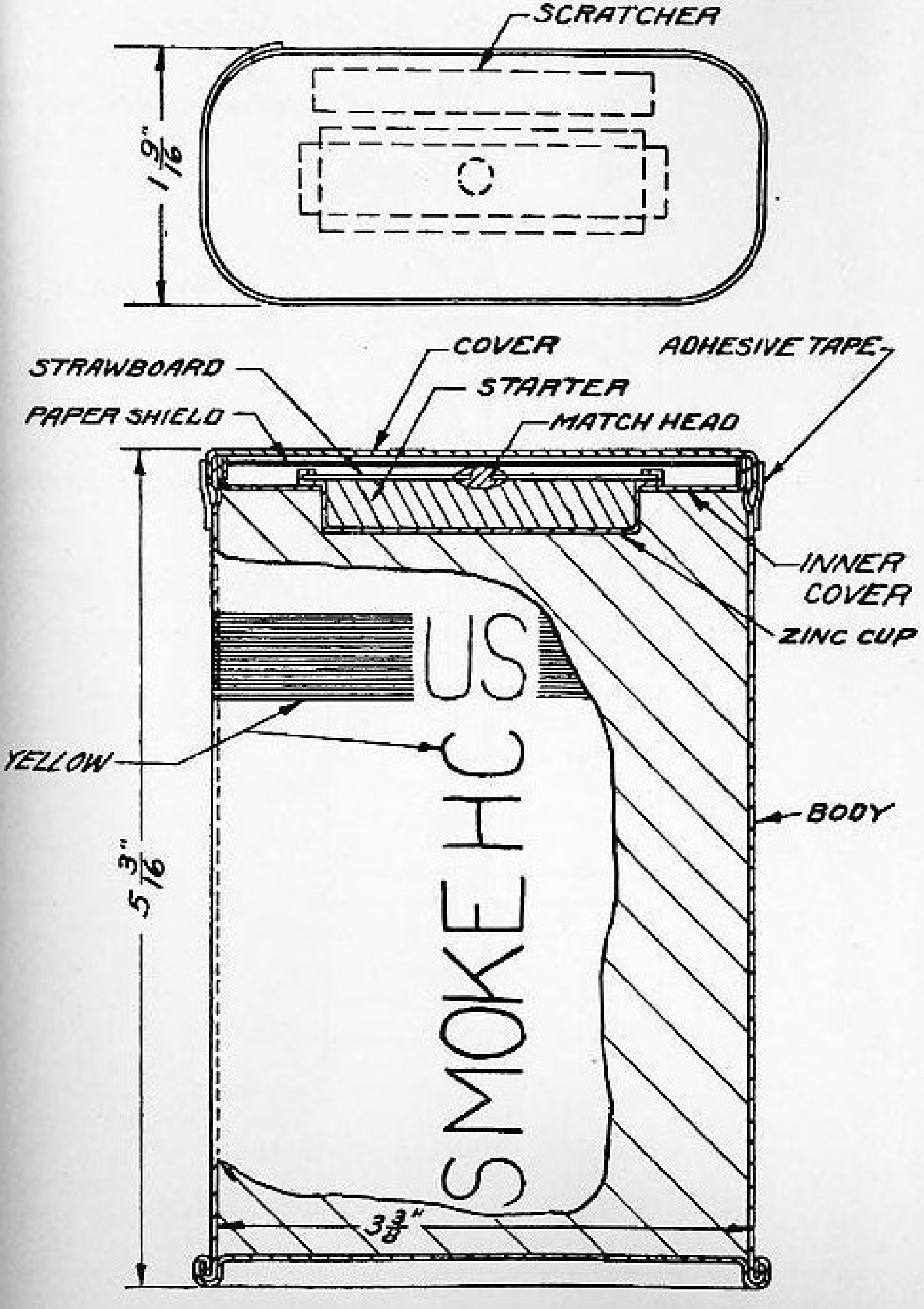
A smoke candle is illustrated in Plate IV. After removing the adhesive tape, the cover, and the paper shield, the scratch-block and match are withdrawn. The latter is ignited on the scratch-block and then is used to ignite the starting mixture. A dense, white, non-lethal smoke of great obscuring value is produced in about ten seconds.

The *chemical cylinder* is the name given to various tanks for the handling and transportation of liquefied gas. The cylinder cloud gas attack was the first significant means employed during the World War for the projection of warfare gases, and for nearly a year after its inception in April, 1915, cloud gas was the most formidable form of chemical attack.

A chemical portable cylinder is shown in Plate V. The cylinder operates on a pressure principle similar to that of the seltzer bottle. When the cap is removed from the outlet and the valve is opened, the pressure above the liquid forces the liquid downward, through the eduction tube and valve outlet. The high vapor pressure of the liquefied gas, *i.e.*, the inherent tendency of the liquid to convert itself into a gas, results in the building up of considerable pressure in the void above the liquid. Upon being projected into the atmosphere, where the pressure is greatly diminished, the agent can no longer maintain its liquid state and immediately gasifies. Non-persistent agents only are used in cylinders. Although chlorine, phosgene, and chlorpicrin were employed singly and in combination during the World War, phosgene is now considered the most efficient.

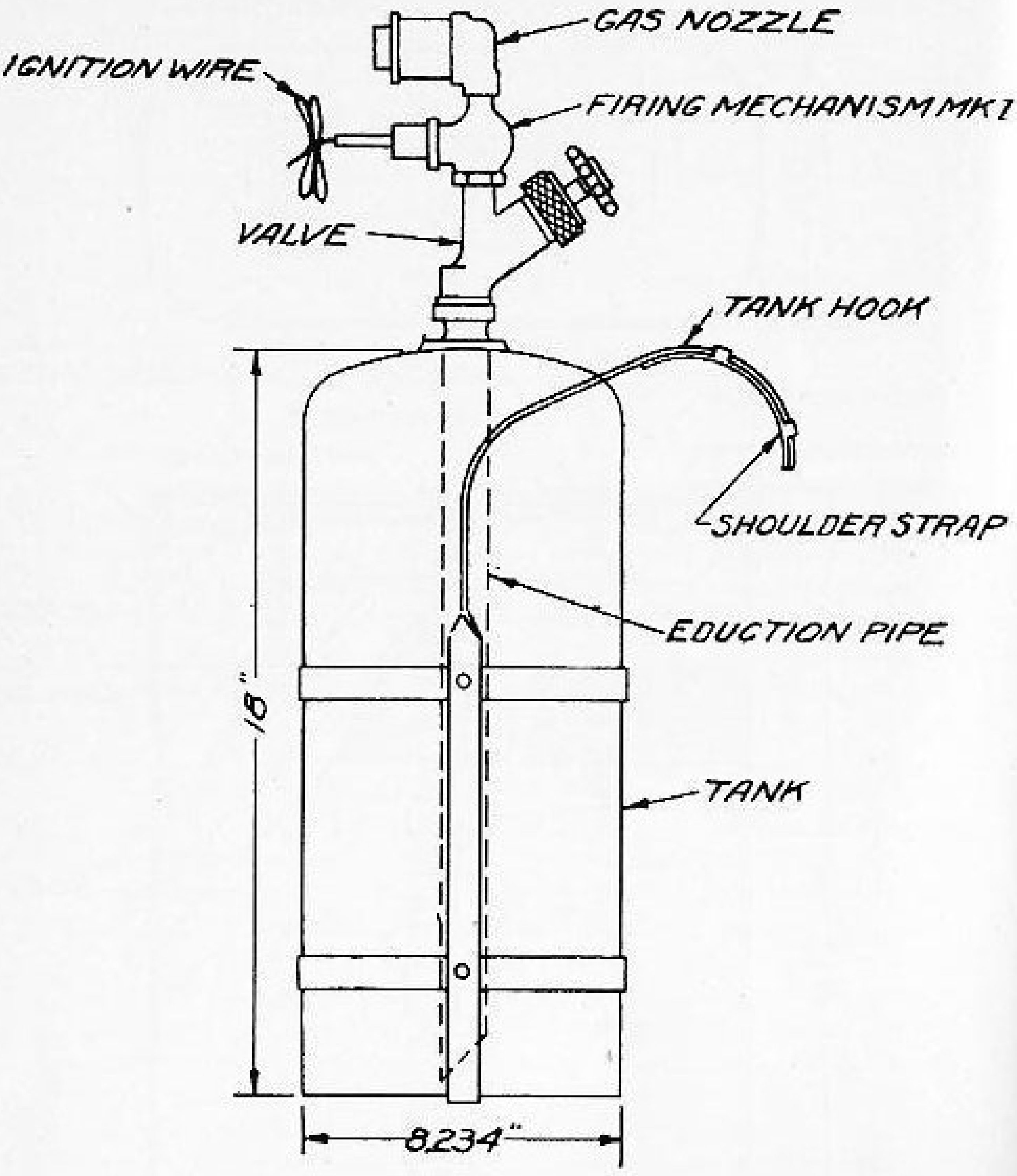
The *Livens projector*, designed by a British captain of that name during the World War, is a crude form of mortar used to throw large quantities of chemical agents. These projectors are usually installed in the ground and fired electrically together in batteries. The British are credited with having installed 6,000 in a single emplacement area. A Livens projector is shown in Plate VI. The shell consists of a body, a bursting mechanism, and the filling. The bursting mechanism operates on the setback principle. After the safety pin has been pulled and the projector is fired, the setback cuts the shear wire and the striker pin penetrates the fulminate cap. The latter ignites the time fuze, a 30–36 second black powder fuze, which in turn explodes the TNT bursting charge. The filling usually used is phosgene or a smoke producer. The propelling charge is a variable charge of smokeless powder, which is placed in a charge container. One of the small bags of powder used in the container is the base or ignition charge; it is red in color and contains a small amount of black powder which surrounds the *electric squib*. An electric squib is a small shell containing black powder that is fired by means of an electric current brought in through wires. They are also used to ignite wing-tip flares on aircraft.

CHAPTER XIV, PLATE IV.



CANDLE, SMOKE, HC, MI

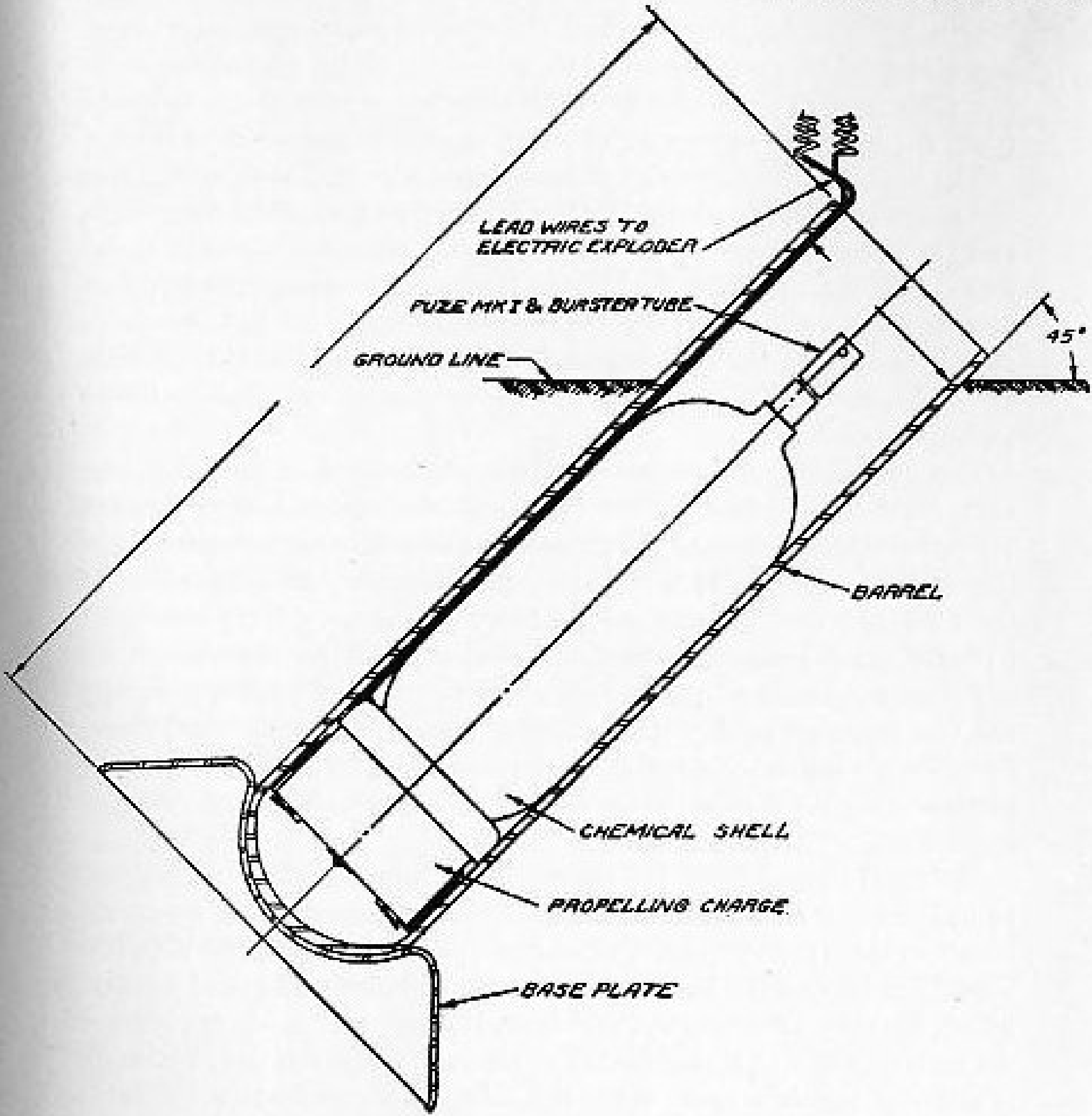
CHAPTER XIV, PLATE V.



CYLINDER, CHEMICAL PORTABLE

MIA1 (WITH NOZZLE AND FIRING DEVICE)

CHAPTER XIV, PLATE VI.



FULL SURFACE SET UP

LIVENS PROJECTOR, MI

Aviation chemical weapons.—Chemical agents were not disseminated by airplane during the World War, except the dropping of smoke bombs for training purposes and the dropping of incendiary bombs containing white phosphorus. At the present time the projection methods from airplanes include (a) sprinkling apparatus of the pressure type, (b) spraying apparatus of a non-pressure type, and (c) bombs.

The *sprinkling apparatus* consists essentially of a tank containing the agent and carbon dioxide to furnish the pressure, a discharge line, and the necessary valves. The apparatus is suspended from the bomb racks and the agent is discharged beneath the plane. The carbon dioxide gives sufficient pressure to expel the agent aft in large drops approximately at the airspeed of the plane. As the tanks necessarily are of heavy construction, this type is limited to being carried only by heavy bombers.

The *spraying apparatus* consists of a streamlined tank, a discharge valve, a discharge line, an air vent, and the necessary connections. When the valve is opened the agent flows down through the discharge line and into the air. It is subjected to the natural shearing effect of the air-blast, and is broken up into very fine particles which drift with the wind. Due to the tendency of the minute droplets to remain in the air and to travel as a fine mist with the wind, the spray normally must be operated at very low altitudes. This type of apparatus, therefore, is more suited to fast, low flying planes. Mustard, tear, and smoke producers are the normal agents used with both sprinkling and spraying apparatus.

Chemical bombs have the same general appearance as demolition bombs and are released from the same type of bomb racks. As an example of this type of bomb a brief description of a 30-pound chemical bomb will be given. The bomb is streamlined and consists of a body, filling, booster, fin assembly, and fuze. It may carry a filling of either mustard or white phosphorus. When the safety pin is pulled, the bomb is released and falls away from the safety pin attached to the rack, thereby permitting the arming vanes in the nose to rotate. After several turns the arming vanes and cup drop off, permitting the arming of the impact fuze. On impact, a shear wire is cut, which allows the firing pin to be driven into the primer.

For low altitudes satisfactory results have been obtained by using tin cans filled with an agent but without a burster charge. The force of the impact bursts the can and disperses the contents.

Another type of chemical bomb, especially designed for naval use, is the floating smoke bomb. It has an aluminum head, a wooden rear body, and is equipped with four steel stabilizers. It carries a water-impact percussion fuze in the nose, and a check valve in the tail. The filling is of hexachlorethane, a smoke mixture. The filled bomb weighs 50 pounds. Upon striking the water, the fuze ignites a starter mixture which kindles the components of the smoke mixture. The bomb, after the initial plunge, returns to the surface and floats tail up. A pure white, dense, non-irritant smoke of great obscuring power is released through the check valve. The bomb continues to burn for 5 minutes.

1408. Pyrotechnic Ammunition.—Pyrotechnic ammunition consists of fireworks (mixtures) adapted to military purposes. It is divided into four classes: Signaling, illuminating, screening, and incendiary. It is further divided into pyrotechnics for ship or ground use and for aircraft use. The difference between chemical and pyrotechnic ammunition in many cases is not sharply defined; the classification depends principally upon usage.

Pyrotechnics are mixtures of oxidizing agents and combustibles (powdered metals and non-metals; reducing agents) to which is frequently added materials for a particular purpose, such as to give colors.

The following are some of the types of pyrotechnic ammunition issued to the service: illuminating elements of projectiles, tracers, Very-star cartridges, rockets (signaling, illuminating, and smoke) with or without parachutes, rifle-grenade lights and smokes, hand lights, position lights, distress signals, aircraft wing-tip flares, aircraft parachute flares, float lights, smoke bombs, smoke boxes, and recognition signals.

1409. Bomb-type ammunition includes aircraft bombs, submarine mines, depth charges, torpedo warheads, and wrecking mines, usually thin-walled containers which are loaded with relatively large bursting charges and which depend upon the destructive blast effect of the explosive rather than on the penetrative effect of the container. Bomb-type ammunition in which the main charge consists of gas, smoke, incendiary, and pyrotechnic materials are classed as either chemical or pyrotechnic ammunition. Bomb-type ammunition is usually loaded with a bursting charge of cast TNT.[2]

Aircraft bombs in general are of the following types:

(a) Fragmentation.—These are of relatively small size, and are designed to give a maximum of fragmentation on detonation. They are for use against exposed personnel.

(b) Demolition.—These may be of any size from 100 to 3,000 pounds. They have comparatively large bursting charges for producing great blast effect. They are used against ships, fortifications, and enemy works of all descriptions.

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[2] As torpedoes, mines, and depth charges are described in another textbook at the Naval Academy, no discussion of them or their parts will be given in this book.

(c) Armor-piercing.—These are heavy-case bombs for use against heavy armored vessels.

(d) Chemical.

(e) Practice.—These are designed for instructional and training purposes. They usually correspond to service types, but are either fully or partially loaded with sand or water.

(f) Miniature practice.—These are fitted with 10-gage blank shotgun shells or special shells for producing a smoke puff on impact.

(g) Dummy.—These are empty bombs or bombs loaded with *inert* materials for instructional and drill purposes.

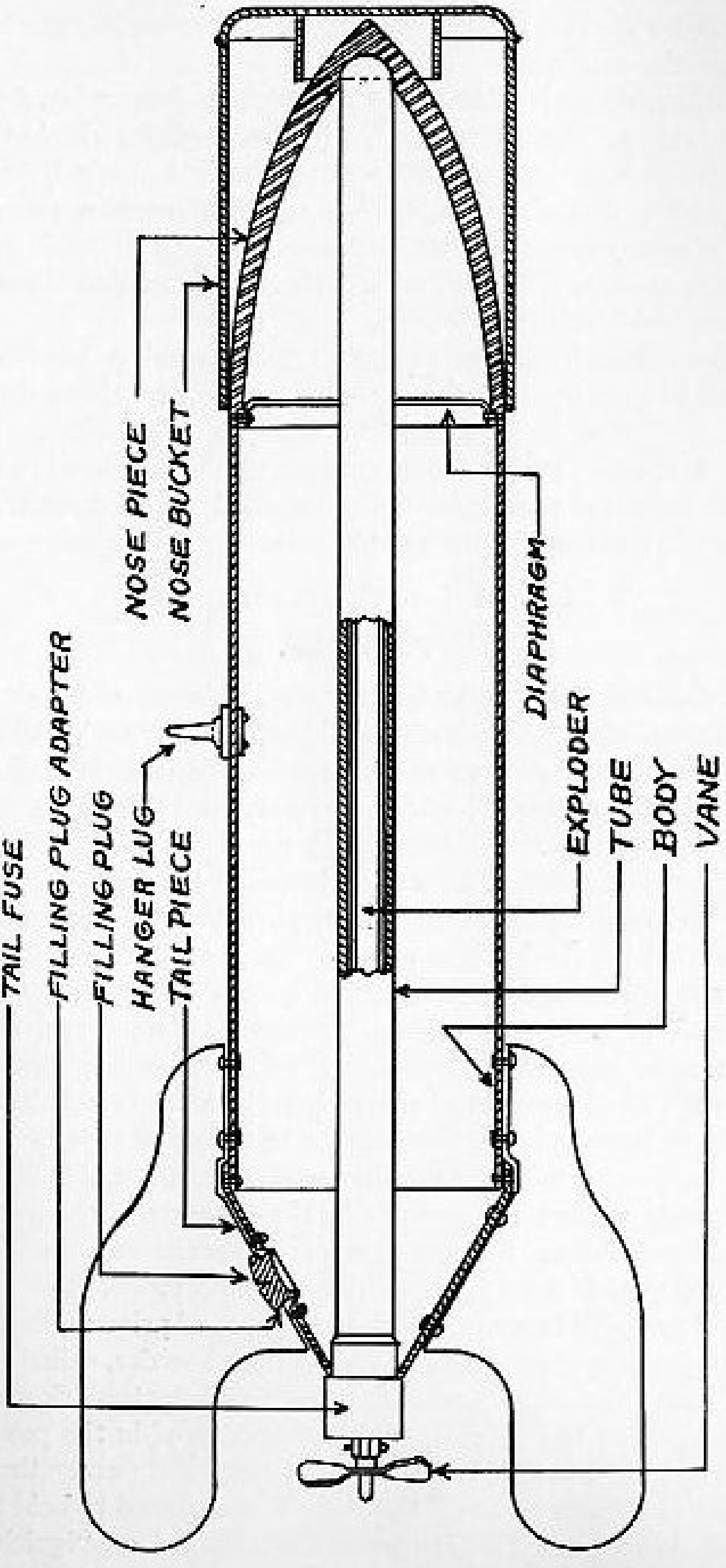
A light case aero bomb is shown in Plate VII. The bomb proper consists of a nose piece, body, and tail piece. The conical nose is of cast steel and is surrounded by a nose bucket. Between the nose piece and the body is a sheet-metal strengthening diaphragm, which is perforated to permit the cast TNT charge to run into the nose. The cylindrical case steel body, at about its midpoint, has a hanger or carrying lug. The tail is cone-shaped and affords a means of securing the four stabilizing vanes. The latter prevent tumbling of the bomb in flight. Running through the center of the bomb is a steel tube, which serves the purpose of strengthening the bomb structure and of holding the granular TNT booster charge. The tail fuze consists of two moving parts, the firing pin and the propellor vanes. In the unarmed position the latter are screwed on to the extension of the firing pin and prevent it from operating. After the bomb is released, the propellor vanes spin off of the firing pin shank and free the firing pin, which is held away from the detonator by means of a safety spring. Upon impact the bomb is retarded, but the firing pin, being free to move forward, compresses the safety spring and fires the detonator cap, which in turn fires the booster charge. Prior to flight a safety pin, which locks the firing pin, is removed when the bomb is attached to the bomb gear rack.

1410. Impulse ammunition.—Impulse ammunition includes specially prepared propellent charges, which are contained in cartridge cases fitted with primers and assembled as blank cartridges, for launching torpedoes, depth charges, line-throwing projectiles, and for catapulting aircraft.

Torpedo impulse charges are prepared in torpedo impulse cartridge cases. The cases are fitted with primer holders, which have been bored to received the standard lock combination primers, and are loaded with the proper weight of spherohexagonal black powder for the type of tube and the size of the torpedo.

Y-gun charges are used to launch depth charges. They are prepared in cartridge cases fitted with cannon primers with a spherohexagonal

CHAPTER XIV, PLATE VII.



LIGHT CASE AERO BOMB

black powder charge. Several weights of charge are supplied in order to control the range.

Line-throwing projectiles are of three types: 6-pounder, 3-pounder, and .45-caliber. The former two are designed for discharge from saluting guns. The charges for these are prepared similarly to saluting charges, with two different weights of black cannon powder. The heavier charge gives a maximum range of about 300–350 yards and the lighter charge, 250–300 yards. The .45-caliber line throwing gun requires a special blank cartridge.

Powder catapult impulse charges are prepared in brass cartridge cases similarly to semi-fixed ammunition. The propelling charge consists of smokeless powder and a special ignition charge of black powder. A special case percussion primer is assembled in the cartridge case. The weight of charge depends upon the type of catapult and gun, the type of plane, and other factors.

Section II.—Primers and Fuzes.

PRIMERS.

1411. General.—A primer is an especially constructed device, the flame from which, when it is exploded by the direct action of the firing mechanism, ignites the powder charge in the chamber of the gun, and causes the explosion, either directly, as in fixed or semi-fixed ammunition, or indirectly through the agency of the **ignition charge**, as in bag ammunition. This action is called the ignition. Smokeless powder is difficult to ignite with the application of a small flame. This is well shown by the ignition of a powder grain in air with a match, whereby it will be seen that the grain ignites slowly, burns relatively slowly, and is easily extinguished. To provide a rapid and certain inflammation of the charge, an amount of black powder is used commensurate with the weight of charge and size of the smokeless-powder grain. Black powder has been found to be the substance best adapted for this purpose, due to the rapidity and ease with which it is ignited and the intense flame it gives off. As the function of the primer is to initiate the explosion, the design depends on the amount of ignition powder required and the form in which it is provided.

1412. Types.—There are two general types of primers, one containing in itself the necessary amount of ignition powder, called the "case primer," and the other containing only sufficient black powder to direct a flame on to the ignition charge contained in the powder bag, called the "lock primer." Where it is necessary to increase the amount of ignition in a "case primer," the stock is lengthened to hold the additional black powder. The primer is then termed an "ignition case" primer to differentiate it from the short case primer. Primers may be divided in another way according to the method in which the ignition is initiated, as simple "percussion primers" where the flame is caused by the action of a hammer on a fulminate cap; simple "electric primers" where the flame is caused by the heating of a high-resistance wire igniting a wisp of guncotton; or a "combination primer" combining both the above features. Formerly many types were issued to the service but they have been narrowed down now to three types for case guns and one for bag guns. They are (1) *the percussion case primer*, (2) *the percussion case ignition primer*, (3) *the combination case ignition primer*, (4) *the combination lock primer.*

Percussion fire only is provided for ammunition for 3-inch guns and below and combination fire is provided for all above 3-inch. This division is made on account of the requirements for assembly and loading the ammunition and the handling of the gun. The percussion element is required for the larger guns in case of failure to fire electrically.

1413. Primer caps.—The percussion or *primer cap* usually consists of a mixture with fulminate of mercury as a base. The composition of the mixture varies with the degree of sensitiveness desired. One or more of the following materials will be found in the ordinary mixtures: sulphide of antimony (which increases the length of the flame), sulphur, chlorate of potash (which increases the heat by its oxidizing action), and ground glass (which increases the sensitiveness).

1414. Powder trains.—In addition to the percussion and electric elements of primers there is a powder train consisting of fine black powder. This powder must be of suitable design and quantity for its purpose, namely, the creation of a flame sufficient to inflame the propellent charge within a proper time interval. If too much black powder is used, erratic pressures and velocities may result; this has been demonstrated by the performance of a primer designed for a 4-inch gun when fired in a 3-inch gun. Three different types of primers are used in case ammunition, while one type has been found to be suitable for all calibers of bag guns.

1415. Percussion primers.—A simple *case percussion primer* is shown in Plate VIII, Fig. 1. When the firing pin of the gun strikes the cup, the latter is indented and the composition pellet or primer cap is exploded. The flame of this explosion passes through a hole in the anvil and ignites the black powder ignition charge in the brass ignition tube, which in turn ignites the propelling charge in the cartridge case. The primer is assembled by forcing it into the primer aperture of the case by a hand press.

A *case percussion ignition primer*, as used in a 3-inch 50-caliber gun

CHAPTER XIV, PLATE VIII.

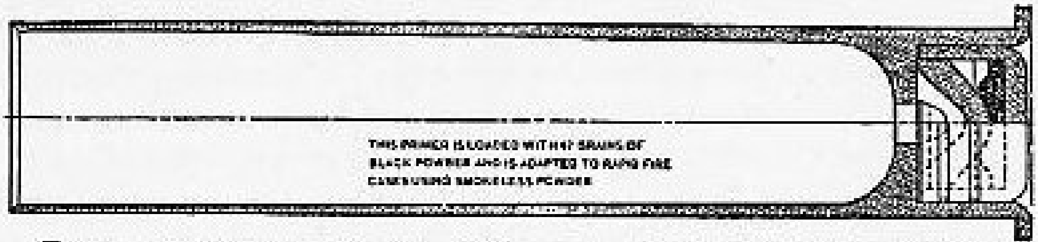


FIG. 1.—PERCUSSION PRIMER. (FOR 1-, 3-, AND 6-POUNDERS AND 3-INCH FIELD-GUN CARTRIDGES.)

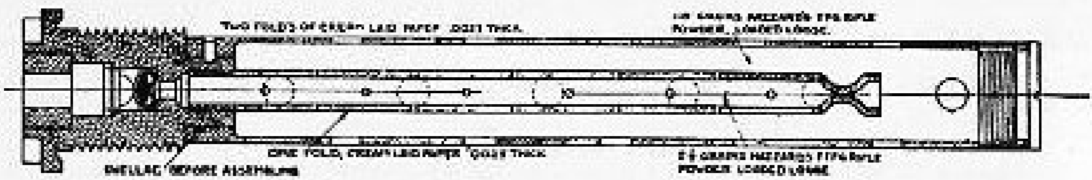


FIG. 2.—CASE PERCUSSION IGNITION PRIMER.

FIG. 3.—CASE COMBINATION IGNITION PRIMER.

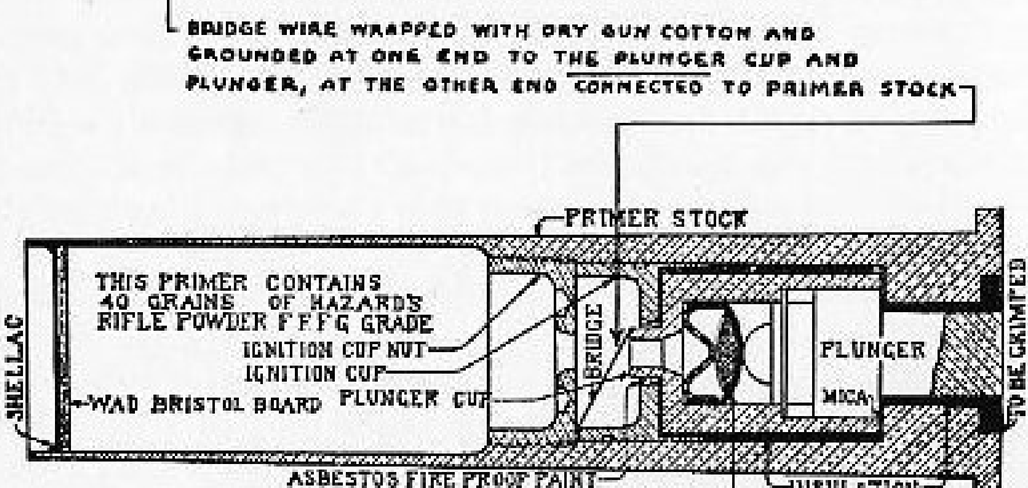


FIG. 4.—COMBINATION LOCK PRIMER.

cartridge, is illustrated in Plate VIII, Fig. 2. The figure clearly shows the firing plug resting on the pellet, the aperture in the plunger cup, the $2\frac{1}{2}$-grain train of fine powder loosely loaded in the interior ignition tube, and the ignition charge of slightly coarser black powder. The flame of the powder is directed first through the holes in the ignition tube, and then through those of the extension tube into the body of the propellent charge.

1416. Combination primers.—A case combination ignition primer, as used in 4-inch fixed ammunition, is shown in Plate VIII, Fig. 3, while Fig. 4 illustrates a combination lock primer. The electric element, consisting of a platinum bridge with a small wisp of dry guncotton wrapped around it, is grounded at one end to a plunger cup and at the other end to the primer stock. The element is surrounded with a mixture of pulverized guncotton and fine black powder in an ignition chamber. The illustrations clearly show the construction details; however, attention is especially directed to the insulation, electrically separating the plunger and plunger cup from the ignition cup and stock.

FUZES

1417. General.—A fuze is a device which, when exploded by the action of its mechanism, ignites or detonates the burster charge of the projectile either on or after impact, or in flight. A fuze functioning on impact is a "percussion" fuze; one functioning by its own internal action after a definite time in flight is a "time" fuze. Certain types combine the features of both these and are called "combination" fuzes.

A fuze must (a) be safe in assembling, handling, transporting, loading, and firing, (b) not function prematurely, (c) be positive in its action, (d) not be subject to deterioration in storage.

A fuze is said to be *armed* when, by the action of its mechanism, the firing point is in a position to impinge on the cap with any forward motion of the plunger.

The "setback" is the action which occurs when the projectile starts to move. That is, the inertia in a movable part will cause it to lag behind the fuze stock which is rigidly attached to the projectile by the fuze threads.

The "creep" is the action of a movable part inside the fuze, due to the retardation of the projectile in flight from air resistance; that is, the part will tend to move forward, as the air resistance does not affect it.

1418. Brief history of development.—The oldest form of time fuze was a piece of "fuzee" or "slow match." This was followed by a wooden fuze forced into the opening in the shot. The wooden fuze contained a compressed black-powder charge, which was ignited by the blast of the gun, and, when burned down to the end, spit through an opening into the burster charge and exploded the projectile. The wooden fuze was cut off or pierced along its length to fix the time of burning. In later developments, metal cases were substituted but the principles involved were the same. In a concussion fuze, an inflammable composition was ignited on discharge of the gun and, on impact, by some contrivance, the flame was admitted to the burster charge. The contrivances used were glass tubes, zinc tubes, which when heated by the burning powder inside would break off on impact, or by plaster of Paris tubes. Due to the fact that a spherical projectile would strike on any point of its surface, percussion fuzes did not operate satisfactorily, though tried in many forms. In one type three distinct double-ended plungers were used with their axes perpendicular to each other. The plunger, whose axis was in line of fire on impact, was arranged to strike a fulminate composition. The plungers were held in place during flight by copper shear wires.

On the introduction of rifled guns and elongated projectiles, the troubles with percussion fuzes were largely eliminated, and as the projectile always struck point first, the use of the motion of a plunger striking a cap on impact was made possible. The adaptation of the rotation of the projectile to additional safety features marked a further advance in the design of fuzes. With the modern use of high explosives a further change was required in providing a detonating element and in producing a delay action feature.

1419. Percussion fuzes act by the forward motion of a plunger in the fuze body, caused by the sudden arresting of the motion of the projectile. The plunger carrying the firing point strikes a primer cap; or else, carrying the primer cap, causes it to impinge on the firing point which is held rigidly in place in the fuze body.

A "percussion fuze" may be either an *ignition fuze* for exploding a black-powder charge or a *detonating fuze* for detonating a high-explosive charge. A percussion fuze may be designed to fit into the base or to fit the nose of the projectile.

In the simpler and older types of percussion fuzes, the plunger was held in a safe position by split rings or by shear pins. The action of setback on discharge caused the plunger to shear the pin or to ride over the split rings and then be in a position to move forward on impact. This was the first form of safety device. It proved insufficient for complete safety as one blow would arm the fuze. To obviate this difficulty advantage was taken of the rotation of the projectile to provide centrifugal safety locks on the plunger to keep the firing point away from the primer cap until the projectile had attained sufficient rotational speed in its passage down the bore. Refinements were then added to prevent complete arming until the projectile had left the muzzle. A premature discharge in the bore would cause a tremendous amount of damage.

The Semple centrifugal plunger illustrates the safety features as now found in fuzes. This mechanism is used by many fuze makers for a number of governments. It is patented in many countries. As certain other features of our fuzes are confidential the plunger action only will be explained. The mechanism, Plate IX, consists of the firing pin 2, plunger body 1, safety pins 3, safety-pin springs 4, firing-pin axis 5, and the creep spring 6. In the safety position, Fig. 1, the small safety-pin springs force the two safety pins inboard effectively to lock the firing pin in the safe position. A side blow would dislodge only one of them so that the fuze is safe from side impact. The fuze is also safe from drop for the firing point is housed in the plunger. When the projectile is rotated the safety pins are forced out against the action of their springs and the firing pin for the same reason rotates on its axis, bringing the firing point into the armed position. The inertia in the firing pin will cause it to lag during the acceleration of the projectile until the projectile leaves the gun, at which time the firing pin assumes the position shown in Figs. 2 and 3. Before assembling the plungers of the fuzes they are tested in a clutch driven by a motor and must arm at a predetermined number of revolutions, varying from 1,300 to 3,000 r.p.m. There is a tendency for the plunger to creep during the flight, as it is not subject to the same retardation due to air resistance as is the projectile. This will permit the plunger to move forward bringing the firing pin in contact with the primer cap. A light spring installed forward and outboard of the plunger obviates this difficulty.

The conditions for safety may be summarized as follows:

(a) Fuze must not be armed when dropped or joggled.
(b) Fuze must not function on setback.
(c) Fuze must not function in bore.
(d) Fuze must not function prematurely in flight.

Certain detonating percussion fuzes are provided with a delay-action element so as to permit the projectile to pierce and detonate behind armor, while some ignition fuzes are so designed as to function on graze for land work or on water impact. The delay action element may be a pellet which burns a predetermined time before exploding the detonator.

1420. Time fuzes are of two types, those with a percussion element and those without a percussion element. Those with percussion ele-

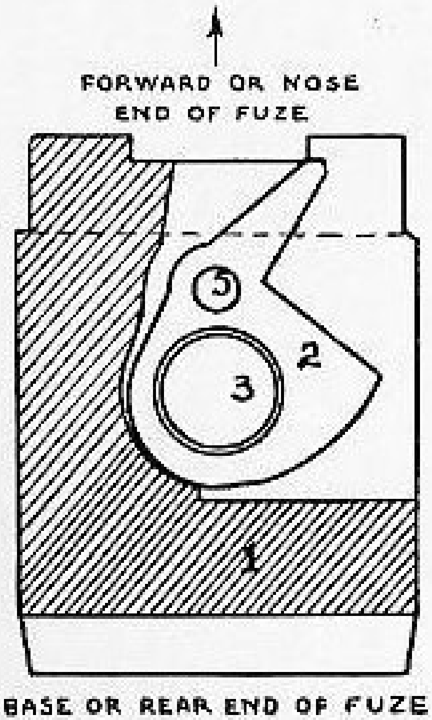


Fig. 1.—Firing Pin Housed.

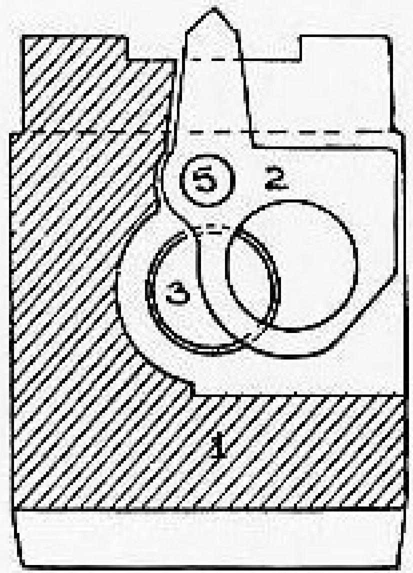


Fig. 2.—Firing Pin Armed.

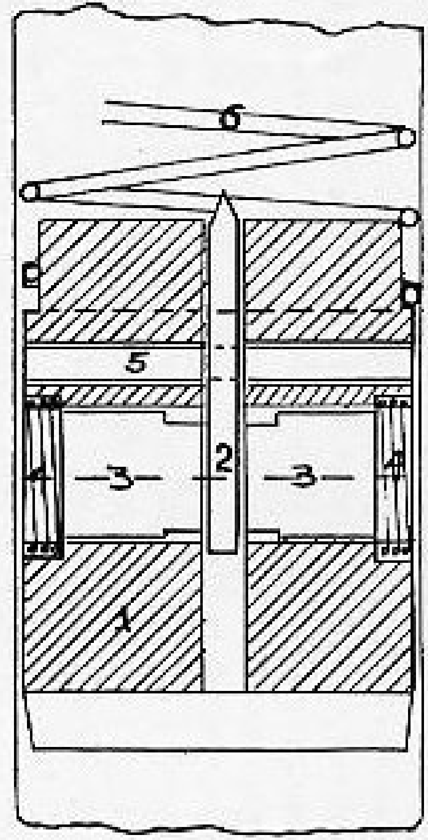


Fig. 3.—Firing Pin Armed.

1. Plunger. 2. Firing Pin. 3. Safety Pins. 4. Safety-Pin Springs. 5. Firing-Pins Axis. 6. Creep Spring.

Semple Centrifugal Plunger.

ments are designated as combination fuzes, while those without are designated simply as time fuzes. Instead of combining both time and percussion elements in one fuze, the time fuze may be installed in the nose, and a separate percussion fuze may be installed in the base of the same projectile.

The time fuze depends upon the burning interval of an especially prepared slow-burning powder compressed into a groove or ring. This composition is carefully mixed to render it as uniform as possible, in order that equal lengths will be consumed in equal time intervals. When the powder has burned to the end of its train, the flame ignites the fuze magazine charge and then the burster charge, exploding the projectile instantly. The setting of the fuze determines the length of powder train which will burn, hence the time interval to the burst. The powder train is ignited by the flame from a primer cap which is struck by the action of the plunger moved either by setback on discharge of the gun or by the rotation of the projectile.

The following conditions affect the uniformity of action in time fuzes with powder trains:

(a) Age of fuze.
(b) Hygroscopic condition due to storage.
(c) Barometric pressure.

Old compositions burn more slowly than new ones, due to chemical changes in the constituents of the composition.

Black powder is very hygroscopic. Fuzes stored in a damp atmosphere will permit the composition to take up moisture and cause it to burn slowly. If they are stored in a warm atmosphere the composition will dry out and burn faster.

Increased atmospheric pressure causes the powder train to burn faster, while decreased pressure causes it to burn slower. This change in rate of burning has become a matter of prime importance in antiaircraft firings. There are two reasons given for the change in rate of burning with change in atmospheric pressure. Each layer in the train is ignited by having its temperature raised by the gases of combustion of the layers above it. With decreased atmospheric pressure the gases expand more freely and consequently are not in such close contact and, furthermore, by the increased expansion, cool more rapidly, causing a decreased rate of burning. On account of these disadvantages, mechanical or clockwork time fuzes are now frequently used in lieu of time fuzes. One such type has a mechanism driven by a steel watch spring which is started by the shock of discharge of the gun and which causes the fuze to function at the time set.

1421. Frankford Arsenal 21-second combination fuze.—This fuze is shown in Plate X. Most of the parts are made of bronze. There are two time-train rings, *c* and *d*, and an annular horseshoe-shaped groove is milled in the lower face of each ring. Meal powder is compressed into these grooves under a pressure of 70,000 pounds per square inch, forming a time train, the total length of which is 7 inches.

The time element of this fuze is composed principally of the following parts: the *time plunger e*, the *split-ring spring e′*, the *firing pin f*, the *vent g* leading to the *upper time train i*, the compressed *powder pellet h*, the *vent j*, the *lower time train k*, the *compressed powder pellet m*, and the *vent o* leading to the *powder magazine p*.

The upper ring *c* is prevented from rotating by the *pins x*.

The vent *g* is drilled through the walls of the time-plunger chamber, and is exactly opposite a hole in the inner surface of the upper time train leading to the end of the train from which the direction of the burning is anti-clockwise. The hole *j* is drilled through the upper face of the lower time train *d*, to the end of the lower time-train groove from which the direction of burning is clockwise.

The lower time-train ring is movable, and is graduated on its outer edge in a clockwise direction from 0 to 21, each full division corresponding to one second of time of burning in flight; these divisions are subdivided into five one-fifth second parts. A radial hole is provided in the lower ring for a pin to be used in setting the fuze. An arrow on the lower flange of the fuze stock is the datum line for settings.

The vent *o* is drilled through the flange of the fuze stock to the powder magazine *p*, and leads to the same end of the lower time train as the vent *j*—that end from which the direction of burning is clockwise—when the fuze is at its "zero" setting.

The action of the fuze as a time fuze is as follows: Assume first the zero setting as shown in the figure. The shock of firing causes the plunger *e*, due to inertia, to act through its conical surface in contact with the split ring *e′* and to expand the latter so that the plunger can pass through the split ring and carry the percussion primer to the firing pin. The flame from the primer passes out through the vent *g*, igniting the pellet *h*, to the end of the upper time train *i*, and down through the vent *j*, to the end of the lower time train *k*, and thence through the vent *o*, to the magazine *p*.

It will be seen that for the zero setting of the fuze the origins of both upper and lower train are in juxtaposition. Assume any other setting, for instance 12 seconds. The vent *j* has now been changed in its position with respect to the vent *g*, leading to the beginning of the upper time train, and the vent *o*, leading to the powder magazine *p*, both of which points are fixed, by the angle subtended between the

CHAPTER XIV, PLATE X.

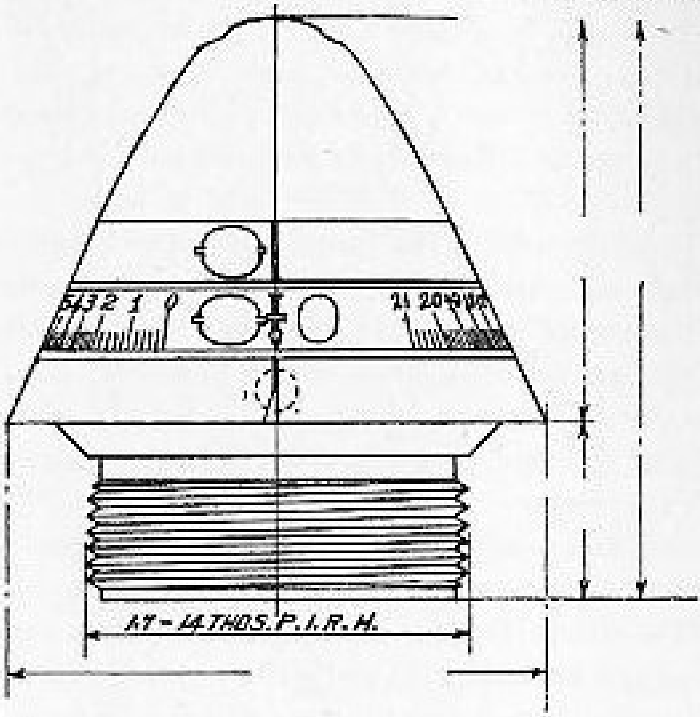


FIG. 1.—Exterior.

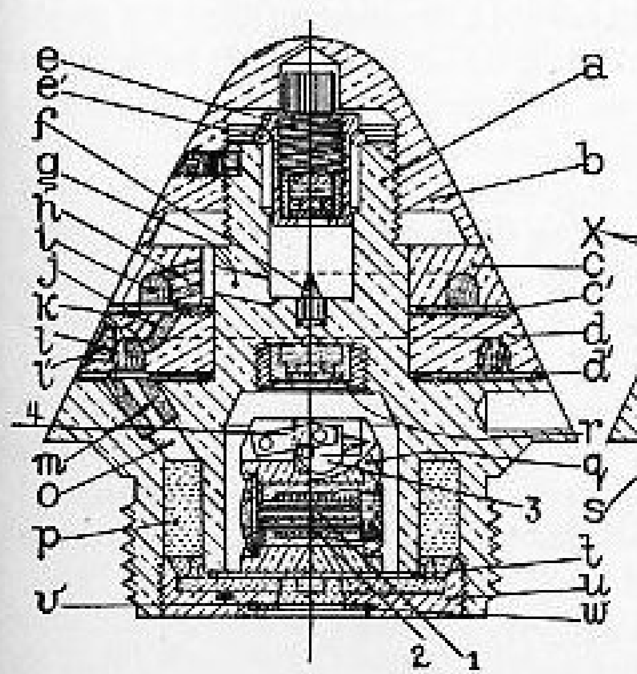


FIG. 2.—Before Arming. Zero Time Setting.

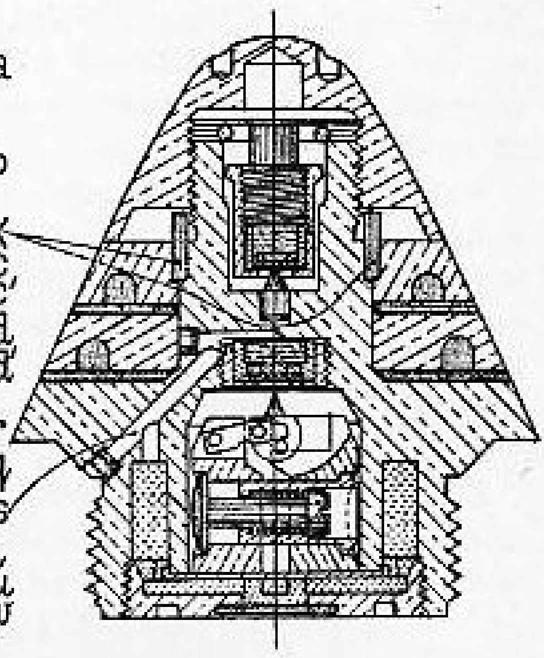


FIG. 3.—After Arming.

FRANKFORD ARSENAL 21-SECOND COMBINATION FUZE.

zero and the 12-second settings. The flame now passes out through the vent *g* and burns along the upper time train in an anti-clockwise direction until the vent *j* is reached, when it passes down to the beginning of the lower train and burns back in a clockwise direction to the position of the vent *o*, whence it is transmitted by the pellet *m* to the magazine *p*.

For the 21-second setting the flame burns the length of both trains. As the trains do not extend all around the fuze, the solid part between the ends of the trains is utilized to obtain a safety setting. When this point, marked *S*, is brought opposite the arrow on the lower flange of the fuze, the vent *j* is covered by the solid metal between the ends of the upper train, and the vent *o* is covered in a similar manner by the lower or movable ring.

The percussion element consists of the *primer r* and the *centrifugal plunger q*. The plunger is in two parts held together by the *bolt* (1), and *spring* (2). When the fuze attains 2,500 revolutions, the plunger opens out and the cross pin (4) pulls the *point* (3) to an upright position, so that upon impact the plunger will fly forward and the point will strike and explode the primer.

The Frankford Arsenal combination fuze is also made with a 45-second time element for use in 4-inch and 5-inch high explosive shells. In Frankford Arsenal combination fuzes now being procured by the Navy, zero time settings are still possible, but such settings will result in "duds." Time explosions will not be possible below 1.8 seconds approximately, as the vents in the powder time trains will be blanked off at all settings from zero to 1.8 as well as at *S* (safety).

Time fuzes are covered with thin brass covers held on by soldered strips. These are removed by tearing the strip preparatory to setting the fuze. Rubber covers are provided and in case the round is not fired the cover is taped in place. It is of the greatest importance to keep powder fuzes dry.

Section III.—Ammunition Details.

1422. Each of the component parts that form a part of assembled ammunition is designated as an ammunition detail. Ammunition details, in addition to primers and fuzes, include:

Detonators	Ammunition tanks and boxes
Boosters	Powder bags
Adapters	Mouth plugs
Tracers	Distance pieces and wads
Projectiles	Powder tanks
Cartridge cases	Explosives

1423. Detonators are designed to initiate high order detonations of high explosives. A typical detonator consists of a copper tube, about 2 inches long and about one quarter inch in diameter, closed at one end and partially filled with fulminate of mercury or a mixture of the latter. They are fired in a manner similar to primers.

1424. Boosters and adapters.—Boosters or primer charges are small high explosive charges, usually of refined explosives, as granular or recrystallized TNT or tetryl, designed to produce proper detonations of the main high explosive bursting charge. Booster charges are usually loaded in a metal tube which is screwed into an *adapter* and extending into the explosive charge. An adapter is a threaded collar or bushing which adapts, for instance, a fuse to fit a shell.

1425. A tracer is a device fitted on a projectile to make it possible for the eye to follow it in flight. There are two kinds, the day tracer for anti-aircraft work and the night tracer. A tracer may be incorporated in the same stock as the base fuze, in which case it is called a *tracer fuze;* however, both are distinct and independent of each other in action.

In a day tracer, a trail of black fluid or smoke is left by allowing the fluid to be thrown out by centrifugal force or by the products of combustion of the tracer compound.

In the night tracer, the illumination is accomplished by means of a highly compressed slow burning composition ignited by a friction element or by a percussion cap.

The action of the friction tracer is as follows (Plate XI): On explosion of the smokeless-powder charge of the gun, the gas of the charge enters the tracer chamber through the gas port; and, while the projectile remains in the bore of the gun, the gas in the tracer chamber is under high pressure. After the projectile leaves the gun, the pressure on the tracer cover disk being released, the cover of the tracer is blown to the rear by means of the expansion of the gas in the chamber. The forcing of the cover to the rear draws the central rod to the rear and ignites the friction element, which, in turn, ignites the slow-burning composition of the tracer. This composition burns from 12 to 15 seconds, depending upon the design of the tracer.

Percussion cap tracers are ignited by the pressure of the propellent gases or by setback causing a firing pin to strike a primer cap.

1426. Projectiles.—As an ammunition detail, loading and fuzing of projectiles is the principal consideration. The explosives used are high explosives or black powder. The cavity of a projectile must be especially prepared to receive the burster charge by treating it with a coat of non-acid paint, in order that no sensitive combinations may be

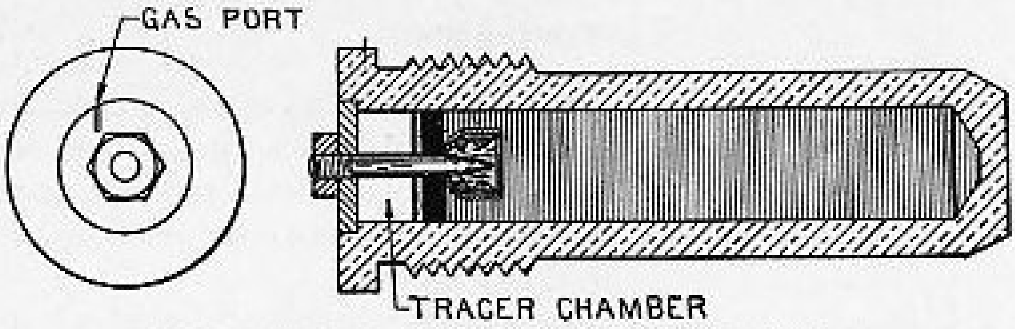


FIG. 1.—Target Tracer for Minor-Caliber Projectiles.

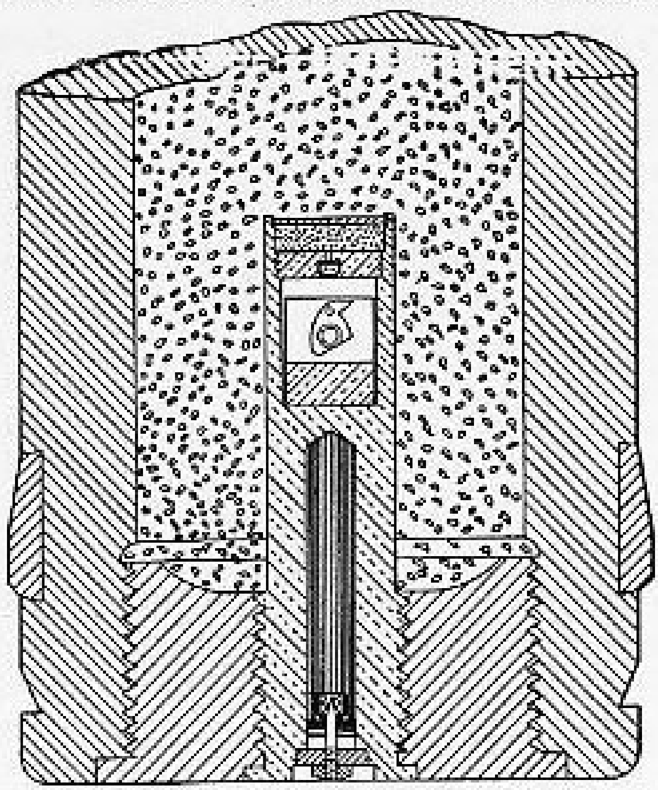


FIG. 2.—Tracer Fuze for Minor-Caliber Projectiles.

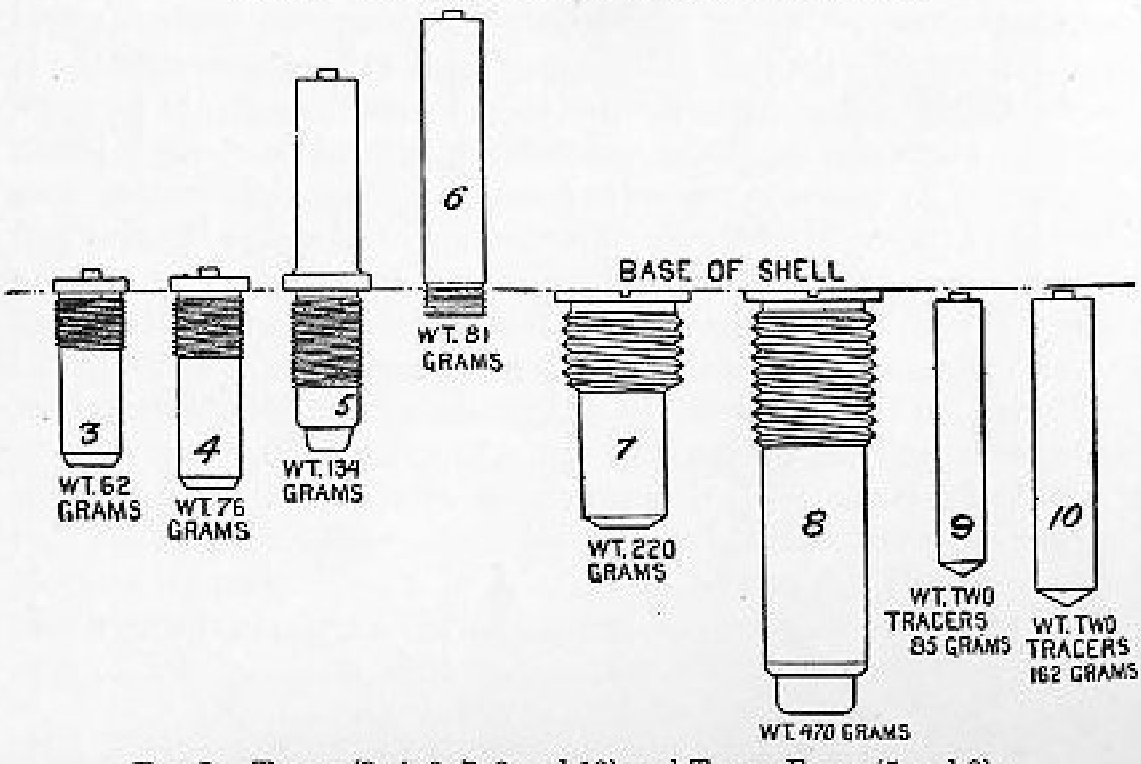


FIG. 3.—Traces (3, 4, 6, 7, 9 and 10) and Tracer Fuzes (5 and 8).

TRACERS AND TRACER FUZES.

formed with the explosive used. The burster charge may be of picric acid or one of its compounds, TNT, ammonium nitrate, tetryl, black powder, or a combination of any of these. In U. S. Navy projectiles explosive "D," TNT, or black powder is used, all of which are stable under ordinary conditions of storage.

The purpose for which a projectile is to be used fixes the kind of burster charge and the type of fuze. The degree of fragmentation is fixed by the character of the burster charge. In armor-piercing projectiles, a high explosive is required. In common projectiles, the proper fragmentation is obtained by mixing a high explosive with black powder. The high explosive in this case is not detonated but gives a low-order detonation, that is, the high explosive is consumed by burning rather than by changing instantaneously into the gaseous state. The present tendency is to substitute a high-order explosive for black powder in all common and bombardment shells. In shrapnel and illuminating projectiles, where the object is to discharge the contents of the projectiles, small black-powder charges are used. Flatnose projectiles are loaded similarly to bombardment projectiles.

The following table shows the assembly of projectiles:

Projectile	Designation	Burster charge	Fuze
Armor piercing....	A.P.	Explosive "D."	Delay action detonating.
Common..........	C.	Black powder with TNT or "D."	Ignition percussion.
Shrapnel..........	Shrap.	Black powder.	Combination.
Illuminating.......	S.S.	Black powder	Time.
Bombardment.....	Bom.	TNT.	Combination.
Flat nose.........	F.N.	TNT.	Sensitive percussion detonating.
Anti-aircraft......	A.A.	TNT. or "D."	Combination.

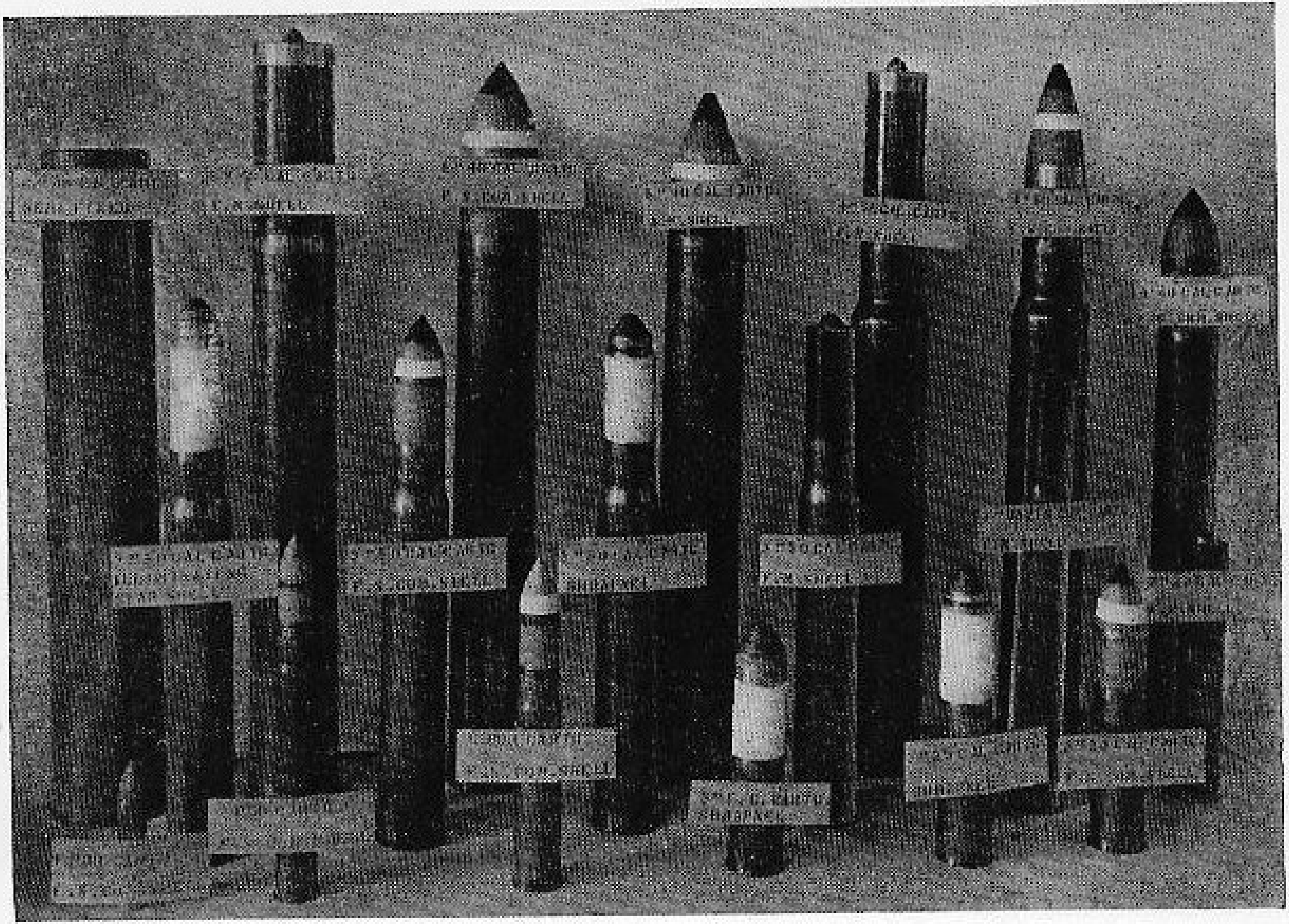
"Distinctive colors indicating use"

Armor piercing	black
Common	slate color
Bombardment	dark green
Shrapnel	white
Target	unpainted
Illuminating	light blue with white star
Anti-aircraft	unpainted

"Kind of explosive of projectile filler"

Black powder	slate color
Explosive "D"	yellow
TNT	dark green
Blind loaded	unpainted.
Gas	red (with geometrical figure).

Any of the above fuzes may have a tracer element, or a tracer fitted in the base.



As issued to ships, the ogivals of projectiles for a distance of 1 caliber from the point toward the bourrelet are painted with distinctive colors to indicate the *kind of projectile filler*, the remainder of the exteriors (except the bourrelet, band, and base), are painted with distinctive colors to indicate the *type of the projectile.*

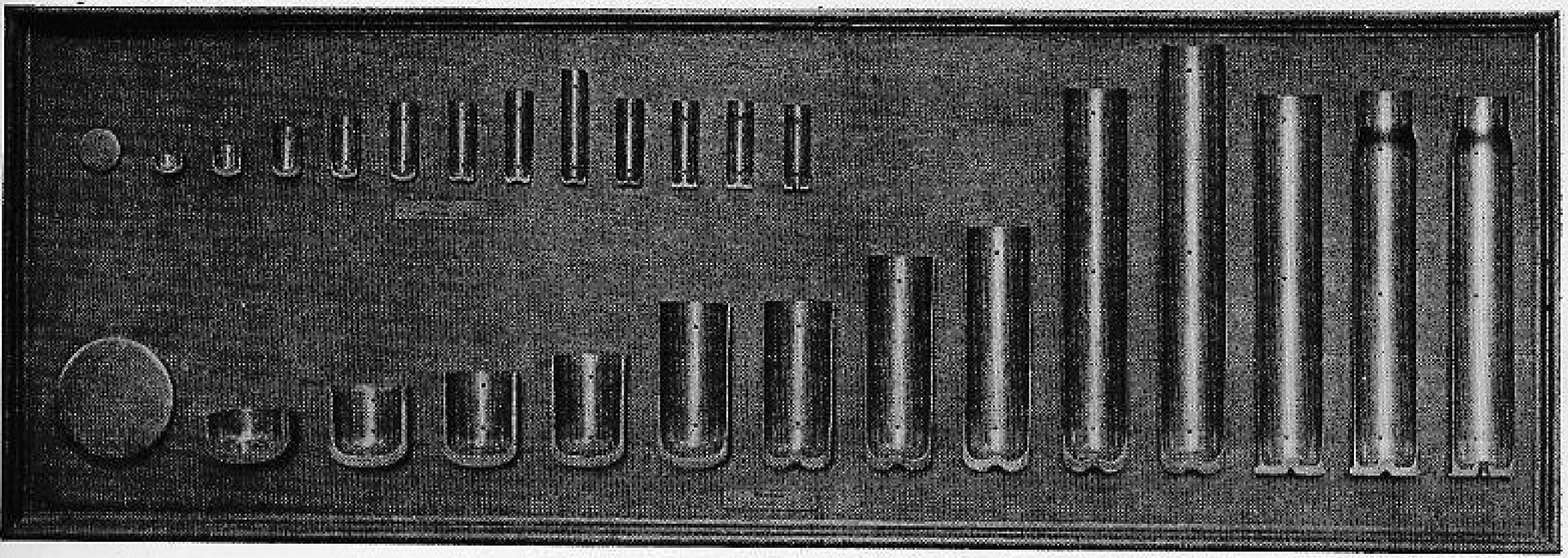
1427. Cartridge cases.—Brass cartridge cases are hollow cylinders with flat bases, shaped to fit the chamber, those for late guns being bottle necked. The base has a rim for the extractor and a central aperture for the primer. The cases are drawn from solid disks in successive passes in hydraulic presses equipped with suitable dies. The disks, 70 per cent copper and 30 zinc, when cast are very malleable and ductile and roll easily. The metal is bright yellow in color. Each case is carefully gauged, after machining, to ascertain that all dimensions may be within the tolerances allowed. It is of the greatest importance that each case should be interchangeable, that the extractor fits the rim, the primer fits the seat, the projectile fits the mouth, and that the length be correct so that the assembled charge will fit the gun.

Cartridge cases are reloadable when they have been cleaned and reformed after firing. They are required to stand six service rounds without deterioration before acceptance from the manufacturer. This fact is established by firing a number from each lot at the Proving Ground. It frequently happens that cases will stand from 30 to 40 rounds before becoming useless.

The base of the case has an internal boss in the center which is drilled out and, when designed to take an ignition primer, the hole is tapped. It is of the greatest importance to have this aperture exactly concentric in order that the primer will be aligned with the firing pin. The depth of seating must be exact in order that the primer will be inset the required amount. If the primer is inset too much a misfire will occur, and if it is not inset a sufficient amount it is a source of danger in the event it is struck against a sharp object. Plate XIII illustrates the steps in drawing a finished case from the solid disk or blank. Plate XIV illustrates different cartridge cases.

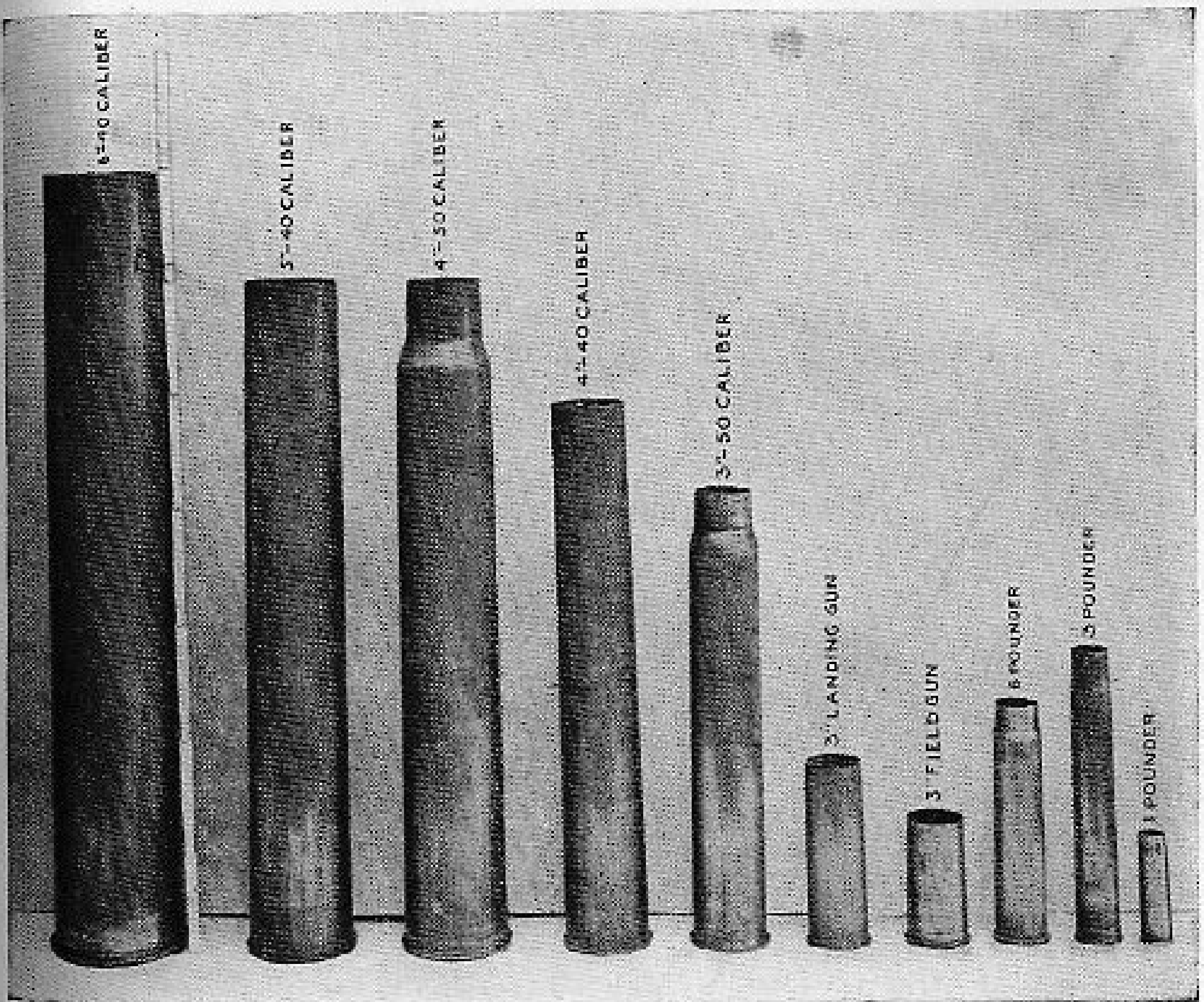
1428. Case ammunition tanks and boxes.—Case ammunition, after it is prepared, is packed in tanks or boxes for issue to the service. This is necessary for its safe transportation and stowage. Standard containers are used, varying in size and capacity with the caliber.

4-inch and above	one per box or tank
3-inch, 50-cal.	four " " " "
6-pounder	eleven " "
3-pounder	sixteen " "
1-pounder anti-aircraft	one hundred per box
1-pounder	sixty per box



Steps in Drawing Finished Case from the "Blank."

CHAPTER XIV, PLATE XIV.



CARTRIDGE CASES.

As the ammunition is stowed in a magazine remote from the guns, the containers must be strong enough to stand considerable handling, especially that which they undergo in passage up the ammunition hoists. The boxes are made of soft pine with one or more rope grommets for ease in handling. The tops are either loose and held in place with marline, or hinged and clamped.

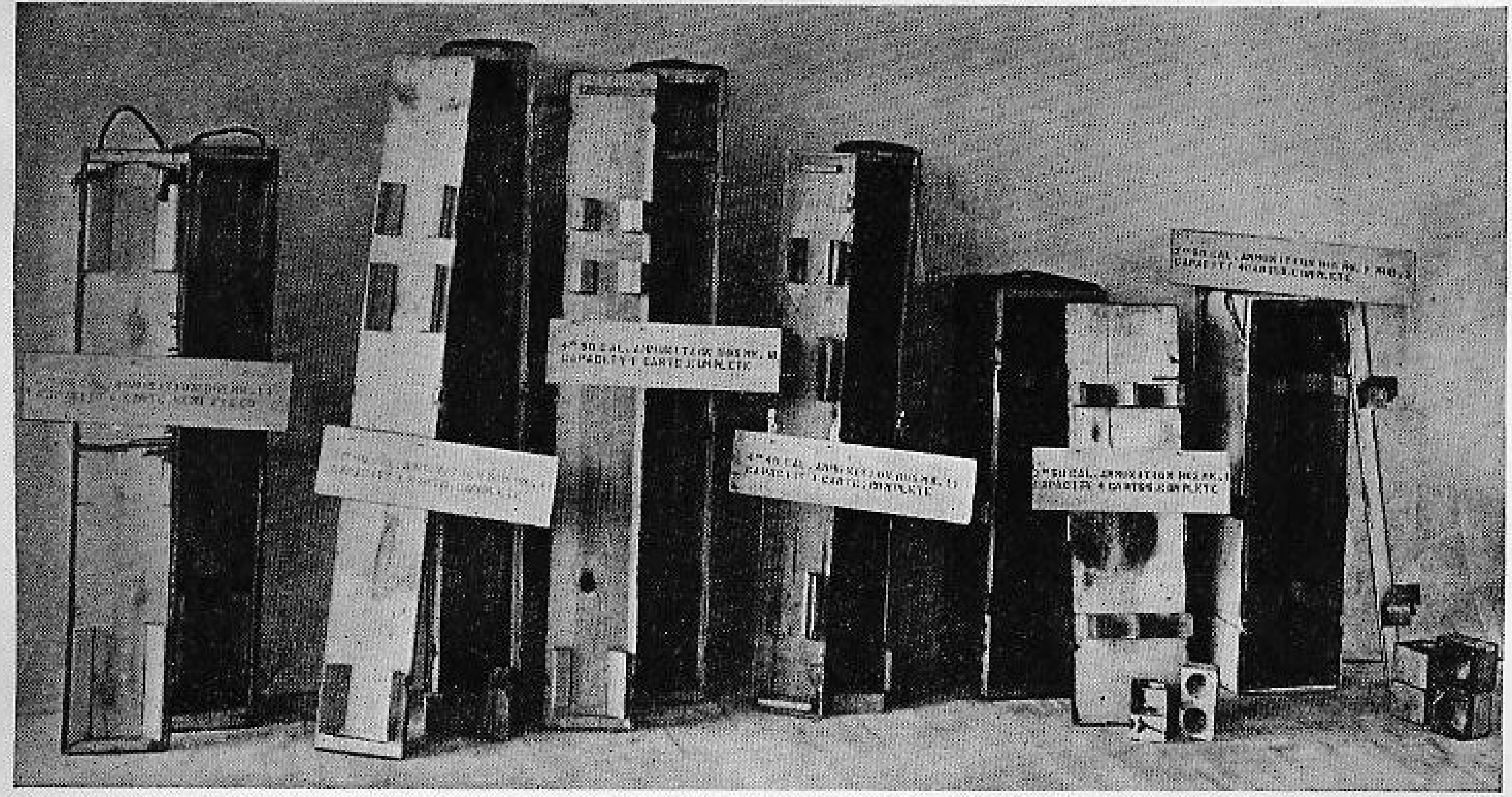
Suitable racks or nests are provided in each box with wooden blocks to protect the ends of the cartridges and to hold them rigidly in place. Ammunition boxes, being of wood, are subject to easy destruction and are not water-tight. In consequence, the tendency in recent years has been to replace them with metal tanks. As leaks may occur around the projectile or the primer, the cartridge case cannot always be relied upon to remain air-tight. Therefore, the present practice is to make the tanks air-tight. This gives the additional advantage of good stowage in "ready service" racks on deck, where the ammunition containers are exposed to the weather. The tops are fitted with rubber gaskets and are secured by a lug and butterfly nut. The tanks are usually circular in cross section, thereby changing the stowage arrangements from boxes, which are all rectangular in shape. The tanks are made from sheet metal with brass top and bottom rings. The body is galvanized after completion. The top and bottom rings are made strong enough to permit of stacking without the use of racks. Metal tanks, for instance, are used for 5-inch 25-caliber and for 4-inch 50-caliber ammunition, and 3-inch 50-caliber and 3-inch 23-caliber for submarines.

The latest type of cartridge tanks are made of aluminum with supporting rings at the top and bottom. The top ring is also a locking ring. Before acceptance, the tanks are required to stand an air-pressure test. Before issue to service containers are painted and tagged to show their contents.

Plates XV and XVI illustrate different types of boxes.

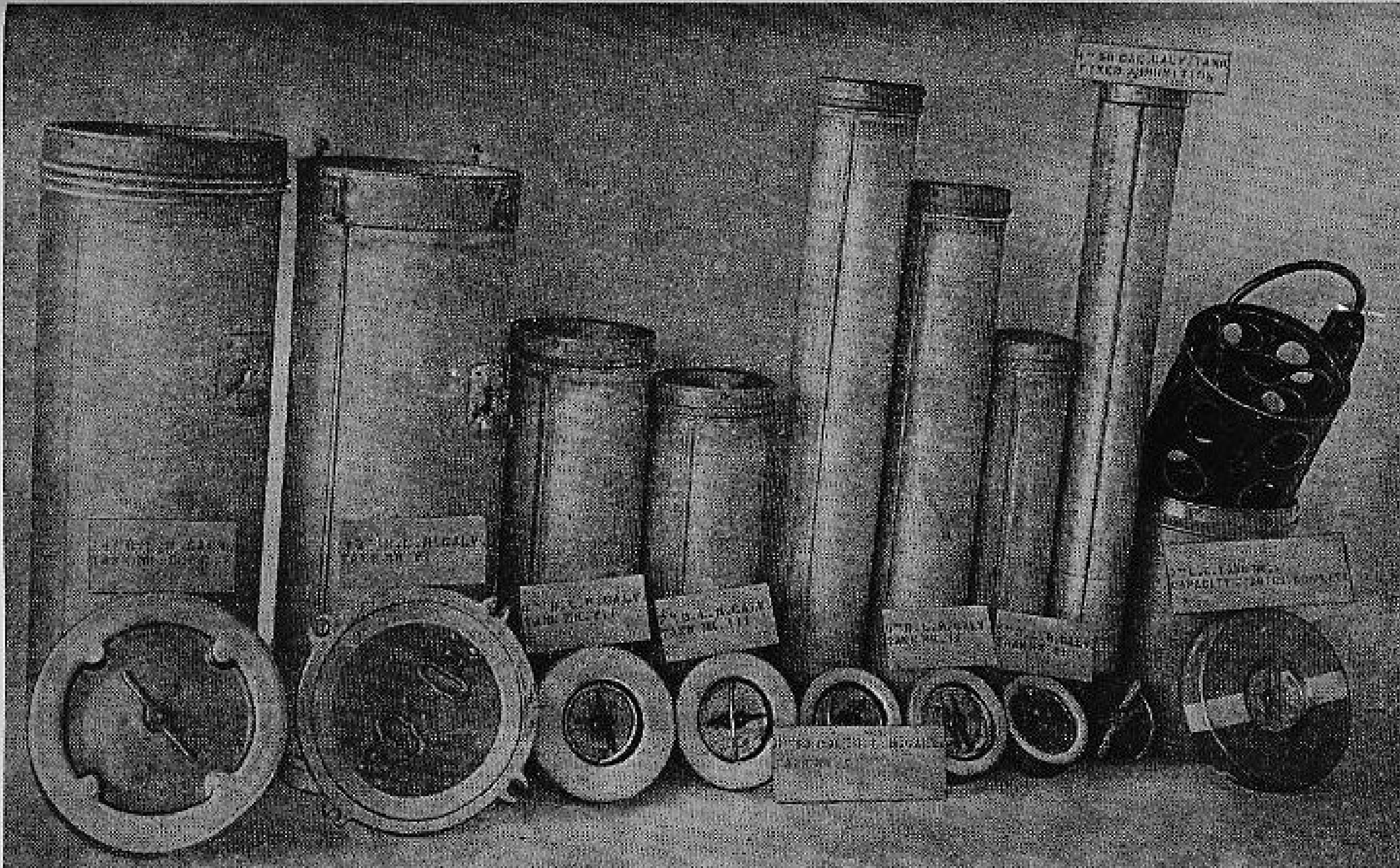
Plates XVII, XVIII and XIX illustrate different types of ammunition tanks.

1429. Powder bags.—The charges for bag guns are prepared by placing the powder in bags made of special silk cloth, sewed with silk thread and laced with a silk cord. The object in using silk instead of a less costly material is to reduce the danger from unconsumed smoldering residue. There are two weights, light and heavy. The body of the bag is made from the heavy in order to withstand better the necessary handling, permit of tight lacing, hold the required weight and reduce the tearing due to cutting by the edges of the grains. The light weight is used for the ignition ends where it is required to hold no weight

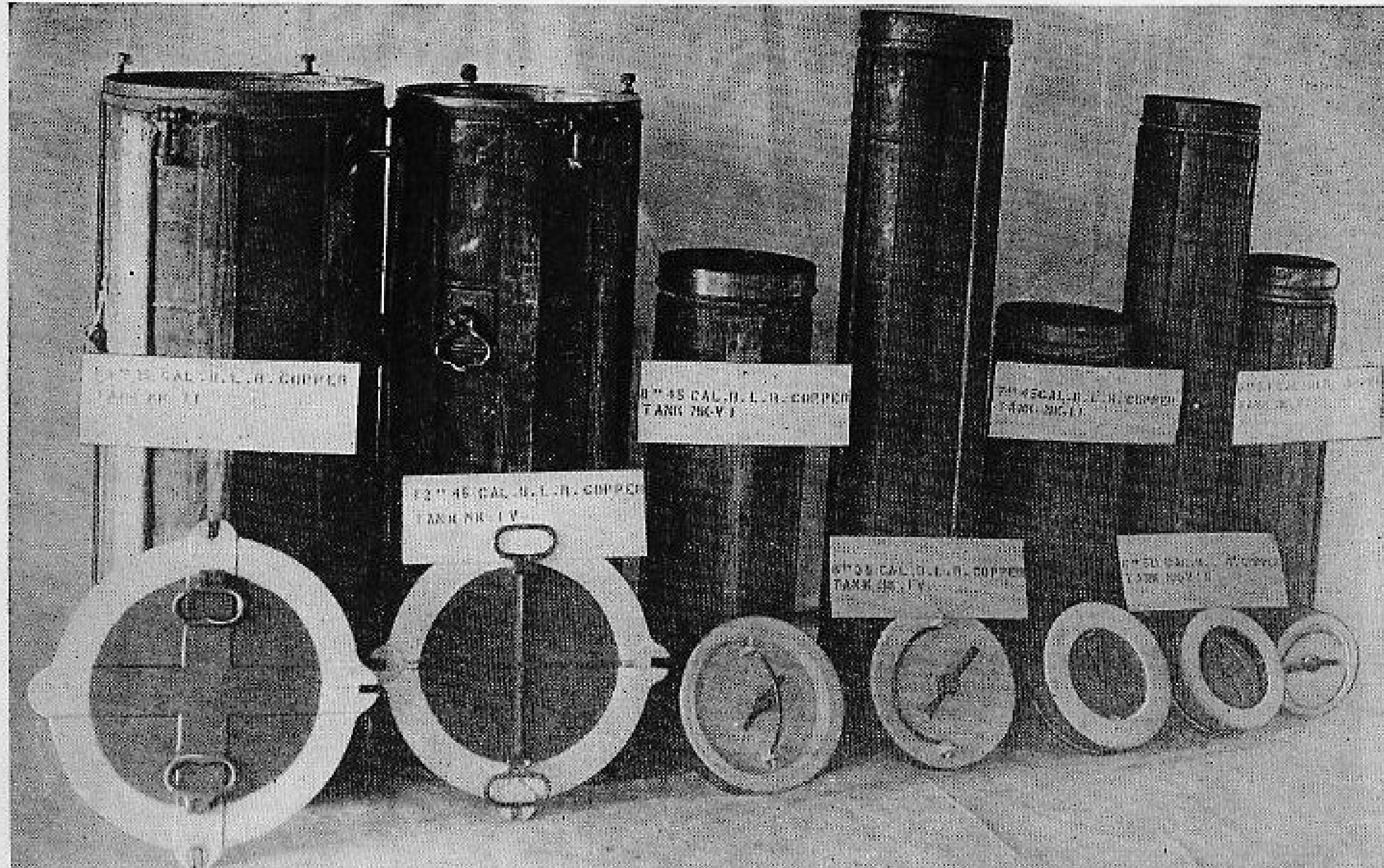


TYPES OF CARTRIDGE BOXES.

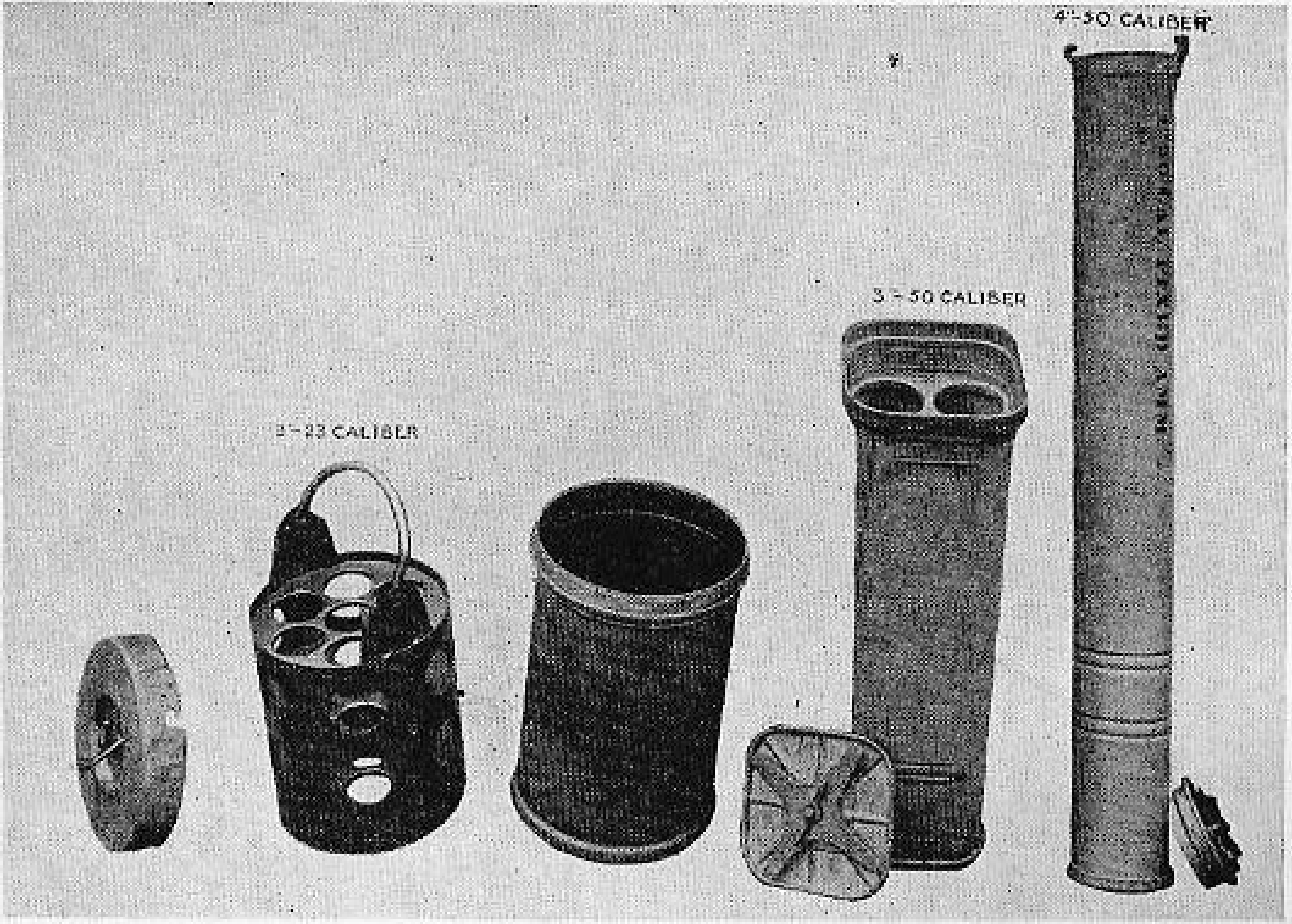
TYPES OF CARTRIDGE BOXES.



Types of Cartridge Tanks.



TYPES OF CARTRIDGE TANKS.



TYPES OF CARTRIDGE TANKS.

and where it is desired to have the flame from the primer burn through readily. Plate XX illustrates the details of powder bags.

The following conditions must be fulfilled by powder bag cloth:

(1) Strong enough to stand handling and transportation, especially the wear and tear of movement in tanks due to the motion of the ship.

(2) Of close weave to contain the powder, especially if dusty.

(3) Permeable to flash for combustion.

(4) Able to withstand chemical changes in case of reactions in the powder.

(5) Entirely consumed.

(6) Free from acids which may react on the powder.

On one end the ignition charge is attached, made by enclosing in a circular bag of thin silk cloth the required amount of black powder, then quilting the sides together to form the ignition pad. The face of this ignition pad, which is to be on the outside, is made from silk cloth previously dyed red. The pad is then sewed to the bottom of the bag. The other end of the bag is fitted with a strap for handling, sewed to the front end with extensions down the side. The straps are strongly made to withstand the required handling in withdrawing the bag from the tank and in the successive steps in loading the gun. In order to make a compact package, two flaps with eyeholes at intervals are sewed down the side at such a distance apart that when laced together by a silk cord enough space will remain to permit of taking up any slack which may result from further shaking down of the charge in service or from any stretch in the material.

1430. Distance pieces and wads.—Formerly powder bags were used with case ammunition, the bags, fitted with an ignition pad, then were loaded with the powder charge and assembled in the cartridge case. The space between the bag and the projectile was filled with excelsior. With the advent of the ignition primer the interior bag has been omitted, and cardboard disks and distance pieces are now used in place of excelsior. Disks are cut slightly larger than the diameter of the case and slit down from the edge to the center. Distance pieces are made by crossing and locking four pieces of cardboard in a manner similar to that used in commercial practice for crates. The distance pieces are cut to the desired length depending on the amount of powder used. Felt wads, cut to the size of the case, are used in place of distance pieces when the charge fits the case snugly, or when saluting charges are prepared.

1431. Mouth plugs.—With separate case ammunition, it was formerly the practice to seal the case with a brass mouth cup. This was in the form of a brass bowl, the sides of which fitted inside of the case. The

CHAPTER XIV, PLATE XX.

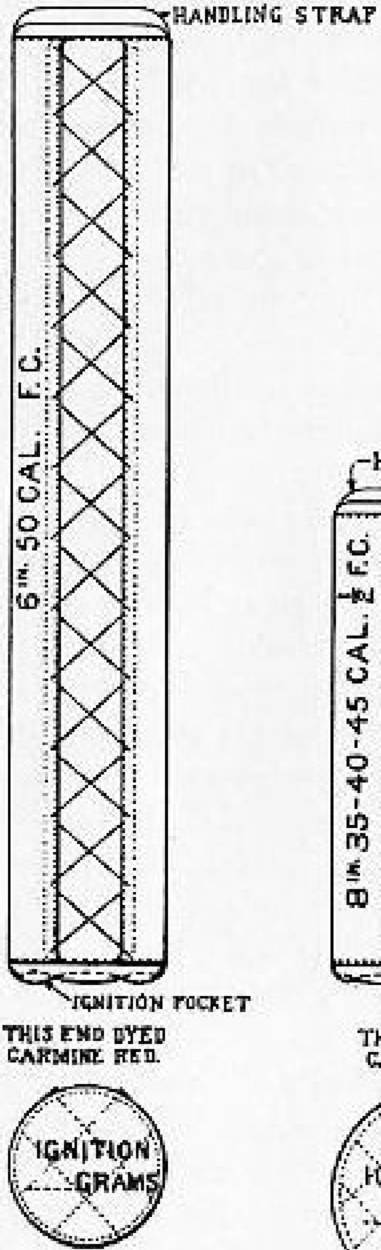


FIG. 1.

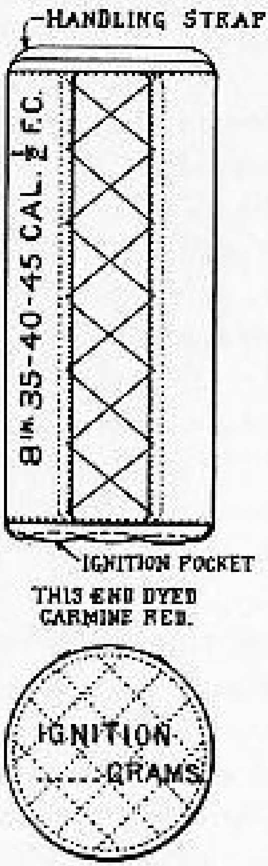


FIG. 2.

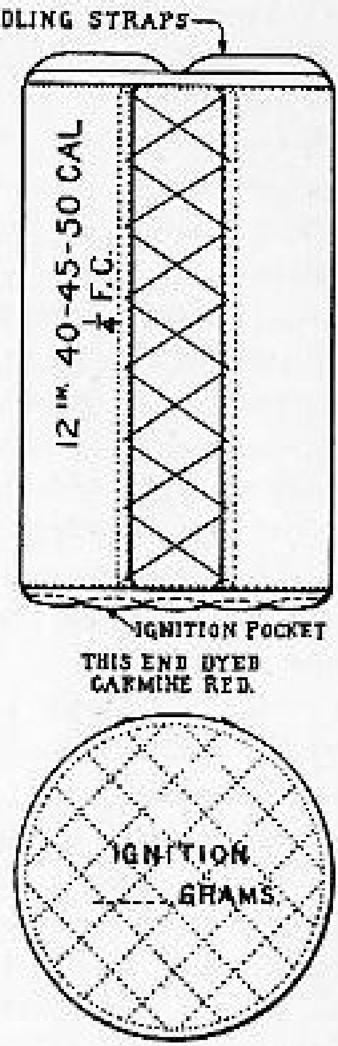


FIG. 3.

POWDER BAGS.

object in its use was twofold, first to form a gas seal in the case to prevent escape of the gases past the rotating band, also to keep gases from breaking cases by outside pressure on the case, before the projectile started to engrave the band in the grooves, and, second, to make the case an air-tight container for the powder charge. It has been shown that the gas escape is insufficient to require this form of seal, and as the brass mouth cup had a tendency to break up and boomerang back, endangering personnel, cork plugs have been substituted.

1432. Powder tanks.—Powder charges for bag guns are stowed in sheet steel, aluminum, or copper tanks. The considerations in the design of a powder tank are:

(a) Air-tightness.
(b) Strength.
(c) Lightness.
(d) Quick opening.
(e) Stowage facilities.
(f) Handling facilities.
(g) Capacity.
(h) Non-acid surface inside.

As smokeless powder changes its ballistic properties when exposed to air, it is essential that the containers remain air-tight while in use for storage of powder. To effect this, the tank closure is fitted with a rubber gasket onto which the cover is forced by various systems of dogs and nuts or cams, either fitted on the outside of the tank or contained in the cover itself. Self-contained closures, with the necessary dogs not projecting beyond the contour of the body of the tank, are considered more desirable as there is less likelihood of loosening the cover, thereby causing a leak. The standard test for air-tightness is to hold a 5-pound pressure for three minutes. Plate XXI, Figs. 3 and 5, shows dogs fitted on the outside; Figs. 2 and 4 show a self-contained closure.

Powder tanks must be strong enough to stand the necessary handling in stowing below and, in case of broadside guns, in handling in the ammunition hoists. They are designed with sufficient strength to withstand normal stresses but should never be subjected to knocks which may result in leaks. The main strength is placed in the top and bottom rings in order to permit stacking. Copper tanks are strengthened by wooden battens on the sides. Handles riveted to the sides are a source of weakness, due to the pulling loose of the rivets when handling the tanks loaded.

The design of all tanks is such as to contain the charge with the least amount of waste space; hence, the cylindrical form has been adopted, as requiring the least amount of metal, the smallest closure, and, except in case of rack stowage, the least stowage space. The inside dimensions of a powder tank should be such that it will be a gauge for the charge, so that charges which fit the tank will fit the guns. To provide for uniformity in loading, it is considered desirable to have the total length of charge bear a fixed relation to the length of chamber. The length of the several sections when placed end to end, as they would be in the gun, should be about two inches less than the distance from the mushroom face to the base of the projectile when seated. This condition is not obtained for all guns in service, due to the design of old tanks.

In order to sustain a good rate of fire it is necessary to have the tanks so designed that the covers can be quickly and easily removed, as it is forbidden by regulations to open more than one charge per gun at a time in a magazine or gun compartment during firing, or to loosen a cover so that more than one charge is exposed during firing. It is desirable to have the least number of men employed in keeping the rate of supply equal to the rate of fire. Special wrenches are provided for the removal of the tank covers.

Special handling facilities are provided for lifting and transporting powder tanks, either as a bail fitted to the cover, or as handles on the sides. The handling arrangements should be such that no injury will result in developing leaks, and in all cases the bail or handles should be fitted to the strong part of the tank. Handles fitted to the sides do not fulfill this condition, and will not be provided in the future; instead, slings around the top ring will be used.

On board ship, powder tanks and cartridge tanks are normally stowed horizontally in tiers. Bulk stowage may be used for all tanks that are to be sent up the hoists to the guns, hence requiring no provision for removing the tank covers while in storage. Powder that is to be removed from the tanks and sent up the hoists to the guns in bags must be stowed so that all tank tops are accessible and also so that tank covers and the powder in the tanks may be readily removed. It was formerly the practice on some ships to stow powder tanks for large-caliber guns in racks so that each tank had to support only its own weight. The present practice is to fit all tanks (powder and cartridge) with supporting rings of the same diameter at top and bottom, and pile the tanks on each other, tier upon tier. The supporting rings take the compression load. The top ring on each tank is also a locking ring. These rings lock each tank with all adjacent tanks to prevent all longitudinal movement of the tanks. The lower tier of tanks is locked to lugs secured to the deck. Some of the older tanks for large-caliber guns were designed for storage in racks only. These tanks are not fitted with supporting rings and are suitable only for rack stowage.

The size of the individual tank should be such that it will contain the largest fraction of the charge and still not be too cumbersome for easy handling. Below 8-inch the entire charge is contained in one tank, from 8-inch to 14-inch inclusive two tanks are required per charge; for 16-inch, 45-cal. two and one-half tanks are required, and for 16-inch, 50-cal. three tanks are required. A tank weighing loaded 300 pounds is considered to be a maximum for ease in handling. The fewer tanks to be used means the fewer closures and the fewer opportunities for leaks and chances for deterioration of the powder.

As a protection for the powder, the interior of a tank must be neutral, clean, dry, and free from dirt. Sheet-steel tanks are painted on the inside with non-acid paint. Tanks constructed by soldering or sweating are treated with alkali water and thoroughly cleaned with fresh water. As a protection to the ignition pad, a sheet of clean manila paper is placed in the bottom of the tank.

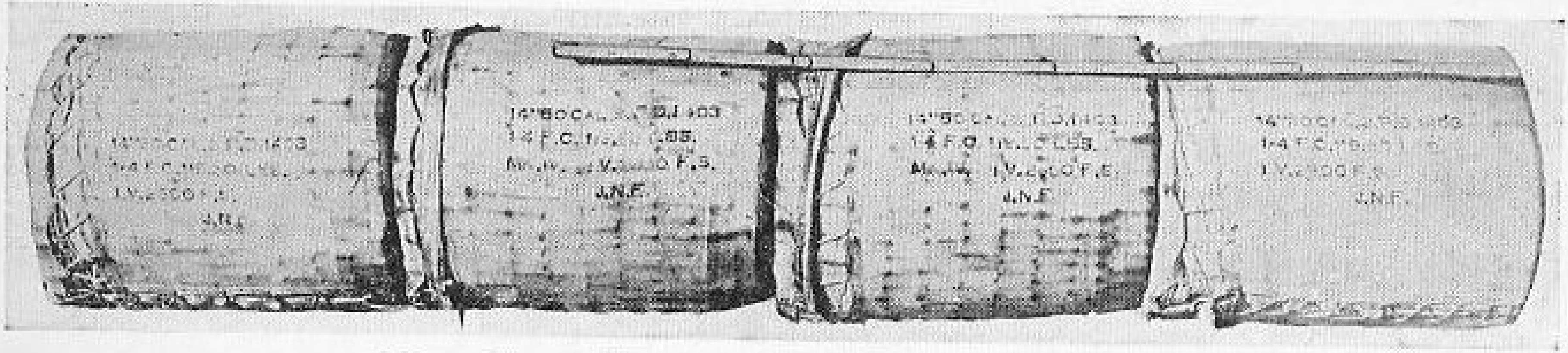
Plate XXI shows the general features of powder tanks. As there are many types in service no attempt will be made to describe any in particular.

1433. Assembly of ammunition.—Ammunition details are received at ammunition depots from the manufacturers, after proof, and stored until required for assembly for issue to the service. When orders are received for the preparation of ammunition, the projectiles are loaded and fuzed, the powder charges assembled, the ammunition packed and marked and prepared for delivery to the ship in such a condition that no further work is required on it.

Projectiles are loaded as a separate operation. Each one is cleaned, gauged, inspected, and then loaded with the proper explosive. Black powder or the mixed filler is loaded in loosely, explosive "D" is loaded under pressure in hydraulic presses, and TNT is loaded either loosely, under pressure, or in the cast form. After the explosive is loaded the projectiles are removed to a separate room where the fuzes are carefully assembled and the projectiles are then painted to show the type of explosive.

Projectiles for bag guns, when issued to the service, have special grommets fitted over their rotating bands. These are supplied to prevent burring of the band, knocking it loose, etc. Formerly, they were made of fiber, but the recent design is a canvas belt with a rope grommet abaft the band, the whole being held in place by a marline lashing.

In assembling case ammunition the cases are inspected, cleaned, gauged, and then the primer is inserted. Case percussion primers are forced into place by hand or machine presses and case ignition primers are screwed into place. Care is taken to see that the primer has the proper seating, neither projecting nor inset too far. The predetermined weight of powder is then weighed out on carefully checked scales and



POWDER CHARGE (STACKED GRAINS), FOR 14-INCH 50-CALIBER GUNS.

poured into the case. A wad is then forced in to keep the powder in position around the primer, a distance piece is then placed on top of the wad and another wad is placed on top of the distance piece. The case is then placed in a press, the base of the loaded and fuzed projectile is entered in the mouth of the case and forced in until the rear of the rotating band takes up against the mouth of the case. The cartridges are then packed in containers with great care to obviate any movements in transit or possibility of damage to the nose fuze, if of that type.

In preparing bag ammunition the ignition ends are prepared first and quilted in special sewing machines using bronze needles. The bags are manufactured for each index of powder as required, as the weights of charge vary with the different indexes. The powder is weighed out, dumped loosely in the bag and the lacing passed. The bag is then rolled a number of times, the lacing tightened and secured and the bag gauged for size, then placed ignition end down on a clean sheet of paper in the powder tank. The tanks, when marked to show the contents, are then ready for delivery.

For preparing stacked charges there are several forms of stacking machines in use, all, however, working on the principle of upending the grains and passing them through apertures and standing them on end on a plate. The grains are then clamped together in a hoop in one layer, and moved over a cylinder which is covered by a brass plate. When the layer is in position the plate is pulled out, the layer drops down onto the one below it and is then forced down the cylinder until there is space for the next layer. When the cylinder has the required number of layers a bag is pulled over it, the cylinder withdrawn and the bag laced and sewed up. Plate XXII shows a stacked charge.

1434. Marking of ammunition.—All ammunition is carefully marked or tagged to identify it. Tags are placed in the powder charge, the powder bags are stenciled, projectiles are painted in colors; ammunition boxes and powder tanks are both painted in colors and stenciled.

These markings are self-explanatory, except the colorings used. By means of the marking information is given as to the caliber of gun for which made, weight of total charge, weights of individual fractions of charge, weight of ignition charge, index number of powder, depot from which shipped, initials of weighers, gaugers, checkers, and inspectors, date put up, standard I. V., and other information of value.

Boxes containing fixed ammunition are painted in colors similar to those on the ogives (see Art. 1426) to indicate the character of the projectiles. The tops of the boxes, however, are painted to indicate the character of the bursting charges. If the ammunition is fitted with tracers, a white band 2 inches wide is painted, encircling the middle of the box and parallel to the ends. This band is painted black in the case of shrapnel.

Galvanized steel cartridge tanks are not painted, but the bottoms of aluminum tanks are painted to indicate the character of the projectile while the covers indicate the kind of bursting charge. Tracer bands, if required, are painted on both the cover and bottom. Powder tanks containing bag ammunition are not marked with distinctive colors but are marked with a circular white band around the edge of the cover upon which is painted in black letters the caliber of the gun, index of the powder, and the proportion of the charge in the tank.

Section IV.—Ammunition Stowage and Supply

1435. Ammunition stowage. (Plates XXIII and XXIV.)—Detonators are stowed in approved places below the water line or protective deck in large surface craft and in submarines, and above the weather deck or in the masts in most small surface craft. Pyrotechnics are stowed in cool dry magazines below decks, preferably above the waterline, or in special pyrotechnic lockers located on the weather decks of surface vessels. With the exceptions mentioned above, all ammunition is stowed in especially constructed stowage spaces or rooms set apart for that purpose alone. These spaces are called magazines. Ready service lockers are provided near the guns for emergency use. Projectiles for broadside guns may be stowed in bins in the compartments or passageways near the foot of the broadside hoists. Turrets may have projectiles stowed outside of the projectile rooms either in the turret or below the turret floor. In the more recent designs, few turret projectile rooms are required, as the projectiles are stowed in the barbette.

In the older battleships, the magazines were placed in groups, forward and aft, connected by wing passages and ammunition passages, which were useful in transporting ammunition from one group to the other in case a turret should become disabled. In the recent designs of all big-gun ships, the location is more complicated. Where there are more than four turrets, the magazines are in three groups and, where there are four turrets, they are in two groups, one forward and one aft, without direct communication.

The simplest arrangement would be to install a magazine and a projectile room directly under the guns it serves with the hoists leading directly up to the guns. This would usually involve placing a line of magazines along each side of the ship, adjacent to machinery spaces. This arrangement is not generally feasible as the rooms would be too near sources of heat, and also the space is required for other purposes. This result is obtained for turret guns, however, as the handling of large charges and projectiles must be reduced to the minimum. Also, the space below turrets is available for division into ammunition spaces.

With broadside and anti-aircraft guns, however, the magazines and projectile rooms are normally grouped forward, some being on the same level as the turret magazines and some being directly under these magazines on the next platform level, but some ships have magazines for broadside and anti-aircraft ammunition aft as well as forward. This requires transportation of these less weighty charges to the base of the various broadside or anti-aircraft ammunition hoists below decks or from the tops of the hoists to the adjacent guns above decks.

The magazine spaces are on the upper and lower platform decks, which places them below both protective decks and also below the water line for security. They are placed inboard as a further protection, in case the skin of the ship is pierced, to reduce the chances of an internal explosion. Outboard of each magazine is a series of from three to five void spaces and fuel tanks to afford protection from torpedoes and mines. Below each magazine is constructed at least one level of storerooms and below the storerooms either a water or fuel tank or a double bottom. The projectiles for main battery guns for the first all big-gun ships and part of the powder are stored on the upper platform deck in ammunition rooms leading off the handling rooms, and the remainder of the powder in compartments, directly below the handling room on the lower platform deck. In later designs, turret projectile rooms are largely dispensed with as noted above. The ammunition for broadside guns is stowed on the lower platform deck, with magazines communicating with handling rooms in which are located the lower ends of the ammunition hoists. In the latest battleship designs it has, in many cases, been necessary to handle the broadside ammunition in two stages, bringing it up from the forward (and after) group to the third deck and transporting it along the third deck on electric conveyors to the bottom of other hoists which take shell or powder from the third deck to the individual gun on the upper decks. Some hoists lead directly from handling rooms to gun compartments.

Adjacent turrets have their handling rooms connected for the interchange of ammunition. To get ammunition from a forward to an after handling room it is necessary to use the passages on the third deck by hoisting ammunition up special hatches and transporting it along the deck suspended from overhead trolleys.

Special rooms are arranged for torpedo war heads, saluting charges, and small-arms ammunition.

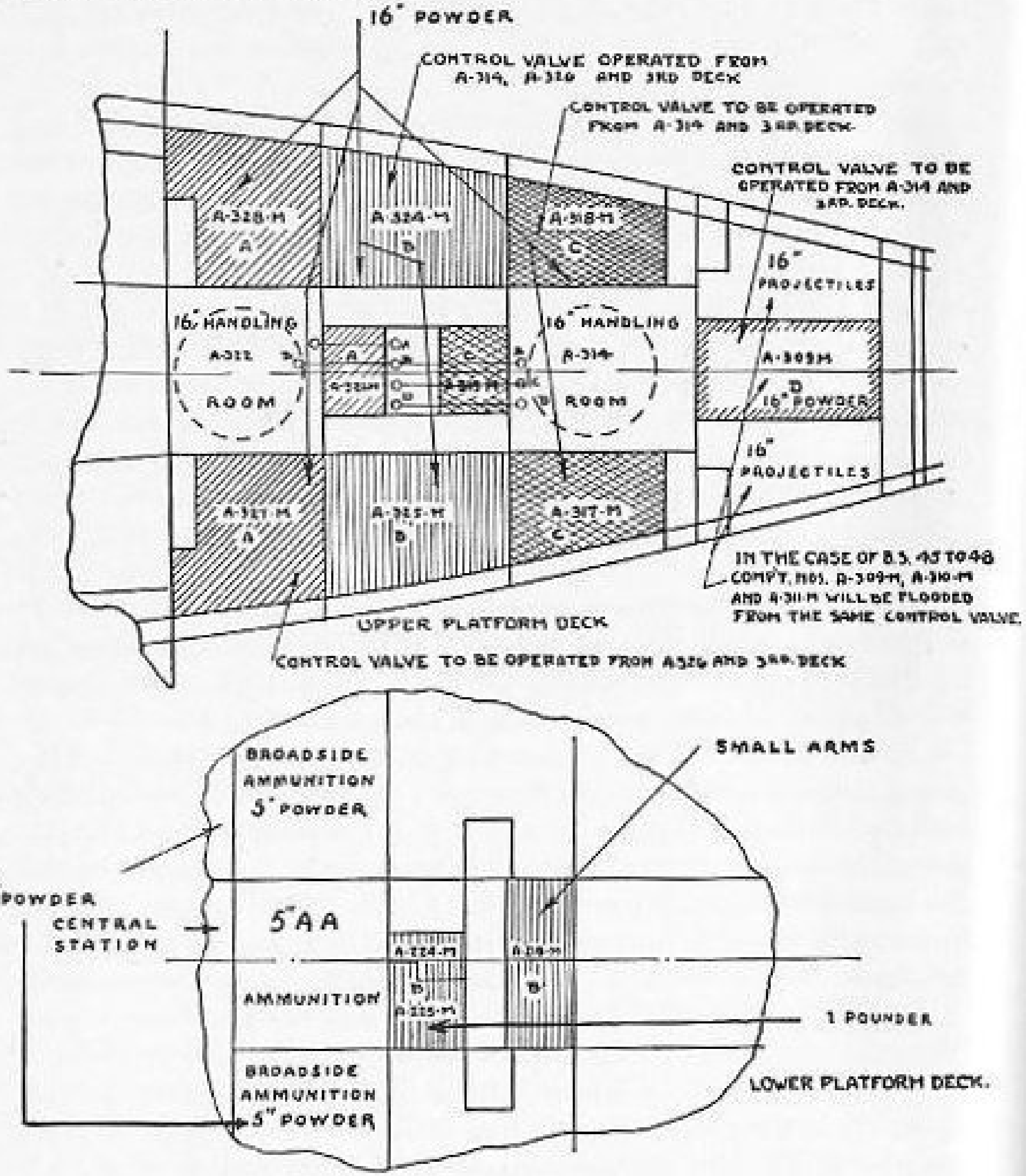
Plate XXIII shows the arrangement of the forward group of magazines of our latest battleships. The arrangement of the after group is essentially the same, except that it contains only main battery ammunition.

The ammunition rooms of other types of ships are arranged in two groups, one forward and one aft with hoists or whips adjacent, thus requiring, in many cases, considerable transportation of ammunition on deck. Submarines have special stowage arrangements due to lack of space and small quantities carried.

1436. Flooding.—The property of an explosive of resisting for a certain time, without decomposition, the action of humidity, heat, and other elements which tend to cause it to decompose, is called its chemical stability. To prevent damage from an explosion due to this loss of chemical stability, especially in the event of fire, flooding arrangements are provided aboard ship. In order to conform to the requirements for water-tight integrity, and to provide against the necessity of flooding, all magazines are water-tight compartments. Arrangements are made for admitting flooding water to each room or compartment where ammunition is stowed. Powder magazines are flooded by a connection from the fire main. (Formerly it was the practice to install flooding connections through sea valves directly to the sea where the location of magazines relative to the water line of the ship afforded a sufficient head of pressure to accomplish flooding. Such installations may still be found on a few of the oldest ships.) For this reason it is absolutely essential that pressure be maintained on the fire main at all times. Torpedo war-head lockers, due to their location, can usually be flooded through local sea valves as well as through the fire main. Where the pipe connection to the fire main has one large opening, it is called a flood pipe. Where the pipe has many small openings on the upper side and is suspended across the top of the powder or projectile stowage racks, it is called a sprinkler pipe. In recent designs, ammunition compartments are fitted with both types. Sprinkler pipes are also fitted over gun-loading positions in turrets, over powder-loading positions in handling rooms, and over projectile bins located in passageways. Sprinkler holes are not over $\frac{3}{8}$ inch in diameter, and the aggregate area equals 150 per cent of the area of the group control valve. When using both flood and sprinkler pipes, sufficient water must flow to fill the compartment in twenty minutes. Where sprinkler pipe alone is used, it must be capable of filling the compartment in one hour. When in dry dock, arrangements for sprinkling and flooding must be maintained by connections to water mains ashore.

On battleships, from the pumps the fire main extends forward and

CHAPTER XIV, PLATE XXIV.



COMP'TS. OF SIMILAR HATCHINGS ON THIS SHEET FLOODED BY SAME CONTROL VALVE.

A-COMP'TS.	LOC. VALVES	B. COMP'TS	LOC. VALVES	C. COMP'TS.	LOC. VALVES	D. COMP'TS.	LOC. VALVES
A-327-M	322	A-324-M	322	A-317-M	314	A-309-M	314
A-328-M	320	A-325-M	314	A-318-M	320		320
A-321-M	3RD. DECK	A-218-M	3RD DECK	A-319-M	3RD DECK		3RD DECK
	ABOVE 320	A-225-M	ABOVE 320		ABOVE 320		ABOVE 320

GROUP CONTROL FLOODING ARRANGEMENTS.

aft on each side of the ship in the form of a salt-water pressure loop below armor. Abreast of each magazine group, an athwartship line connects the starboard and port branches of the fire main. Cut-out valves at each end of the athwartship cross-connection are habitually kept open. From a group control valve in this cross-connection, a flood pipe with branches leads to each magazine within the group. In the various branches of the group flood pipe, are located individual cut-out valves at each magazine within the group. The group control valve is habitually kept closed and locked. The individual magazine cut-out valves are habitually kept open and locked. Thus, to flood all magazines in a group quickly it is only necessary to open the one group control valve. To flood a single magazine in a group, it is necessary to close the individual cut-out valves for each of the other magazines in the group and then open the group control valve. A spindle from each group control valve permits operation of the valve locally or from the third deck above. Where the spindle passes through the third deck it is fitted with a water-tight stuffing box. At the group control valve there is an operating wheel and on the third deck the valve operating spindle terminates in another valve wheel or other mechanical means for operating the group control valve through the operating spindle. Both at the group control valve and on the third deck, the valve wheel or other mechanical device for operating the group control valve is enclosed in a locked metal box fitted with a glass top or front. The keys for these boxes are kept with the magazine keys in the captain's cabin. In an emergency, of course, the glass is broken in order to have access to the operating gear. Cut-out valves at each individual magazine can only be operated locally.

As indicated in Plate XXIV, the forward group of main battery magazines may be divided into three small flooding groups, while the black powder, small arms, broadside, and anti-aircraft magazines, as shown, may be divided either into separate groups or included in one of the main battery groups. The flooding arrangements of cruisers, destroyers, and other ships are fundamentally the same as those for battleships.

To insure that the flooding and sprinkling systems are maintained in efficient condition, a weekly test of group control valves and their operating gear is conducted. A test cap is fitted in each magazine which closes off the flooding lines; the group control valve is then opened, permitting the water from the fire main to pass through it as far as the test cap. The group control valve is again closed, locked, and the water between the valve and the cap is drained into a bucket through a cock in the magazine cut-out valve.

A diagram similar to Plate XXIV is mounted in the vicinity of each flooding station to give the number and location of each magazine flooded by each valve. In addition, especially shaped plates, similar to Fig. 1401, are secured nearby to give the same information.

FIG. 1401.

As the fire main pressure would be communicated to the bulkheads if a magazine became filled, it is necessary to provide a relief. This is usually in the form of an exhaust ventilator of such diameter that the flow of water will not permit the pressure in the flooded compartment to rise above that due to the head of water within the compartment, for which pressure the compartment is periodically tested.

Magazines are not directly connected to the ship's drainage system. If flooded for any reason, they are ordinarily drained by cracking the magazine door to permit the water to escape to the adjacent handling room from whence the water can be pumped by a portable pump, or it may be permitted to drain to the bilge or to another compartment having a connection to the main or secondary drainage system.

1437. Cooling and ventilating.—The property of imparting on firing, after a length of time in storage, the velocity and pressure found on acceptance test is called the "ballistic stability" of a propellent powder. In order that this property be not impaired, special lagging and ventilation equipment are installed in magazines to provide storage conditions as uniform and favorable as possible. It has been found that a temperature of 70° to 80° F. is suitable for the storage of standard Navy smokeless powder, while its life is rapidly shortened by temperatures over 90° F. To provide a uniform cool atmosphere in the magazines, various systems of refrigeration have, in the past, been tried with varying success. However, at the present time, due to increased stability of our powders, and to improved methods of ventilation, and because of the difficulties in refrigeration systems, refrigeration is no longer resorted to.

The following considerations govern the installation of ventilation systems for magazines:

(a) Ventilating pipes must be so installed that no magazine can be flooded from another through the ventilating pipes.

(b) Ventilating pipes, water-tight below the lowest armored deck (third deck).

(c) Intakes, so located as to minimize the possibility of drawing in gas from fires in action.

(d) Natural exhausts, fitted to a fixed height above the water line, behind armor.

(e) Natural exhausts, located inside turret barbettes, where practicable.

(f) Lower ends of exhausts, fitted with check valves to permit egress of water or air, but not to permit ingress of either.

(g) Lower ends of supply ducts, fitted with water-tight covers for sealing in action.

(h) When ducts pass through a deck or bulkhead, construction must be water-tight and fitted with a slip joint and water-tight cover for sealing.

(i) Intakes, fitted to prevent foreign matter entering.

An exhaust duct is fitted with a non-return flapper valve and leads up through the deck inside a barbette, where practicable, where it ends in a goose-neck covered with wire mesh. When a magazine is fully flooded, the water escapes in the same way, preventing pressure being brought on the bulkheads. The height of the duct is fixed above the water line by the hydrostatic pressure which the compartment is designed to withstand. Magazines are not ventilated in action, so the blowers are stopped and the supply ducts sealed with hinged covers.

Magazines are insulated with cork composition in order to reduce changes in temperature to the minimum. When the outside temperature is above 90° F. in the day time, magazines may be kept cool by running the blowers only at night, when the magazines may be filled with air at the minimum temperature.

1438. Magazine lighting.—In the older type ships, light boxes are inset in the bulkheads, so as to throw light through round double lens ports in three directions. The boxes are water-tight and open only from the outside of the compartment they illuminate. Each one contains incandescent lamps and a fitting for a candle in case the lamp fails. They are arranged so that the bottom may be covered with water in case the candles are used. Modern ships are provided with two separate and independent lighting systems—standard and auxiliary. The standard lighting system is operated from the ship's service generators. The auxiliary lighting system is operated from a storage-battery supply. The systems are interconnected and controlled through relays designed so that the line contactors to the ship's service busses shall remain closed and feed the lights from the generators' service as long as the ship's service voltage is above 103 volts, but in case the ship's service voltage drops to the foregoing value or below, the relays operate to open the contactors to the ship's service busses and close the contactors to the auxiliary storage-battery supply. As soon as the ship's service voltage rises to 108 volts, the foregoing operation of contactors is reversed and the feed to lights changed to normal generator supply.

As a second means of auxiliary lighting, it is the present practice to equip all magazines with portable hand electric dry-battery lanterns. They are hung on brackets attached to the bulkheads.

In general the following requirements for magazines are met: The light fixtures are steam- and water-tight, and are connected to separate feeders on the magazine circuits, which are distinct from other circuits. The control switches are removed from the paths of ammunition handling and are grouped at feeding centers in flame-proof lockers. No fuse boxes, switches, nor electric connection boxes are located in magazines. All electric cables are protected in conduits built up from light channel bars. No steam lines are located in magazines.

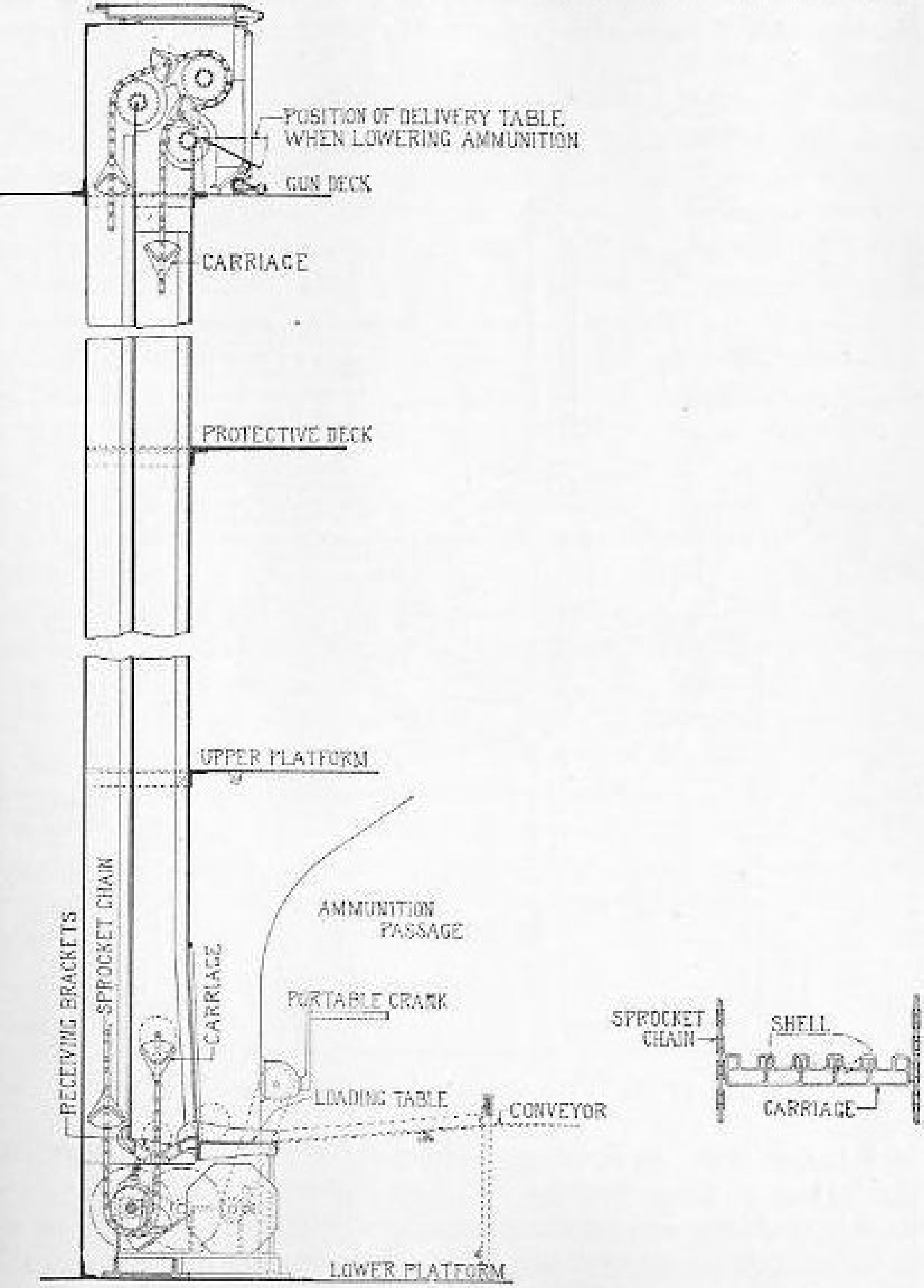
Turrets are lighted in the same manner as magazines.

1439. Supply.—The efficient supply of ammunition to the guns is of prime importance, and must be so arranged as to permit a sustained fire without causing a delay at the gun for lack of it, or an excess accumulation with the attendant danger of an explosion initiated by a shot from the enemy.

The problem varies with each individual installation. The design is the best that can be worked out for the individual ship for it must be co-ordinated with the other factors. The success will depend on the proper utilization of the equipment provided, so that many losses in time attributed to the equipment may be eliminated with the proper stationing and training of the personnel.

The supply in turrets is very simple. Ammunition hoists for turrets are described in Chapter IX. The broadside and anti-aircraft guns are served by motor-driven, endless-chain hoists that deliver approximately 20 pieces of ammunition per minute. The broadside 6-inch, 53-caliber guns on the 7,500-ton cruisers, however, have hoists of the pusher type instead of endless-chain hoists. On battleships the broadside guns usually have the equivalent of a hoist for each gun. Anti-aircraft guns fire so rapidly that it is absolutely necessary to have ammunition up in advance. No attempt is made to install sufficient hoists to supply anti-aircraft ammunition as fast as it can be fired. The lower end of the endless-chain hoist is usually situated in a broadside or an anti-aircraft magazine handling room, or in an ammunition passageway. At top and at bottom the openings, for inserting powder into and removing powder from the hoist, are covered by flame-proof doors.

CHAPTER XIV, PLATE XXV.



5-Inch Chain Ammunition Hoist.

Plate XXV shows such a broadside endless-chain hoist without flame-proof doors. In the newer designs of battleships where fore-and-aft communication is impossible below the third deck, it is necessary to have two sets of hoists with fore-and-aft electric conveyors on the third

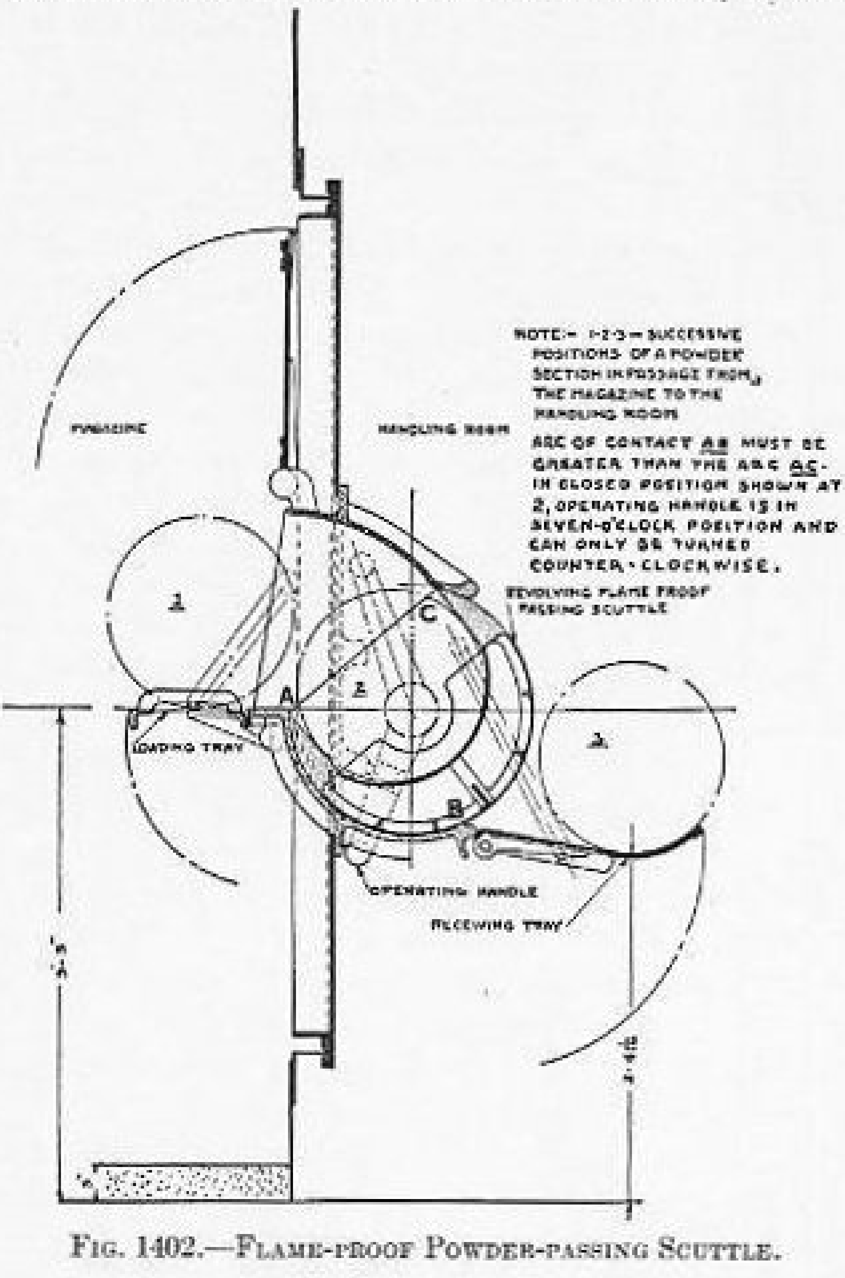


FIG. 1402.—FLAME-PROOF POWDER-PASSING SCUTTLE.

deck to distribute the ammunition from the top of one set of hoists to the bottom of the second set of hoists. The ammunition is sent from its own magazine and handling room, up to the third deck by one set of hoists, then distributed along the third deck by conveyors to the foot of the second set of hoists, which take the ammunition from the third deck and deliver it to the guns located on the upper decks. Some few guns, located vertically above the magazines, may be served by a single hoist from handling room to gun direct.

Five-inch broadside ammunition hoists are not suitable for hoisting 5-inch anti-aircraft ammunition because of the difference in length of the two different containers, but 5-inch broadside ammunition can be hoisted in the hoists for 5-inch anti-aircraft ammunition.

To supply a turret aft from a turret forward, or vice versa, the same procedure is necessary as in the case of broadside ammunition supply; *i.e.*, from the turret handling room on the upper platform deck, ammunition is hoisted to the third deck by a small portable electric hoist or by whip, then along the third deck on an overhead trolley, and finally lowered by hoist or whip to the turret handling room. Redistribution of turret ammunition is an extremely slow process and would be done only during a lull in an engagement.

1440. Powder paths.—When powder has been removed from tanks, special precautions must be taken to prevent the exposure of the powder to flames. Also special precautions must be taken to guard against the spread of flames in all compartments in which explosives are handled or stowed. Ammunition trains are designed with the maximum number of flame-proof compartments compatible with the efficient handling of the ammunition. These various compartments are fitted with flame-proof scuttles or other form of flame-proof seals. Water tanks are also arranged at intervals to permit the immediate immersion of powder bags in the vicinity in case of fire or explosion. The older type of magazine powder scuttle consisted of a swinging brass flap fitted over the opening in a door or bulkhead and swinging outward from the magazine. Such a flap is open and is not an efficient flame seal during the time that ammunition is being passed through it. Figure 1402 shows a late type of rotating flame-proof scuttle for transferring powder bags from one flame-proof compartment to another.

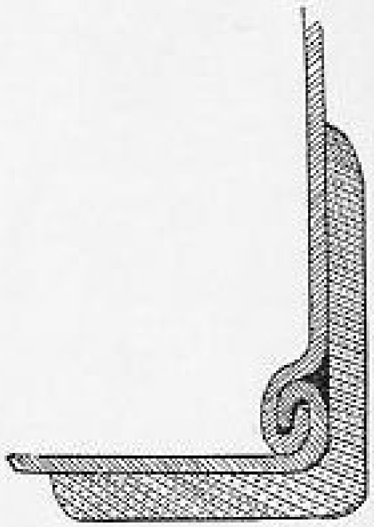


FIG. 1.—Bottom of Tank.

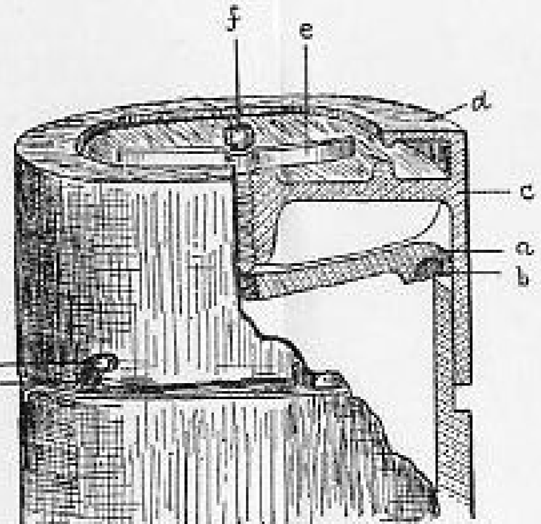


FIG. 2.—6-Inch Tank, Mark VII.

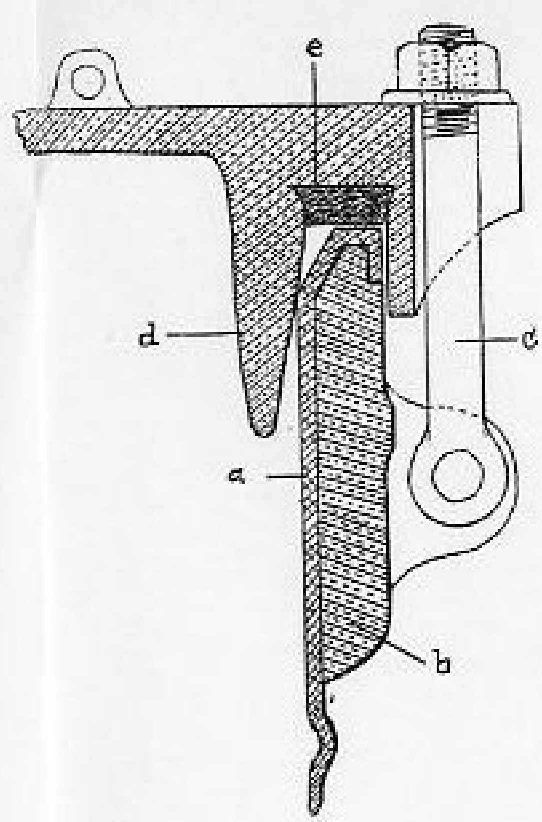


FIG. 3.—12-Inch Tank.

POWDER TANKS.

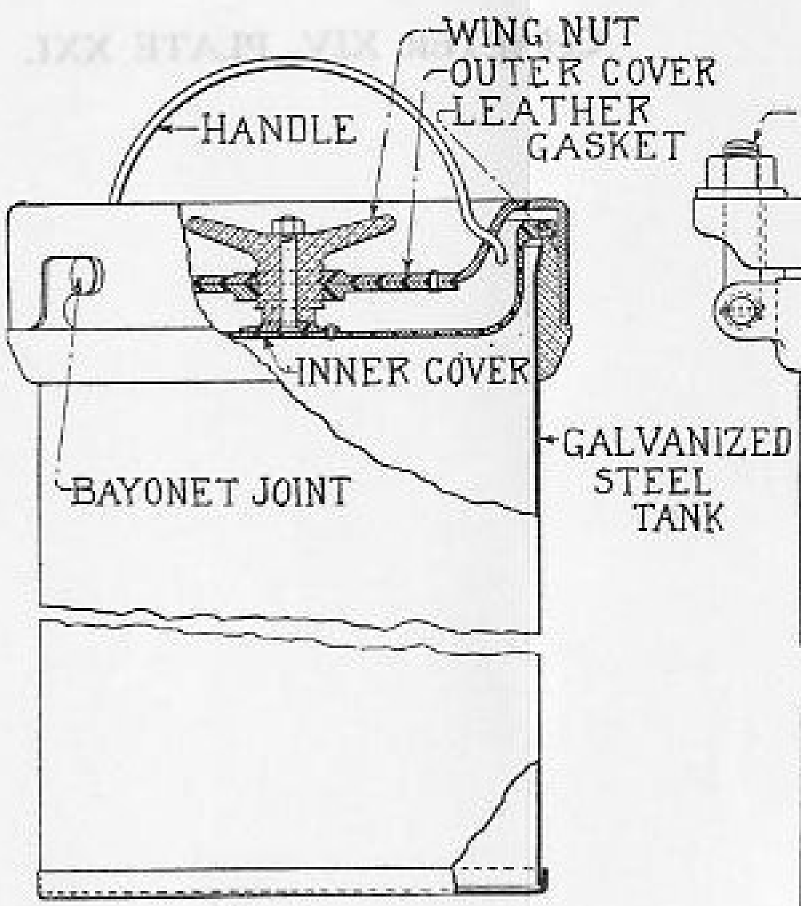


FIG. 4.

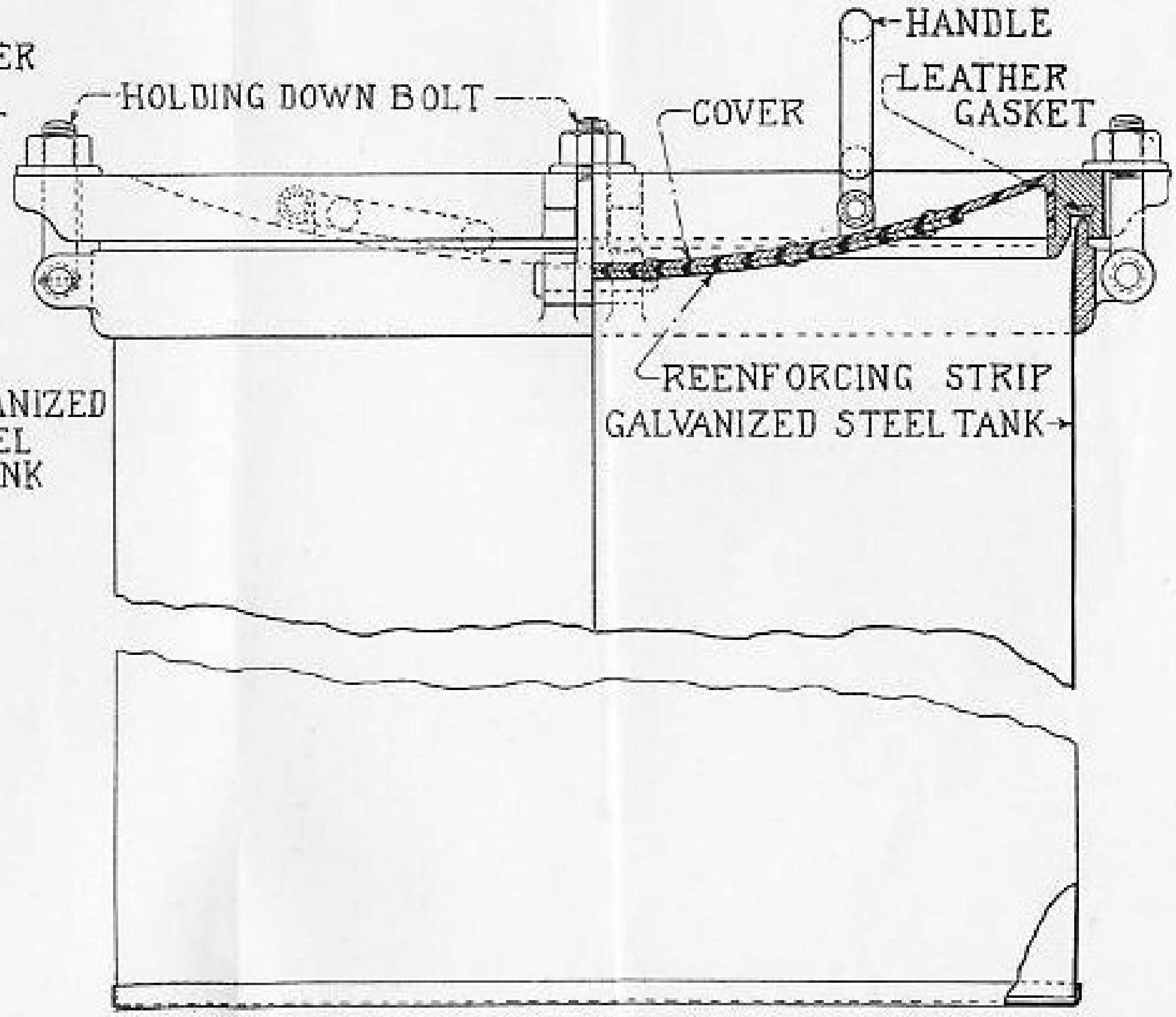
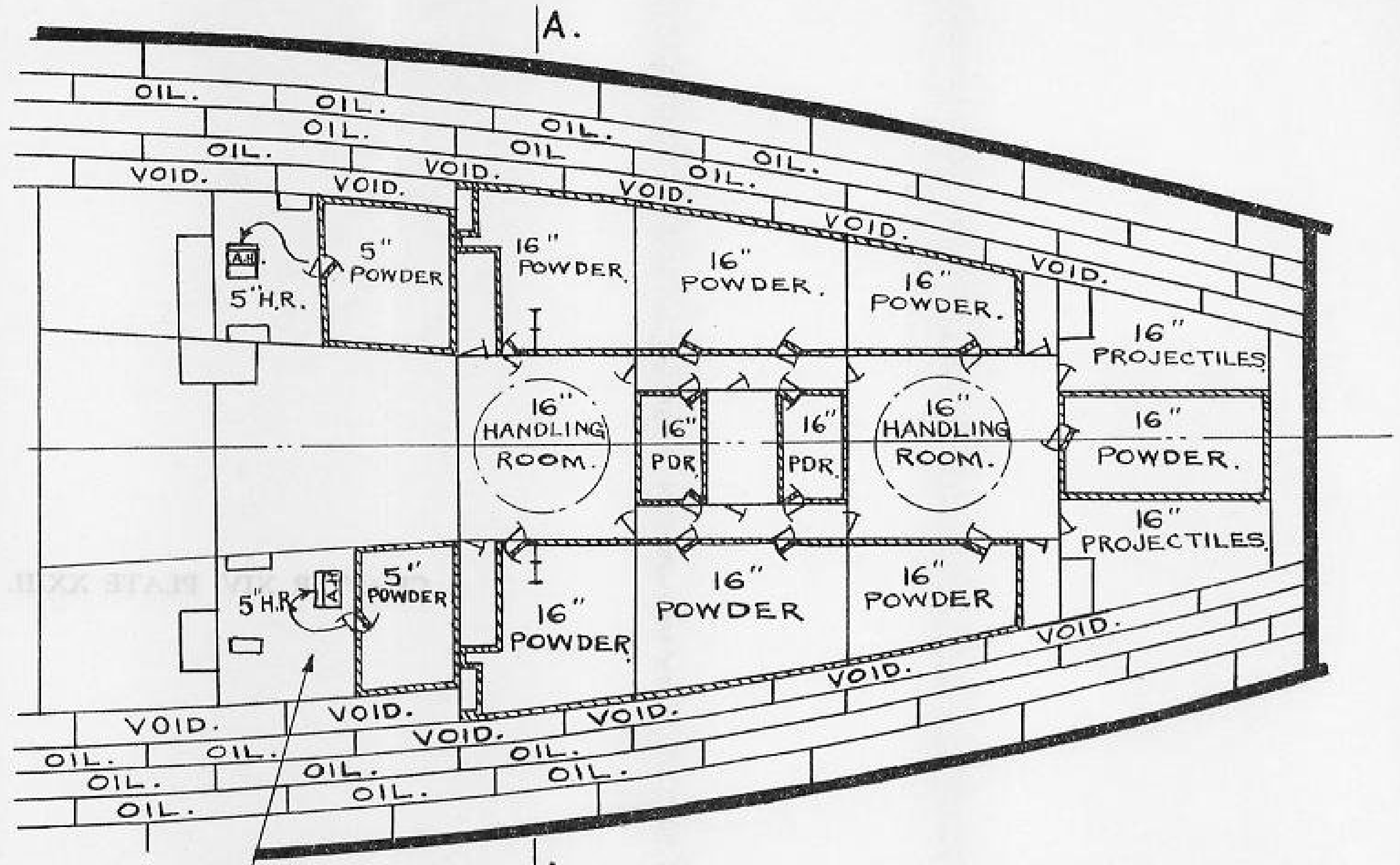


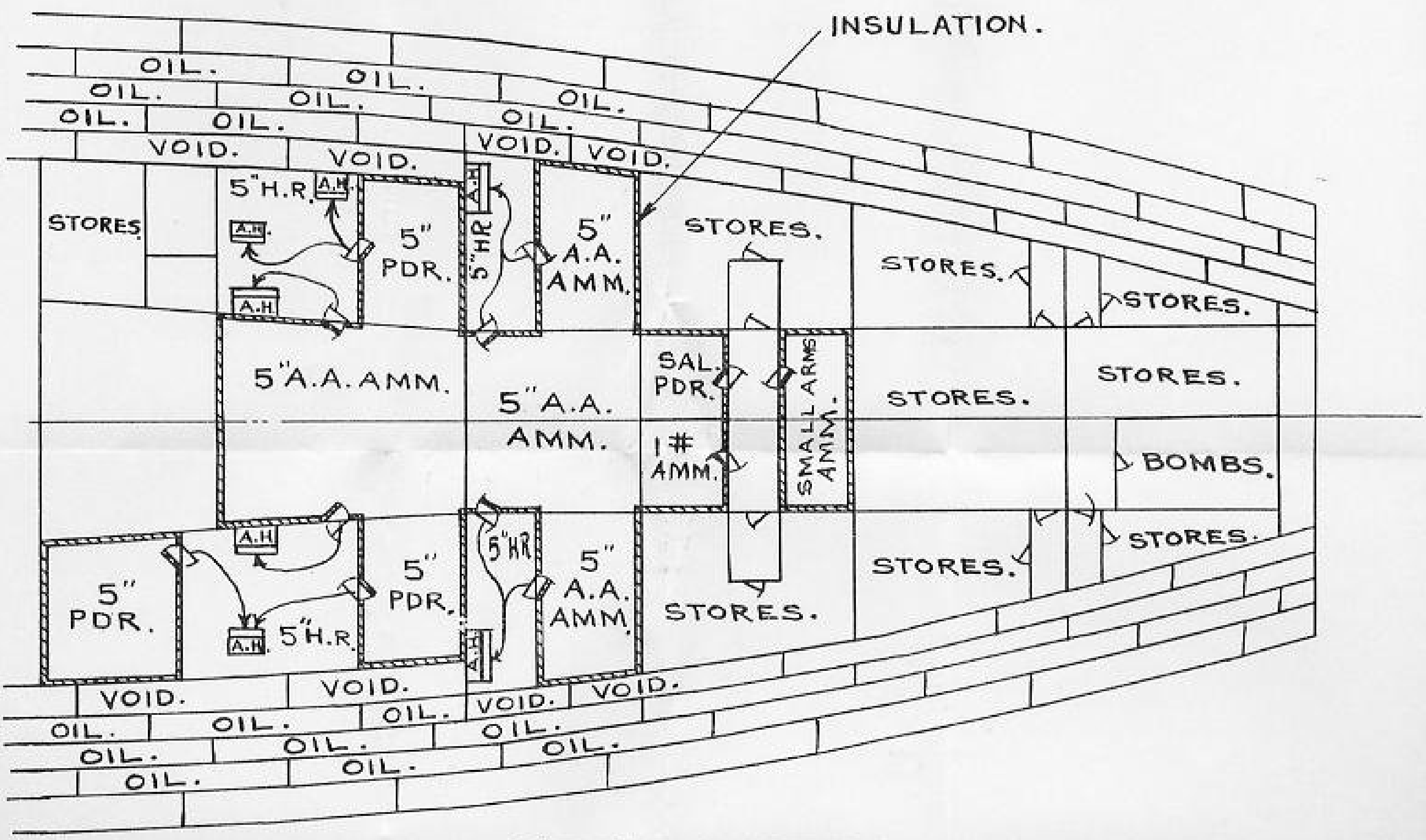
FIG. 5.

DESIGNS OF POWDER TANKS.



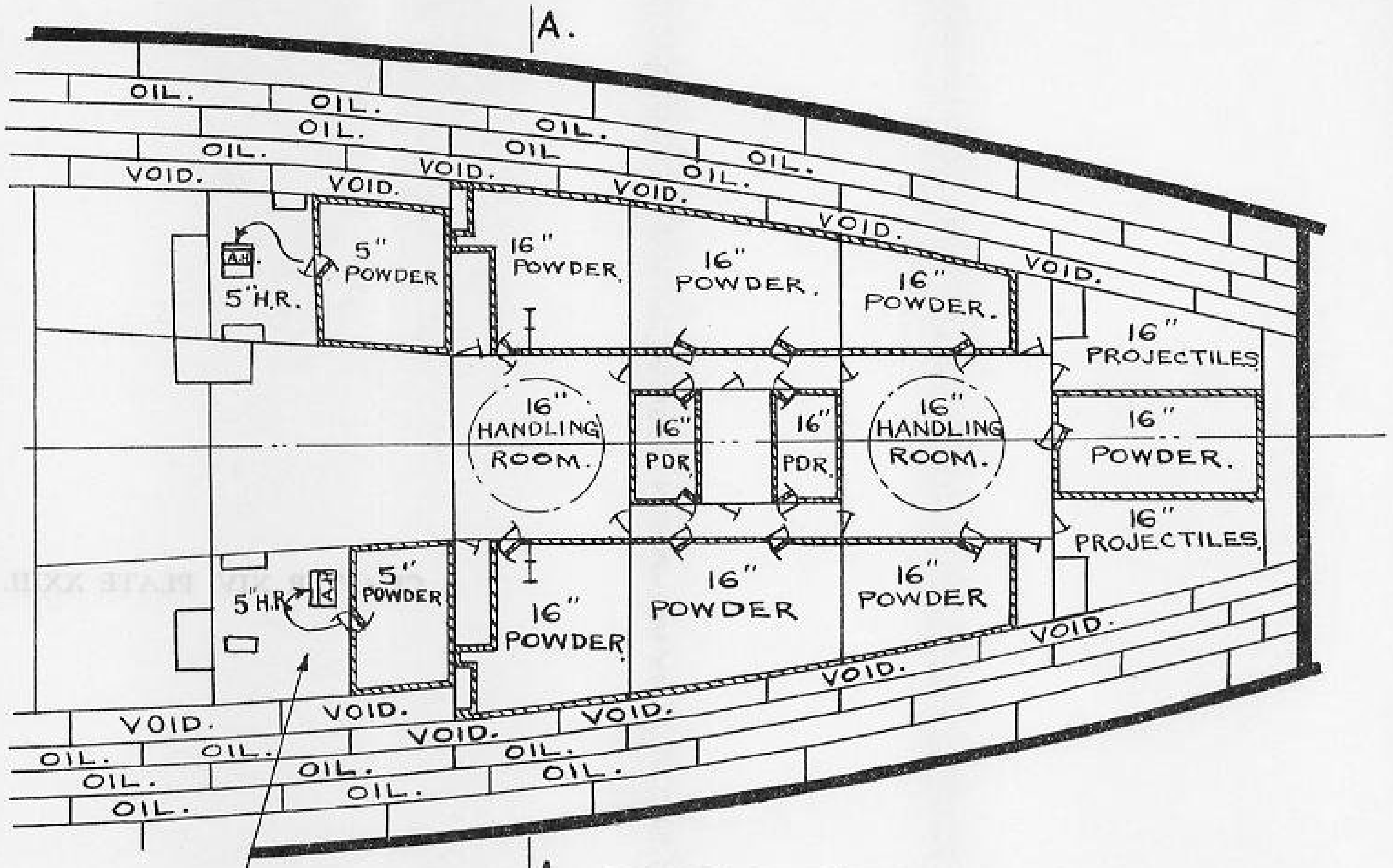
5" HANDLING ROOM AND PROJECTILE STOWAGE.

FIRST PLATFORM.

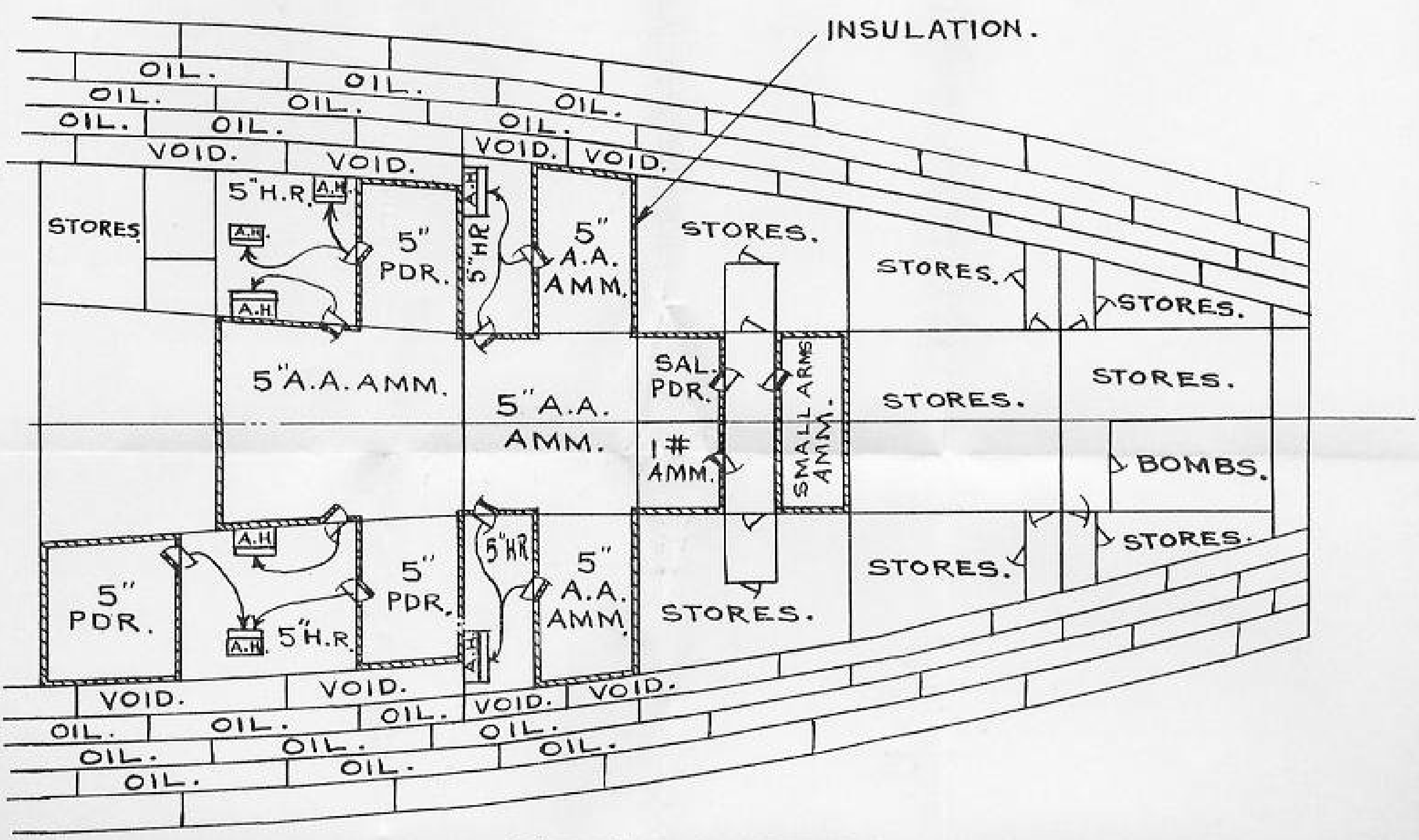


SECOND PLATFORM.

ABBREVIATIONS



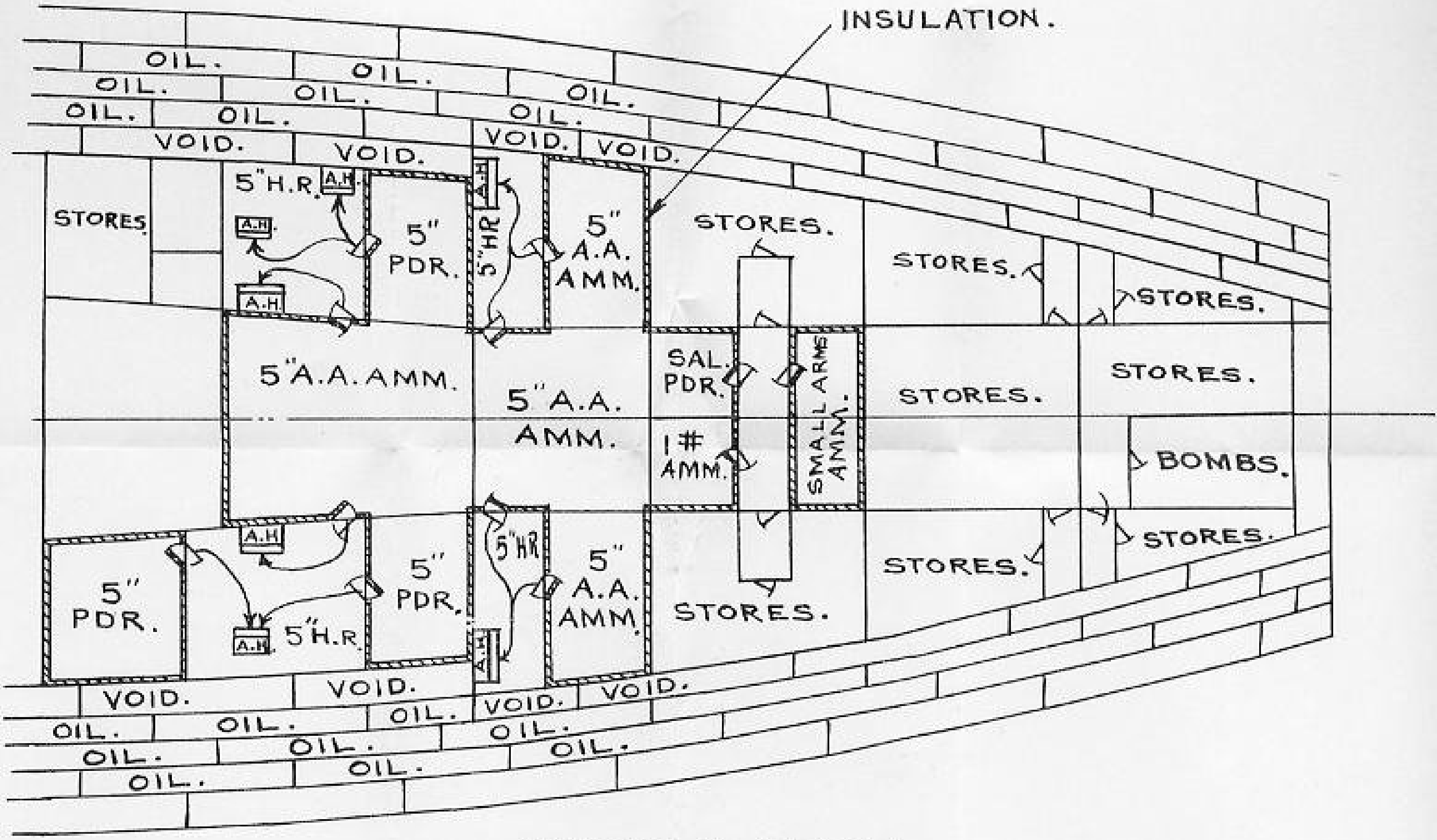
FIRST PLATFORM.



SECOND PLATFORM.

ABBREVIATIONS

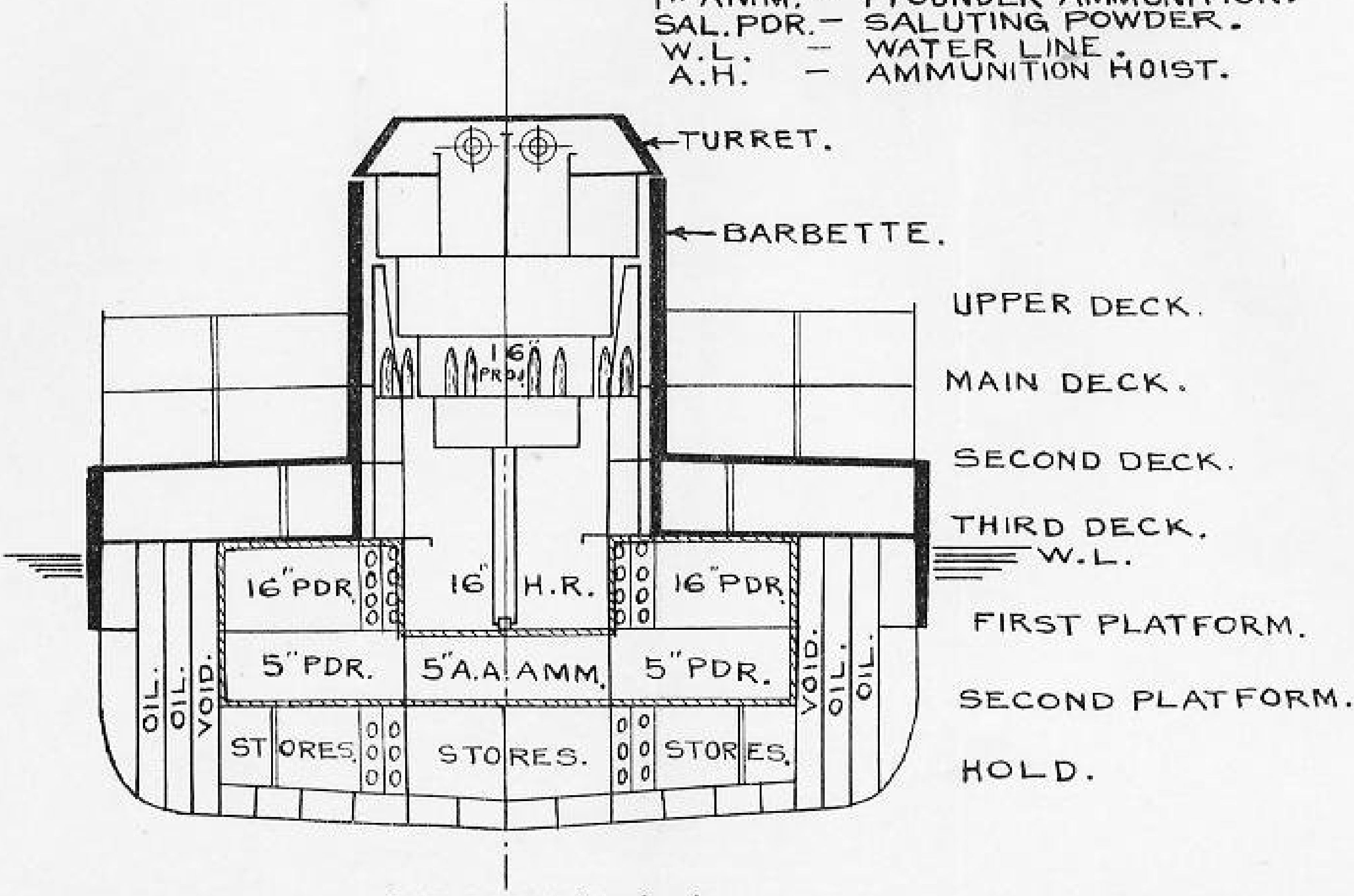
AND PROJECTILE STOWAGE.



SECOND PLATFORM.

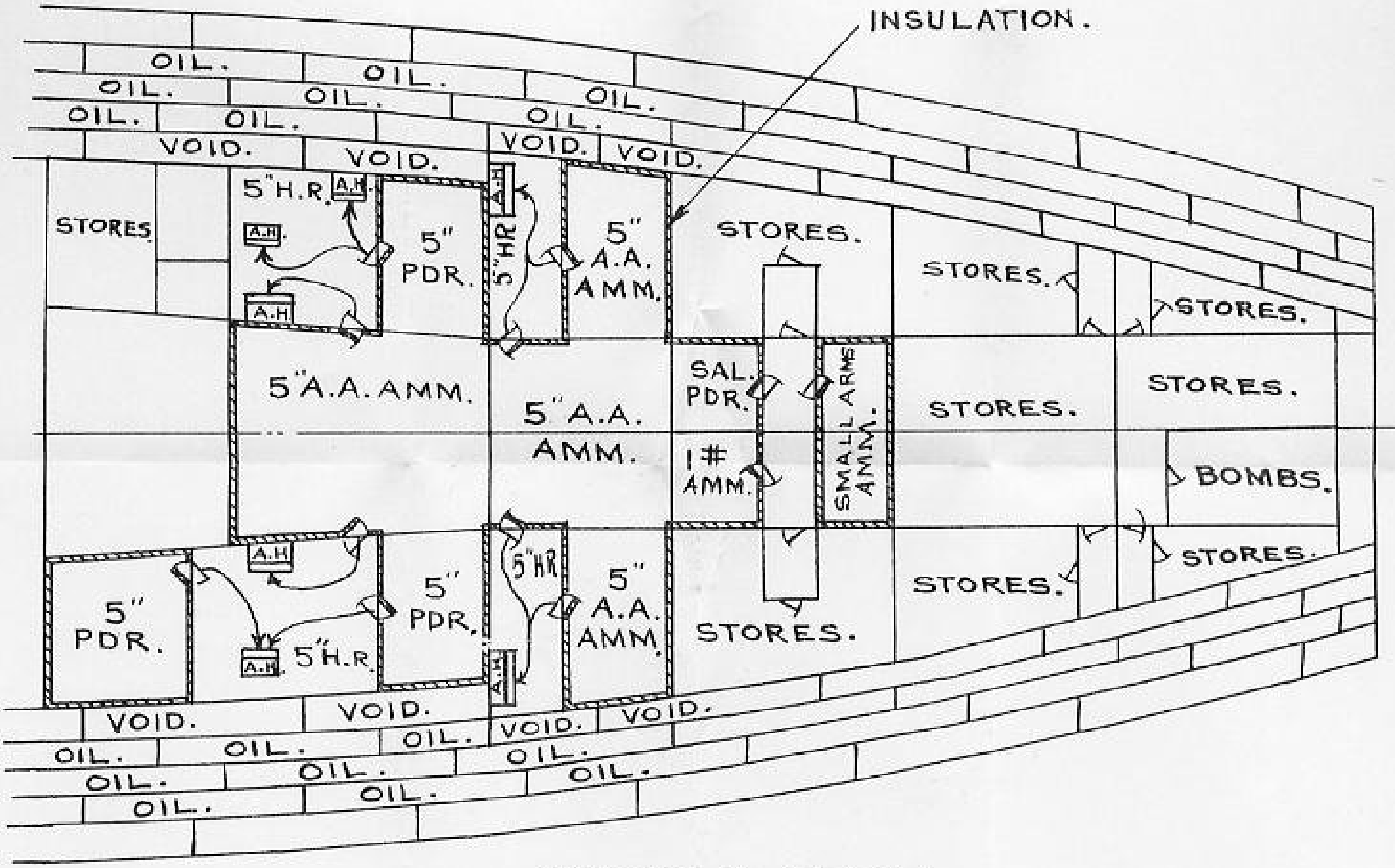
ABBREVIATIONS.

H.R. — HANDLING ROOM.
A.A. AMM.- ANTIAIRCRAFT AMMUNITION.
PDR. — POWDER.
PROJ. — PROJECTILE.
1# AMM. — 1 POUNDER AMMUNITION.
SAL. PDR. — SALUTING POWDER.
W.L. — WATER LINE.
A.H. — AMMUNITION HOIST.



SECTION A-A

AND PROJECTILE STOWAGE.



SECOND PLATFORM.

ABBREVIATIONS.

H.R. — HANDLING ROOM.
A.A. AMM.— ANTIAIRCRAFT AMMUNITION.
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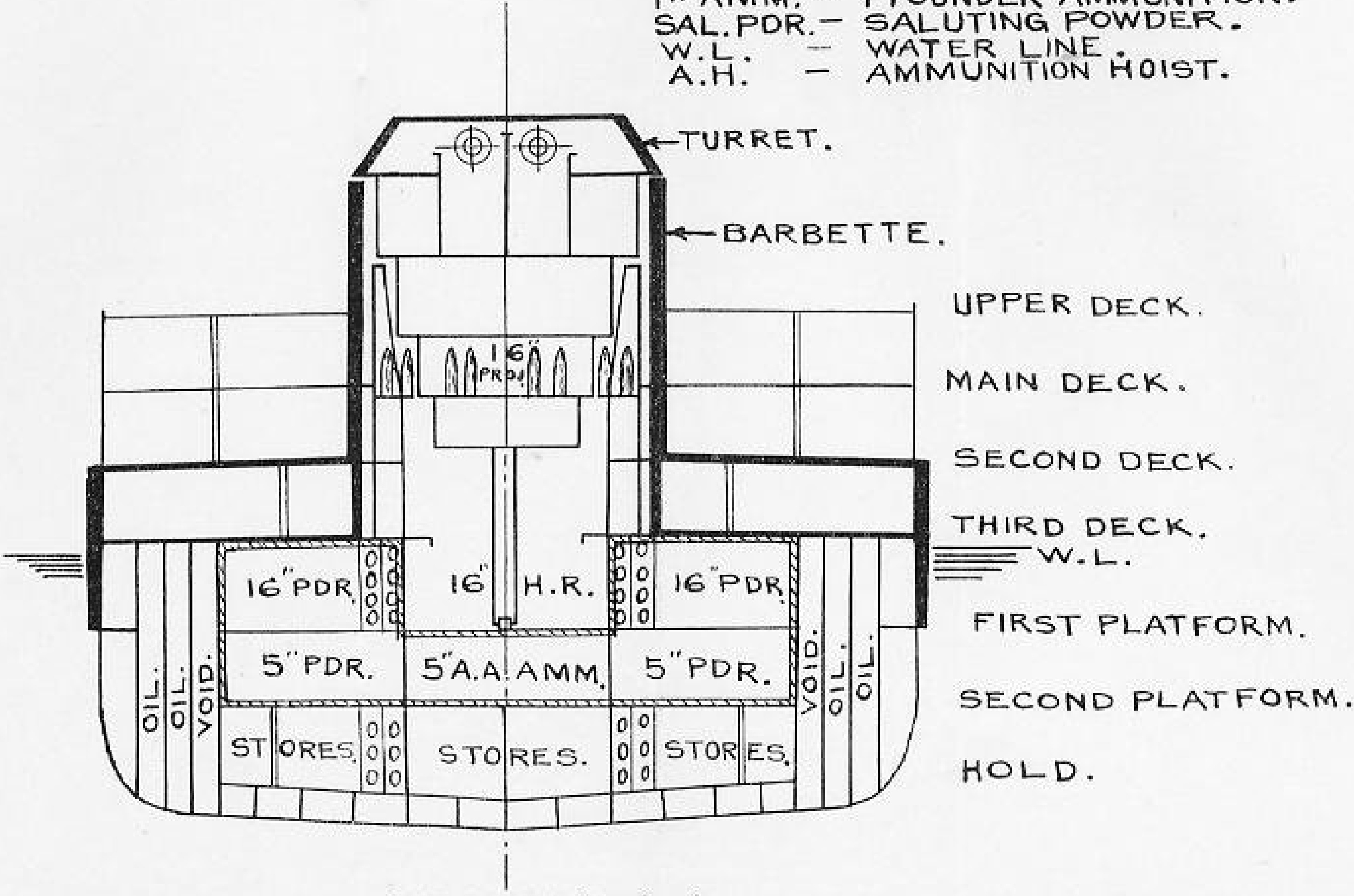

SECTION A-A