The carbonizing material is a mixture of wood and animal charcoal. The time necessary for carbonization varies as with the gas furnace, according to the thickness of the plate. It takes generally from four to ten days to bring a furnace up to heat, after which it is maintained from four to ten days at the heat of carbonization. The charge is then cooled slowly and the plates removed after they have cooled down below a red heat.

70. The Krupp Process.—Many of the details of both the Harvey and Krupp processes are secret. The peculiarities and advantages of Krupp armor are secured as much by its chemical composition—especially as regards chrome, nickel and manganese —as by the method of carbonization employed. Even when cementation is accomplished in the same manner, carbon will be absorbed to a greater depth in Krupp than in Harvey armor, giving a greater depth of chill or hard face, and an increased resistance to penetration of about 25 per cent.

The ingot being cast in a mould, cooled and stripped, is reheated and forged. The plate is then charged in a furnace, which is brought to a temperature of approximately 2000° F., and coal gas is passed along the face of the place which is to be carbonized. The heat breaks up the gas and deposits carbon on the face of the plate, and this carbon is gradually absorbed until the desired degree of carbonization is obtained. From the time of charging until the operation is completed requires a little over three weeks.

71. Gas Carbon Furnace.—Carbonizing furnaces are of two kinds, *dry carbon* and *gas*. The former has been described in par. 69. In the latter the gas flame is supplied to the furnace through a row of ports on each side, only one side being used at a time, that is, one side is used for a short time, when the flame is shut off from that side and the ports on the other side opened, the flame in each case being deflected from the ceiling of the furnace. During carbonization, temperatures are taken with a Siemens pyrometer, the temperature balls being placed on top of the upper plate. The time necessary for carbonization varies with the thickness of the plate; it takes about two days to bring the furnace up to heat, after which five to thirteen days are needed.

72. Depth of Carbonization.—In both Krupp and Harvey processes it is impossible to regulate the depth to which carbon is introduced or to increase that depth beyond a certain point. The reason of this is that the carbon is absorbed decrementally—that is, it begins to shade away from the surface, the carbon in each successive layer being absorbed from that immediately preceding it, so that the limit in the surface layer being fixed to retain the characteristics of steel, the depth to which carbon is introduced is determined by that limit.

73. **Treatment after Carbonization.**—The plate is then taken from the furnace, scaled, then heated and reforged to the thickness required for the finished plate.

74. **The Oil Tempering** consists in plunging the heated plate into a large, deep tank of oil.

75. **In Annealing,** the plate is slowly heated, being gradually moved into the heated furnace; and is also allowed to cool slowly.

76. **Machine Work.**—Whatever machine work can best be done on the plate before bending is now done.

77. **Bending.**—Krupp plates are bent to the required shape under the bending press and again annealed.

Much greater care is needed with a Krupp than with a Harvey plate.

Bethlehem Steel Co's. 7000-ton Hydraulic Bending Press.

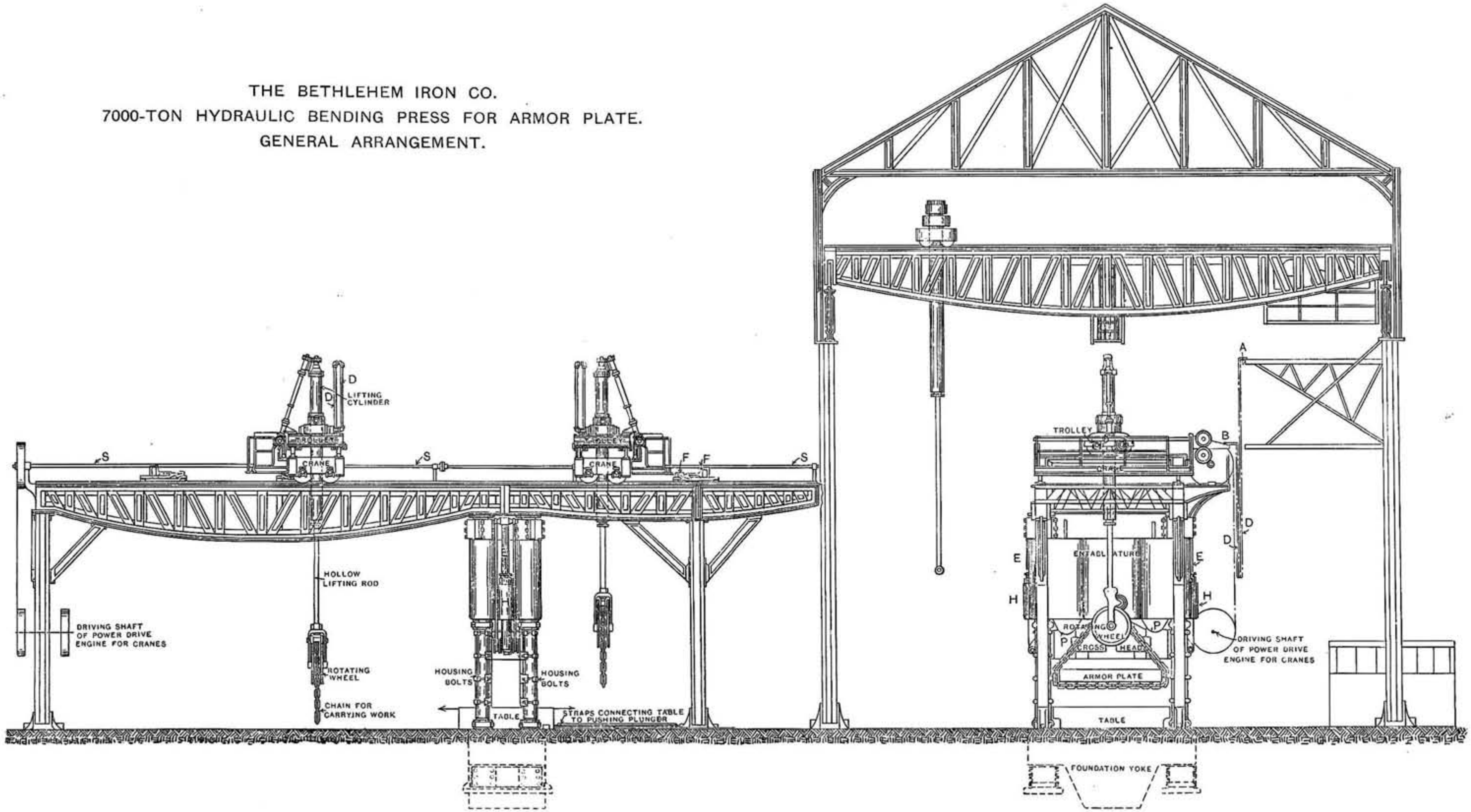
78. **The Bending Press,** shown in Plate VI, is, in general, similar to the forging press, having a *foundation yoke* and *entablature* connected by four housing bolts and having two plungers operating a cross-head and sliding in two vertical cylinders contained in the entablature.

A *sliding table* is, however, arranged on the floor of the press in place of removable dies, as in the forging press.

The two plungers P. P. have rounded ends on the bottom, forming with the rounded cavities on the cross-head a pair of ball and socket joints which allow the cross-head to be inclined to a horizontal when necessary, to produce a twist or warp in the armor plate.

The cranes are operated by a steam engine bolted to one of the columns supporting the crane trusses. This engine is connected to a long shaft (marked "S") by means of a belt fastened over two belt pulleys.

THE BETHLEHEM IRON CO.
7000-TON HYDRAULIC BENDING PRESS FOR ARMOR PLATE.
GENERAL ARRANGEMENT.



Back Plate VI, Chapter I, Par. 78
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The cranes are similar to those at the forging press and the *scissors pipe* hydraulic connections are shown at " D " " D " being connected with the stationary pipe at "A" and with the moving pipe at " B."

The long shaft (" S ") is supported at the extreme ends and at its center by stationary bearings; intermediate between these bearings are arranged special *tumbler bearings* (shown at " F " " F ") so arranged that when the crane is about to occupy the space where one side of the bearing supports the shaft, this side of the bearing is made to fall out of the way, and by falling to elevate the other side of the bearing into position to support the shaft.

79. **Bending Process.**—The armor plate is brought by the crane to the bending press and landed on the table, where it is gradually bent to the required curvature by men who, by long experience, are specially skilled in conducting this operation.

80. **Spraying.**—After bending, plates are sometimes heated and hardened by spraying with water. This operation usually causes the plate to warp, so that it must be rectified under a heavy press. It is then finish-machined and erected. The result is a plate extremely hard on the face to a depth of about ½ inch, this hardness shading away into chilled metal to a depth of about 2 inches from the surface, and this, in turn, shading away into a tough fibrous backing.

81. **Armor Specifications and Tests.**—The Inspector of Ordnance where armor is being manufactured for the Navy shall be permitted to examine freely the raw material, and to witness the processes of manufacture, in order that the finished product may conform to the specifications.

82. **Manufacture and Chemical Analysis.**—All the plates of each class of armor should be of the same quality, and, therefore, the steel used for their manufacture must be prepared from the same materials and by the same process. The plates must be cast, pressed, bent, cemented, tempered, and face-hardened according to the best methods, under similar conditions, and the whole method of manufacture must be practically identical for all the plates of the same class.

The chemical composition of all armor shall be such as will produce plates of the most resisting quality, and shall contain about 3¼ per cent nickel.

All raw material shall be chemically analyzed in the most approved manner by the contractor before use, and proper records thereof and proper melting records shall be kept by him. The product shall be uniform, and shall be manufactured by the open-hearth process.

83. **Processes.**—The ingot to be used in the manufacture of armor plates shall be so proportioned that it will produce the best result, and its weight shall be not less than twice that of the trimmed and finished plate, or, if more than one plate is made from an ingot, its weight shall be at least twice the combined weight of all the trimmed and finished plates made therefrom, except where plates to be manufactured from the ingot are to have a finished thickness greater than 6 inches, in which case the ingot shall be so proportioned that the amount of discard will be such as will produce the proper result, but in no case less than one and two-thirds times the combined weight of all the trimmed and finished plates made therefrom, and a discard of not less than 25 per cent shall be made from the upper end. In estimating for the observance of this rule, the calculated weights of the finished plates shall be used. In manufacture, a discard of not less than 30 per cent of the weight of the ingot shall be made from the upper end.

The ingot shall be forged or rolled as much as the best practice requires, but the ratio between the mean cross section of the ingot and that of the trimmed and finished plates shall not be less than three, except in special cases of very large plates, when less reduction may be allowed, except where plates to be manufactured from the ingot are of a finished thickness greater than 6 inches, in which case the ingot shall be forged or rolled as much as the best practice requires, but the ratio between the mean cross section of the ingot and that of the trimmed and finished plate shall be what good practice dictates but shall not be less than two and one-half, except in special cases of very large plates, when less reduction may be allowed.

During the process of reduction no metal shall be cut off, except such as will clearly have no further beneficial effect on the working of the metal which is to compose the finished plate.

Whatever method may be adopted for producing the ingot the part used must be equal in quality and in all other respects to an ingot cast in the usual way, from which at least 30 per cent by weight has been discarded from the upper end. In the manufacture of hollow armor forgings, if fluid-compressed ingots are used, a discard of not less than 25 per cent of the weight of the ingot shall be made from the upper end.

Ingots must be free from imperfections that would injuriously affect the finished plate.

At least one chemical analysis shall be made, by and at the expense of the contractor, from each plate or forging. This analysis may be made from trimmings taken from physical test specimens to be cut from the plate before hardening.

If more than one plate is made from an ingot, an analysis shall be made from a specimen cut from the upper end of the uppermost plate, with reference to its position in the ingot, and the second analysis shall be made from a specimen cut from the lower end of the lowermost plate. An additional analysis may also be taken from time to time from the central region of such plates.

In face-hardened plates, an additional analysis for carbon shall be made from drillings taken from the treated surface at each end of each plate in such manner as to determine the amount of the carbonization, at depths of 1/16 inch, ½ inch, and 1 inch.

84. Tests for Uniformity.—After the plates have been subjected to all the treatment they are to receive, tests will be made from them for the purpose of exhibiting relative quality. For this purpose the character of the metal in the plates at ends will be compared and two specimens may be taken from points indicated by the inspector where results representative of the comparative quality of the plates will be obtained. In the case of face-hardened plates these tests shall be taken after hardening, unless the thickness or hardness of the plates renders it impracticable.

In all cases where test specimens are cut from face-hardened plates after carbonization or after water-hardening, they shall be located well in from the surface in order that the elongation and strength may not be affected by an accidental carbonization or decarbonization of the surface metal.

The hardened surface of all face-hardened plates shall be carefully examined after tempering, to detect any lack of uniformity in the hardness. For this purpose center punches, files, or hammer and chisel, or similar means, shall be employed, and any marked departure from the desired uniformity shall be remedied by additional treatment.

Cracks in the hardened face of plates that are characteristic of the process by which they are manufactured will not necessarily be considered defects if not of such a character as to affect the ballistic quality of the plates.

The most important point to which attention will, at this time, be directed is uniformity of quality in the plates.

85. Rectifying Curvature.—When it is necessary to correct the curvature or rectify plates by bending after final treatment and testing, they may be heated to a temperature which will enable rectification, but not higher than 100° F. less than that of the last annealing. The hardness of the face must not, however, be impaired.

86. Ballistic tests are described in chapter XXIX, after which the plates which belong to the same class as the one which passes the test are ready for delivery.

CHAPTER II.

NAVAL RIFLED GUNS.

General Discussion.—Definitions.

1. **Rifled Gun.**—A *rifled* gun is so called on account of the spiral grooves which are cut in the surface of the bore, and into which the projections or soft metal bands on the projectile are forced, thus imparting rotation to the projectile about its longitudinal axis when it is driven out of the bore. When the charge and projectile are placed in the gun from the breech end it is termed a *breech-loading gun*, and is generally designated by the calibre in inches, and by the initials B. L. R.; or by R. F. if a *rapid-fire gun*.

2. **Lands.**—The spaces between grooves are called lands.

3. **Rib Rifling.**—When the grooves are very wide and the lands very narrow the gun is said to be *rib rifled*, and the lands are called *ribs*.

4. **Calibre.**—The calibre of a rifled gun is the diameter of a cylinder which touches the *highest* points of all the *lands*. In the case of rib rifling it is the diameter of a cylinder which touches the *lowest* points of all the grooves.

5. **The Term "Mark."**—For the sake of convenience or brevity, each gun of whatsoever calibre that differs considerably from those preceding is given a "mark," numbered serially, thus, 6-inch Mark I, 6-inch Mark VI, etc. There may be one or a large number of guns in each mark.

The differences creating marks may lie either in the construction of the gun, type of breech mechanism, manner of mounting (if a change on the gun is involved), or a difference in some important part or dimension.

This system of marks is carried on throughout ordnance, not only for guns, but for gun mounts, breech mechanisms, sights, powder tanks, firing mechanisms; in fact, all articles made according to standard drawings.

6. The Bore of a Gun is the cylindrical hole cut, or left, in the direction of the length and in the axis, to form a path for the projectile. It serves also to contain the powder charge before firing, as well as to confine the powder gases after firing.

In all modern breech-loading guns, the bore extends from the rear face of the gun tube to the muzzle face. This is called the *length of the bore.*

7. Length in Calibres.—It has become customary to designate guns by their length in calibres; for example, a "30-calibre 6-inch B. L. R." This term defines the *total length* of the gun, and gives an approximate idea as to its power. But a more accurate method of comparing the power of guns of the same calibre is to give the *travel of the projectile in the bore* in calibres, since the velocity, and therefore the power of the gun is a function of the *travel.*

8. Powder Chamber.—The powder chamber is that part of the bore in which the powder charge is placed, and the *capacity* of the powder chamber is the cubical contents of all the space between the base of the projectile and the face of the breech-plug, whatever the shape of that space may be. Powder chambers in high-powered B. L. guns are larger in diameter than the remainder of the bore. The cylindrical part of the chamber is joined to the "compression slope" by an easy slope called the *slope of the powder chamber*. The "compression slope" is the short and comparatively steep slope against which the rotation band seats when the projectile is rammed home.

9. Increase in Diameter of Powder Chamber.—The development of great velocity and power has been accomplished by the use of relatively heavy charges of powder in guns of great length. And in order to keep the maximum pressure within reasonable limits (and thus avoid making guns too heavy and unwieldy) "slow burning" or "progressive powders" are used. If the powder chamber were maintained the same size as the rifled part of the bore, the cartridge would be too long and thus cause wave pressures, which might endanger the safety of the gun. Wave pressures are believed to occur only when very long cartridges are used; therefore the chamber must be greater in diameter than the rest of the bore in order to *reduce the length* of the cartridge for the same weight of charge.

10. Parts of a Gun as viewed from the outside: All guns have these parts, viz., the breech, muzzle, body or cylinder, and chase; and some guns the base, reenforce, trunnions, rimbases, and elevating band.

The *breech* is the rear end of the gun, while the *muzzle* is the front end. In the case of the old muzzle-loading guns "breech" used to be defined as the mass of solid metal to the rear of the bottom of the bore called "base," while the muzzle was that part terminating the chase where there was increased thickness of metal.

The *body* or cylinder, at the breech end of a gun, is that part over the chamber (and in high-power guns over part of the rifled bore) where the metal is the thickest. The outside diameter being about the same for the above distance gives rise to the name *cylinder*.

The *chase* of a gun may be defined as the sloping portion forward of the cylinder extending to the muzzle, whether in one taper or in stepped tapers caused by hoops.

The *reenforce,* found on cast guns, is the curved portion connecting the cylindrical "body" with the "chase," or sloping portion.

In long high-powered guns, the end of the chase forms a curve at the muzzle of increased diameter, which is known as the "bell muzzle." The metal is increased at that point to give greater strength and thus prevent enlargement of the bore due to high muzzle pressures from smokeless powder. It is easily seen that the metal at the end of a tube has not the same support as a section further to the rear.

Trunnions are two cylindrical arms on the sides of a gun at right angles to the axis, at or near the center of gravity, to support the gun on the carriage. In cast guns the trunnions are in one with the gun, while in "built-up" guns they are carried on a separate band. No gun, in our service, over 8 inches in calibre has trunnions.

The *rimbases* are the larger parts of the trunnions next to the gun which take against the sides of the carriage.

All guns are now made *trunnionless*, being supported by sleeves within which the gun recoils, the recoil being checked by hydraulic cylinders attached to the sleeves, the pistons of which are connected by their rods to a yoke on the gun. These sleeves have trunnions that rest in seats on the gun carriage. The first heavy guns built, exceeding 8 inches in calibre, rest in saddles, and are held thereto by suitable straps passing over the gun body. The saddle slides on the mount which carries the gun, and the recoil is checked by the hydraulic cylinders fixed to the mounting, the piston rods being secured to the saddle.

11. **The Object in Rifling a Gun,** primarily, is to give rotation to the projectile about its longer axis. Hence, of necessity, elongated projectiles are used in rifles.

Rotation is necessary to prevent the shell from "tumbling"; to cause the shell to fly steadily point first.

The principle of the rifle may be illustrated by a rapidly spinning top which stands upright. The projectile on leaving the muzzle of the gun has imparted to it a velocity of translation, or onward velocity; and a velocity of rotation about the longer axis.

12. **Manner in which Rotation is Given.**—In breech-loading rifles, rotation is accomplished by a copper rotation or driving band which is pressed into an annular score in the body of the projectile near the base and is kept from turning by roughening the score; the band moulds itself into the grooves of the rifling as the projectile moves along the bore.

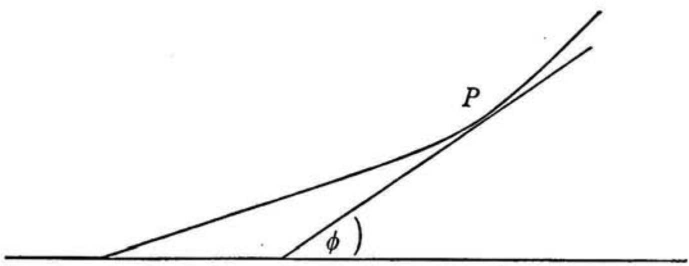
13. **Definition of Twist** as applied to rifling: *Twist* is the term generally used to define the angle of inclination of the groove, at any point, to the axis of the gun's bore; or the pitch of the rifling; or the distance in which the spiral makes one complete turn. Hence rifling may be treated like a screw thread.

The latter term is the usual one used to describe rifling, and it is customary to use as a unit of measurement the calibre of the gun itself. Thus, one turn in 25 calibres for a 6-inch gun means that the rifling would cause the shell to revolve once around its axis while traversing a distance of $25 \times 6 = 150$ inches, in the direction of the axis.

14. **Kinds of Twist.**—There are, (1) "uniform twist," or where the angle of inclination is the same throughout the bore; (2) "increasing twist," or where the angle of inclination con-

stantly increases toward the muzzle. This twist may start from o, or a small inclination, and increase to the full amount at the muzzle. Uniformily *increasing* twist is the one adopted for all modern United States Navy guns, and it usually increases from o at the origin to one turn in 25 calibres at the muzzle. (3) Combined uniform and increasing twist (not used in our service).

15. **Measure of Twist.**—If the rifling of a gun be developed, each land will show as a curve as shown in the sketch. The angle ϕ which the tangent to the curve at any point P makes with the axial line is a measure of the twist of the rifling at that point. The twist is usually expressed as the tangent of the angle ϕ.



Curve of Rifling. Par. 15.

16. **The Forms of Rifling Grooves** (see Plate I).—There are various forms, but only two are found in the United States Navy. They are called (1) "poly-groove plain section" and (2) "poly-groove hooked section." The term "poly-groove" simply means a *large number* of wide shallow grooves of equal width suitable for soft rotation bands.

Plain-section grooves (Fig. 1) are those in which the bottom of each is concentric with the bore, the sides terminating in quadrants of a small circle, both alike. This form is used for all guns below 6 inches in calibre (except the 5-inch Mark V), and is used on the Marks I and II 6-inch and 8-inch guns.

Hooked-section groove (Fig. 2) is a shallow groove consisting of a driving side, the curve of which is a part of small circle (radius about 0.09 inch), then a small portion (about one-quarter) of the groove is concentric with the bore, while the remaining side is sloped off into the bore by radii and a straight taper,

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Plate I,
Chapter II,
Paragraph 16

FIG. I. PLAIN SECTION GROOVES.

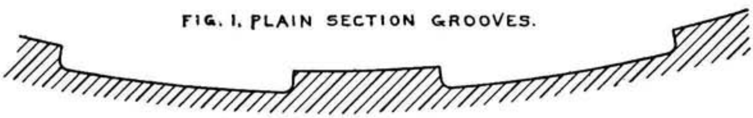
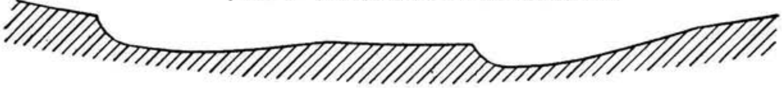


FIG. 2 HOOKED SECTION GROOVES



FORMS OF RIFLING.

forming the *lands* between the grooves. This is the more modern groove and is used for all guns of and above 6 inches in calibre and for the 5-inch Mark V gun. The depth of a groove is usually 0.05 inch (for large guns); the width usually decreases from the breech toward the muzzle, in order that the rotation band may completely fill the groove and thus prevent the escape of the powder gas around the projectile. If the grooves were not narrowed, the cutting away of the metal on the rotation band would leave a gradually increasing space for the gases to flow through and thus produce erosion of the bore.

17. **Driving Side of a Groove** (see Figs. 1 and 2).—Facing the muzzle of the gun, if the twist be right-handed (always right-handed in United States Navy guns), the driving edge is on the right hand.

By "driving edge" is meant that edge which forces the band, and with it the shell, to rotate about the longitudinal axis.

18. **Uniform compared with Increasing Twist.**—Uniform twist is simpler; the *mean* pressure between driving surfaces is less, but the *maximum* pressure is greater than with "increasing twist." The maximum pressure between driving surfaces in uniform twist is greatest at the *start* and the band is more or less apt to strip for this reason.

With "increasing twist" the *least* pressure is at the beginning of the projectile's movement, as the rotation band is not forced to take the whole twist of the rifling at once, while the *greatest* pressure is at the muzzle. The rifling has a better grip on the band at the start. Thus it will be seen that "increasing twist" is more suitable for heavy guns, especially when large powder charges are used, giving high velocities.

It should be noted, (1) that *powder erosion* is less with increasing twist, due probably to the fact that new metal of the band is constantly moulded into the grooves, thus preventing the escape of gas around the projectile; (2) a narrower band must be used with increasing twist than with uniform, on account of the constantly changing angle of the rifling.

19. **Windage** means the space left between the outer surface of a projectile and the surface of the bore of a smoothbore gun. The projectile in this case must be a trifle smaller in diameter than the calibre of the gun, in order to load easily.

In the case of smoothbore guns, as there is no rotation band on the shell, there must be some escape of powder gas on firing. It is not usual to say that a breech-loading rifle has windage, because the rotation band fills the space.

20. Guns Classed Aboard Ship.—The following is the usual, or general, shipboard classification: (1) Main-battery guns; (2) secondary-battery guns; (3) field guns; (4) small arms.

21. Main-battery Guns.—All guns of and above 4 inches in calibre constitute the "main battery."

Some small vessels, such as torpedo boats and destroyers, may not carry a gun as large as a 4-inch; in this case such as are carried constitute the "battery."

22. Classes and Calibres of United States Navy Main-battery Guns.—The main-battery guns are divided into: (1) Heavy-calibre and turret guns. These are the 13-inch, 12-inch, 10-inch, and 8-inch guns. (2) Intermediate-calibre guns. These are the ordinary rapid-fire and quick-fire types, represented by the 6-inch, 5-inch, and 4-inch guns (and the new 7-inch).

23. Secondary-battery or Light-calibre Guns.—All guns, of whatever type, of a calibre less than 4 inches, and guns of small-arm calibre (not fired from the shoulder or held in the hand), such as machine guns, constitute the "secondary battery." Some small vessels carry nothing but "secondary-battery" guns.

24. Types and Calibres of United States Navy Secondary Guns.—(1) Rapid-firing guns. These are the 3-inch 50-calibre (or 14-pounder guns); the 6-pounder, calibre 2.244 inches; the 3-pounder, calibre 1.85 inches; and the 1-pounder, calibre 1.457 inches. (2) Semi-automatic rapid-fire guns: The 6-pounder, calibre 2.244 inches; 3-pounder, calibre 1.85 inches. (3) Automatic rapid-fire guns: The Maxim 1-pounder, calibre 1.457 inches. (4) Machine guns; the Gatlings of 30 and 6 millimeter (or 0.236 inch) calibres; the automatic guns, calibre 30 and 6 millimeters (or 0.236 inch); the revolving cannon, 53-millimeter, 47-millimeter, and 37-millimeter calibres, firing shell weighing 3.9 pounds, 2.4 pounds, and 1 pound, respectively. There are only a few revolving cannon now in the service.

25. Field Guns.—These are light guns, usually of, or less than, 3 inches in calibre, mounted on "field carriages" for operations on shore. When of a single-shot or rapid-fire type, specially designated as "field," they are usually lighter in weight and shorter than the Navy gun of the same calibre.

The secondary guns of a ship's battery, especially the 1-pounder revolving cannon, machine, or automatic guns, are, however, often mounted on "field carriages" and used as "field guns."

There are two types of "field guns," (1) ordinary and (2) rapid-firing. The ordinary type is represented by the old 3-inch breech-loading rifled howitzer, of which a number are still in the service. The rapid-fire type is represented by the Fletcher 3-inch field gun, firing a shrapnel (weight, 12 pounds), and a 6-pounder Driggs-Schroeder field gun.

26. Small Arms are those fired from the shoulder or held in the hand. They are usually of a calibre less than .50 inch. The types are the rifle (musket) and revolver.

The rifles are the Hotchkiss magazine, of .45 calibre; the Lee bolt magazine, .45 calibre; the Lee straight pull, calibre 6 millimeters; and the United States magazine rifle, .30 calibre (Krag-Jorgensen). The two former are used only for subcalibre practice. The revolvers used are the Colt's and the Smith and Wesson double-action Navy, calibre .38, six shots.

27. Boat Guns.—These are the "field" or lighter guns of the secondary battery, mounted on special boat mounts in a ship's larger boats, such as launches and cutters.

28. Top Guns are a part of a ship's secondary battery mounted in the "military tops" on special "top mounts." The smaller-calibre guns, such as the 1-pounder rapid-fire, 1-pounder automatic rapid-fire, Colt automatic, and Gatling guns are those generally used as "top guns."

29. Minor-calibre Guns.—The term "minor-calibre" is sometimes applied to guns of a calibre less than 4 inches, and hence means a "secondary-battery" gun.

30. Great Guns is an old term used for the guns of the main battery, arising probably from their weight or size, to distinguish from howitzers, small arms, etc. The term is still often used as an adjective, thus: "Great-gun practice."

31. Definition of Rapid-fire Guns.—A rapid-fire gun is a single-shot (single barrel) gun of a greater calibre than small arms, using "fixed ammunition," or a cartridge case, and having a quick-acting breech mechanism operated by a single movement of the hand, or automatically opened by the gun's discharge.

The short definition used by some is: A gun that uses a metallic cartridge case, on the supposition that it is known that the breech mechanism is quick-acting.

Strictly speaking, the gun mount should be included in the definition. A mount permitting quick and easy elevation and train, having practically a "run-out position" of the gun is a *sine qua non*.

32. **Definition of Automatic Gun.**—This is one in which, the first shot having been fired by hand, the explosion of each cartridge successively and continuously operates the mechanism to eject the empty case and to load and fire another cartridge, so long as ammunition is properly fed.

33. **Definition of Semi-automatic Rapid-fire Gun.**—This is a single-shot gun in which one operation of the hand is required for each fire, the other operations being performed automatically by the explosion of the cartridge.

34. **Definition of Automatic Rapid-fire Gun.**—It is an automatic gun, the calibre of which is of a size to permit the use of an explosive shell (calibre greater than 1 inch, weight of shell not less than 1 pound).

NOTE.—It will thus be seen that the only distinction between an automatic gun and an automatic rapid-fire gun is that of the calibre. The simple term "automatic gun" is used to denote a gun of *small arm calibre*.

35. **Definition of Machine Gun.**—This is one of small-arm calibre only (in a broad sense a machine gun may be of any calibre, and in that sense is so used later on for the purpose of classification), from which a continuous rapid fire can be maintained by the operation of its mechanism either by hand or by motor power, causing successively the loading, firing, and the extraction of the empty case, the ammunition being suitably supplied.

36. **Definition of Revolving Cannon.**—It is a gun of minor

calibre, firing explosive shells, in which by the simple turning of a crank, a number of barrels intermittently revolve in front of a hollowed-out breechlock containing the mechanism. This mechanism performs for each barrel, during its revolution, the successive operations of loading, firing, and extracting.

The rapidity of fire, therefore, depends upon the speed of the revolution of the crank, the ammunition being properly supplied. The ammunition is usually fed by hand into a hopper or trough.

37. **Definition of Quick-fire Gun.**—This is a single-shot gun, usually of a calibre not less than 4 inches nor greater than 8 inches, having a quick-acting breech mechanism operated by a single movement of the hand, or in some automatic manner; not using a metallic cartridge case, but loaded in the ordinary manner and provided with a suitable "gas check."

NOTE.—It will thus be seen that the essential differences between a rapid-fire gun and a quick-fire gun are in the ammunition, manner of loading, and the provision of a "gas-check."

38. **Names of Standard Main-battery Rapid-fire and Quick-fire Guns:**

Four-inch rapid-fire, Dashiell, Fletcher, and Driggs-Schroeder.

Five-inch rapid-fire, Dashiell and Fletcher.

Five-inch quick-fire, Vickers.

Six-inch rapid-fire, Fletcher and one Dashiell.

Six-inch quick-fire, Vickers (and one experimental Fletcher).

Also six-inch rapid-fire, with Bethlehem breech closure for the U. S. S. Baltimore.

39. **Names of Standard Secondary Guns:**

First, rapid-fire guns—Hotchkiss and Driggs-Schroeder 6-pounders, 3-pounders, and 1-pounders.

Second, semi-automatic rapid-fire guns—Maxim (Nordenfelt) 6-pounder and 3-pounder.

Third, automatic rapid-fire guns—Maxim (Nordenfelt) 37-millimeter or 1-pounder.

Fourth, machine guns—Gatlings, .45 calibre and .30 calibre; Colt automatic guns, calibre .30 and 6 millimeters (0.236 inch); revolving cannon, Hotchkiss 47-

millimeter and 37-millimeter (also a few 53-millimeter).

40. Names, Types, and Calibres of Foreign-built Guns used in the Service:

Armstrong 6-inch rapid-fire (on *New Orleans* and *Albany*).

Vickers 6-inch quick-fire (only one).

Armstrong 4.7-inch rapid fire (on *New Orleans* and *Albany*).

Maxim-Nordenfelt 4.7-inch rapid-fire (only two), Melstrom breech mechanism. Made by Vickers & Co.

Welin 4.7-inch rapid-fire (only one). Made by Vickers & Co.

Hotchkiss 14-pounder and 9-pounder rapid-fire guns.

Maxim-Nordenfelt 3-inch, or 12½-pounder, rapid-fire gun, Melstrom breech mechanism (only one).

Nordenfelt 6-pounder rapid-fire guns, Mark II.

Maxim (Nordenfelt) 6-pounder and 3-pounder semi-automatic rapid-fire guns.

Maxim (Nordenfelt) 3-pounder rapid-fire guns; Maxim 1-pounder automatic, and a number of English and French built Hotchkiss 6-pounder and 3-pounder rapid-fire guns; French 1-pounder Hotchkiss guns; a few French-built Hotchkiss revolving cannon of 53-millimeter and 47-millimeter calibres.

41. A Pneumatic Gun is one in which highly compressed air instead of powder gas is used to propel the projectile. The construction is quite different from that of powder guns, the form being cylindrical, as the air pressure is not great. The only guns in our service of this type are the so-called dynamite guns formerly used on board the *Vesuvius*.

42. Designation of Guns.—Guns are usually named or designated either by (1) calibre in inches; (2) weight of projectile expressed in pounds (if not less than one pound); (3) the name of the breech mechanism or its character; (4) combination of (1) and (3) or (2) and (3). Sometimes these are followed by the length of bore in calibres, and an abbreviation for the "distinguishing terms," breech-loading, or muzzle-loading, rifle; or the special terms, rapid-fire gun (R. F. G.), quick-fire gun (Q. F. G.), or the character of the ammunition.

Thus, for modern guns of or above 3-inch calibre, 6-inch 40-calibre B. L. R. means a 6-inch breech-loading rifle 40 calibres length of bore; 5-inch R. F. G., a 5-inch rapid-fire gun; 6-inch 50-calibre Q. F. G., a 6-inch quick-firing gun 50 calibres long; and 8-inch M. L. R., an 8-inch muzzle-loading rifle.

For old smoothbore guns, the number indicating the inches of calibre is written in the Roman style and no distinguishing term is used, thus, XV-inch gun.

For modern guns below 3 inches in calibre, 6-pounder H., means a 6-pounder Hotchkiss gun; a 6-pounder 50-calibre D. S. R. F. G., a 6-pounder Driggs-Schroeder rapid-fire gun 50 calibres length of bore; Maxim (Nordenfelt) heavy 1-pounder, a gun firing a one-pound shell fitted with a Maxim (Nordenfelt) breech action and using a heavy charge to distinguish from the same calibre gun using a lighter charge; Colt automatic gun, a gun with the automatic breech action of the Colt patent (see definition of automatic guns).

For small arms, the designation in our service has not followed any rule; 45-calibre Lee means a rifle of .45-inch calibre with a Lee breech mechanism; 6-mm. rifle, a rifle of 6-millimeter calibre with a Lee straight-pull breech mechanism; U. S. magazine rifle, a rifle of .30-inch calibre with Krag breech mechanism.

In addition to the above, where there are different marks (see definition of term) of the same calibre, the following form or designation is sometimes used: 5-inch 40-calibre R. F. G., Mark III, or 6-pounder Maxim (Nordenfelt), Mark III. Some guns retain their foreign designation; 37-mm. Hotchkiss R. C., meaning a Hotchkiss revolving cannon, calibre 37 millimeters (1.456 inches).

The usual *service method* is to write the calibre and the mark only, thus, 8-inch Mark III; 6-pounder Mark II, Hotchkiss.

43. High-Powered Guns.—Previous to the year 1879 a muzzle velocity of 1350 to 1450 f. s. was considered good with a rifled gun, and the power of the projectile to penetrate armor, and the other ballistic properties of the gun were limited by those velocities.

The introduction of slow burning *brown powder*, and a considerable increase in the length of naval guns had the effect to increase the muzzle velocity to about 2000 f. s., which was the rule for several years.

The comparatively recent perfection of smokeless powders, marks the next increase in muzzle velocity. The absence of solid residue, after the combustion of smokeless powder, leaves more space for gases in the chamber. With the same, or even a smaller maximum pressure, about double the initial volume of gas is evolved, which, expanding to the muzzle (and being constantly augmented by the evolution of more gas from the slow or progressive burning powder), increases the pressure along the bore and gives to the projectile increased acceleration and a much greater initial or muzzle velocity.

The new types of naval guns are designed for a muzzle velocity of about 3000 f. s.

Still greater velocities have been attained in experimental guns.

44. **Increase in Power since 1879.**—The power, or energy, of the projectile at any range increases as the square of the velocity; it is, therefore, evident that by increasing the muzzle velocity from 1450 f. s. to 3000 f. s. the muzzle energy is more than quadrupled with the same weight of projectile. Hence the term *high-powered guns* is applied to guns having an attainable muzzle velocity of about 2500 f. s. and upward, and the term is applied to guns of all calibres.

The only low-powered guns at present in service are the field guns.

45. **Practical Questions in Gun Construction.**—A *high-powered breech-loading gun* being a necessity, the question arises, how shall the gun be constructed?

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

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

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

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

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

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

From the above it is clear that guns made by casting iron, bronze, or steel into homogeneous cylinders cannot be made strong enough to bear more than a certain pressure from within. Now, the working pressure which we require a high-powered gun to withstand is not less than 18 tons per square inch, and we require, further, that this pressure shall not strain the gun beyond the elastic limit of the metal, in order that the bore of the gun shall not be permanently enlarged. Now, the elastic limit of cast steel is from 15 to 20 tons per square inch, and we have seen that steel has a higher elastic limit than either iron or bronze, so that, allowing a margin of safety, it will not do to make a high-powered gun of cast homogeneous metal even when we use cast steel. We must resort, then, to what is termed the built-up system, and it can be shown mathematically that a built-up gun, properly constructed, of the same dimensions and material as a homogeneous gun, is stronger than the latter. A *built-up* gun is one in which the principal parts are separately constructed and then united in a peculiar manner; and guns so constructed may be composed of different kinds of metal, or of the same kind of metal throughout. We now come to the two principles of construction for strong and heavy guns. They are:

46. First—The Principle of Varying Elasticities.—This consists in placing that metal which stretches most *within its elastic limit* around the surface of the bore, so that by its enlargement the explosive stress is transmitted to the other parts exterior to it. This method is exemplified in guns which have a steel tube surrounded by wrought iron coils, and in the Palliser system, in which a wrought iron or steel tube is surrounded by cast iron. With different grades of steel—high and low steel for example—the steel which shows the greater elongation within the elastic limit is the more suitable to be placed next to the bore. Carrying out this theory in practice is another matter, because in the case of very long tubes there is more difficulty and uncertainty of manufacture with the higher grades of steel than with the lower, and the difficulty increases with the size. *For this reason the principle of varying elasticities is only applicable where the different parts of a gun are made of different metals.*

47. Second—The Principle of Initial Tensions.—This consists in giving to the exterior portions of the gun a certain initial tension, gradually decreasing toward the interior, and giving to the interior parts a certain normal state of compression by the grip of the outer cylinders and coils.

If by the system of initial tensions the interior can be put in a state of compression within the elastic limit of the metal, the amount of compression is so much additional strength to the interior tube, since the compression must be first overcome before the powder gases can exert a tension on the interior tube, as will be shown in the theory of gun construction. In order to exert compression, then, the outer coils or hoops must be in a state of normal tension, and in addition to that they must have a margin of strength within their elastic limits to withstand the additional tension transmitted by the explosion of the charge.

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

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

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

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

If the method of *shrinkage* be employed, the hoops or tubes to be shrunk on must be accurately bored, and the outer coil expanded by heat until it is sufficiently large to fit easily over the inner coil or tube. The inner diameter of the outside coil when cold must be a little smaller than the outside diameter of the inner tube, and this difference of diameters is called the *shrinkage*. While the outer coil is cooling and contracting it compresses the inner one, making the diameter of the latter a little smaller than before. The amount by which the exterior diameter is decreased is called the *compression*.

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

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

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

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

After a drawing of the gun has been completed, the elastic strength to resist powder pressure is computed at all points, together with the shrinkages. The strength curve is then compared with the pressure curve, and if there is not a sufficient margin of safety, a re-adjustment of the dimensions of the parts of the gun is then made, and the elastic strength is re-computed.

50. Built-up Guns in the Service.—These comprise all guns of the main battery and the larger part of the secondary battery. The 6-pounder and 3-pounder Maxim semi-automatic rapid-fire; 1-pounder Maxim automatic rapid-fire; 53-millimeter, 47-millimeter, and 37-millimeter revolving cannon, are *single* forgings.

51. Building up Secondary Guns.—The principle of the system is the same as for main-battery guns. The number of the parts usually does not exceed three, viz., tube, jacket, and locking hoop. The latter is usually screwed on, and bears the front sight.

52. The Wire-Wound Gun.—As stated above, this is an example of the "initial tension" system. The wire is wound in layers around an inner tube of steel. Each layer is wound with a different tension of the wire, and each layer exerts a compression on the layers which are inside of it. The result is that when completed the outer layers are in extension, gradually diminishing to the inner layers, which are in compression; all within the elastic limit. As wire can be made of enormous strength (as much as 200,000 pounds per square inch tensile strength), this type of gun is the strongest for the same weight of any yet developed.

In the different types of wire-wound guns, the inner tube may be either one piece of steel, or a number of longitudinal bars of special shape like the staves of a barrel gripped together by the wire to form a tube. As narrow bars can be made stronger than one large forging, this "stave" or "*segmental*" *wire-wound gun* is *supposed* to represent the highest type of built-up gun and will stand enormous pressure (35 tons per square inch and more have been recorded).

The usual way, however, of building up wire-wound guns is to have a solid forging for the tube, stepped at the rear end, the wire being wound only over the parts covering the chamber and the rear end of the rifled bore. The ordinary hoops are shrunk on over the chase, and an outer hoop or hoops, also shrunk on, cover the wire-wound part.

There are no wire-wound guns in our service. There are some difficulties incident to the manufacture, and other drawbacks as to protection of wire, defective *longitudinal* strength, etc., which make this type, on the whole, less satisfactory than the ordinary hooped gun. A good many wire-wound guns from 5 to 12 inches in calibre are found in the English service.

53. Foreign Wire-Wound Guns.—The 12-inch 40-calibre wire-wound gun of British type is constructed with two tubes, one inside the other, extending the whole length of the gun, thus admitting of rapid and efficient repair when the inner tube is worn out or injured. The radial strains on firing are overcome by the shrinkage of the outer tube over the inner, and by winding wire at varying tensions over the outer tube from the breech to a point near the muzzle. The jacket and a long chase hoop are then shrunk on over the wire to confine it, and are locked together. The longitudinal strain is taken by connecting the outer tube (in which the breechblock houses) to the jacket by a breech ring.

Plate II shows the 6-inch 50-calibre wire-wound gun now being constructed by Vickers Sons and Maxim for the Japanese government. It will be seen by reference to this diagram that the wire only extends for about one-half the length of the shot travel, the radial strains in the chase being taken by a solid steel hoop shrunk over the inner tube. In guns of 50 calibres length, the elimination of the wire over the chase enables the girder strength to be somewhat improved, so that there is no fear of the extra length causing the gun to droop. It will be seen that the breechblock houses in the jacket and that the latter is connected by a large breech ring to an outer jacket which is shrunk on over the wire and securely locked to the chase hoop. By this system of construction great longitudinal strength is secured.

54. Nickel Steel v. Wire Winding.—Messrs. Krupp, who have done so much for the improvement of ordnance generally, use

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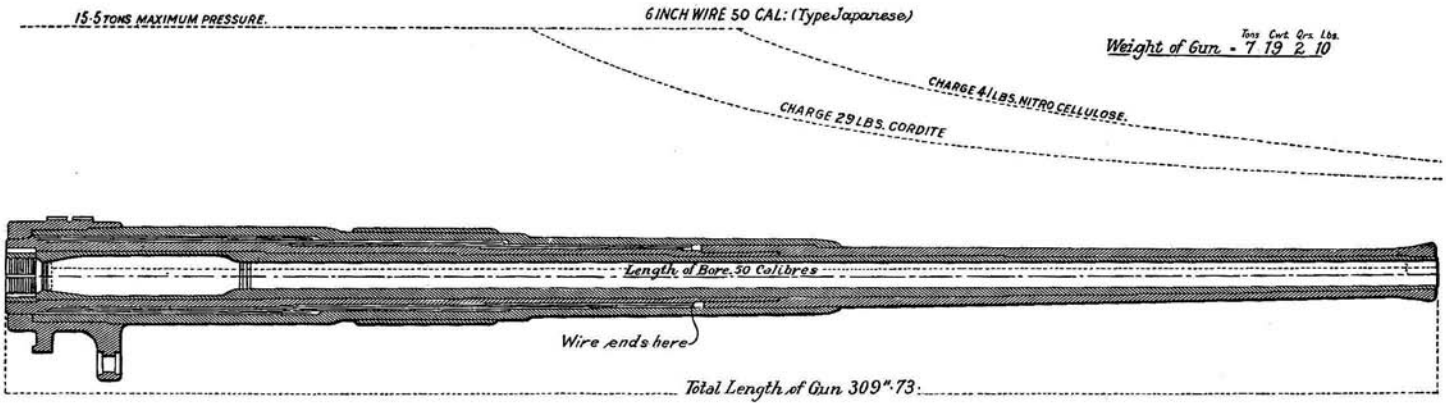
Plate II, Chapter II,
Paragraph 53



FOREIGN WIRE WOUND GUNS. Par. 53.

Ballistics.	Cordite.	Nitro-Cellulose.
Weight of Projectiles...........	100 Lbs.	100 Lbs.
Weight of Charge	29 "	41 "
Muzzle Velocity (Ft. Secs.)	3000 "	3000 "
Muzzle Energy (Ft. Tons).......	6240 "	6240 "

nickel steel for all the tubes except the inner. The use of nickel steel instead of ordinary steel has no doubt some advantages, notably greater strength of material; but this high quality of steel is not so necessary with wire-wound guns, owing to the extra strength given by the wire far exceeding that of any ordinary nickel steel. There is much in favor of using a steel giving a high elastic limit and good elongation for the smaller types of guns, for which the wire system is perhaps less suited. By using suitable steel and treating it by a special process the necessary strength can be obtained without the addition of nickel.

(General Information Series No. 21, July, 1902.)

CHAPTER III.

CONSTRUCTION OF NAVAL GUNS.

Details of Construction at the Gun Factory.*

1. General Features of Main Battery Guns.—The *heavy guns*, as before designated, have the same general features, speaking of the gun body alone, and are represented in section in Plates IV, V and VI.

The guns are composed of a *steel tube*, in one piece, extending the whole length of the bore; a *jacket* shrunk over the tube from its breech end, extending about two-fifths of the length of the tube; *jacket hoops* shrunk over the jacket; *locking hoops;* and *chase hoops*, extending to the muzzle, except in guns of over 35 calibres in length, in which cases the chase hoops end at a length of 35 calibres, approximately; the later marks of guns have longer jacket and chase hoops than the earlier models, reducing the number of parts materially.

2. Recent and Future Changes in Gun Construction.—The general use of smokeless powder in all naval guns, with the consequent increase in the powder pressure along the bore toward the muzzle, requires that the chase of new guns shall be strengthened. In recent designs, therefore, the chase hoops have been carried to the muzzle. In the 6-inch Mark VIII, 7-inch Mark II, and the 12-inch Mark V, there is one long chase hoop extending from the trunnions to the muzzle, and the muzzle has a "swell" to give additional strength at that point.

Future designs may provide for two continuous tubes, so that the inner tube or "liner," in case of injury to the bore from premature explosion of shells or other cause, may be replaced by a new tube, thus prolonging the life of the gun.

*The greater part of the information used in the revision of this chapter was obtained from the pamphlet edited by Lieut. F. K. Hill, U. S. Navy, Bureau of Ordnance.

3. Gun Forgings.—As has been stated, the forgings for tube, jackets, breech-plugs, and hoops are of open hearth steel, forged, oil-tempered, and annealed, and are furnished by the steel makers to the Naval Gun Factory, at Washington, D. C., rough-bored and turned to dimensions fixed by the Bureau of Ordnance, Navy Department.

The physical characteristics of each piece are determined at the steel works in the presence of the Government Inspector.

The trunnion bands, plug trays, and hinges for plug trays are open hearth steel castings; elevating bands are of wrought iron.

The material for face plates of breech-plugs, racks, pinions, and other parts of the breech mechanism is forged steel, specially ordered with regard to its physical properties for the purpose.

4. Receipt of Forgings.—(1) Forgings when received at the gun factory are weighed, carefully examined for the steel works' and inspector of ordnance marks for identification, and no work is to be done unless the latter are found. They are measured to ascertain if they are of proper size and shape to work out the finished drawings. A careful examination is made for gouges, etc., in rough machining, or for any defects not likely to disappear in finish machining; and an examination for any warping, especially of the tube, jacket, and the long chase hoop forward of the jacket, is made by placing the piece in a lathe and observing how much the outside "runs out of true." If there is any doubt about any of the above points the matter is referred to the Bureau of Ordnance. The forgings are entered on a rough forging book which shows the date of receipt, marks, weight, and dimensions, usually by a sketch, and the assignment for guns serially is at once made and placed on each forging. The above are the personal duties of the Assistant Inspector of Ordnance, responsible to the Superintendent of the gun factory.

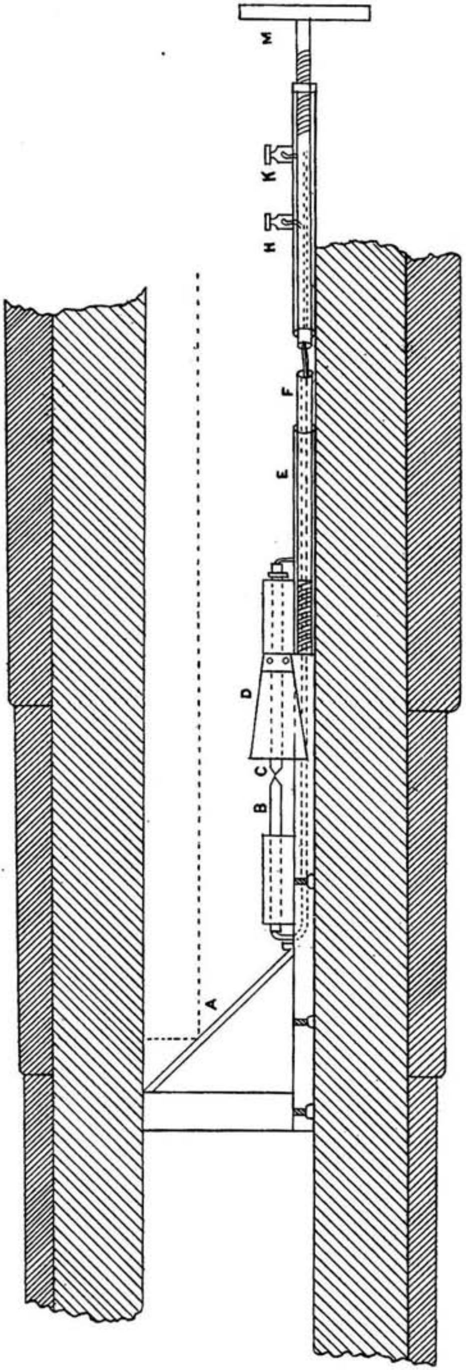
5. The Assignment of Shrinkages is made by the Bureau of Ordnance, and is generally the same for guns made from a lot of forgings ordered when the characteristics of the metal are prescribed and strictly adhered to within certain tolerances. Hence, for each order, if the specifications differ, a new table of shrinkages is assigned. This matter being one theoretically worked out, will not be treated of in this book. The shrinkage of course differs with the characteristics of the metal of the parts.

A thumb rule for shrinkages is as follows for metal as found to-day, or recently used: The jacket and first chase hoop have shrinkages in thousandths of an inch nearly equal to twice the calibre of the gun in inches, thus 4-inch jacket Marks II to VI, 0.008-inch; 4-inch Mark VII jacket, 0.009-inch; 4-inch B hoops Marks II to VI, 0.008-inch; 6-inch Mark IV jacket, 0.012-inch; 6-inch Mark IV D hoop 0.013-inch. Jacket hoops usually have a shrinkage in thousandths of an inch nearly equal to four times the calibre of the gun in inches; thus 6-inch Mark IV, A and B hoops, 0.024-inch; 6-inch Mark IV, C hoop, 0.022-inch. Chamber liners for converted guns have a shrinkage in thousandths of an inch nearly equal to one and one-half times the calibre of the gun in inches; thus 6-inch Marks II or III, chamber liners, 0.009-inch.

6. Rough Boring and Turning of Forgings.—The first step in the construction of guns is to rough bore all jackets, tubes and hoops, and rough turn the shrinkage surface of the tube, and the outer surface of the jackets. During these operations careful examinations are made to discover indications of defects, and discolorations of the metal which are examined under a magnifying glass. No discolorations, sand seams, or splits, specks, snakes, blowholes, etc., are overlooked however slight, and note is made of all. This inspection is the personal duty of the assistant inspector supervising the work. Experience is the guide in these cases, and great care is imperative to ensure nothing but sound metal in the gun. In machining, should marks be removed they are transferred elsewhere. If any piece is scant on one side, or warped, care is taken to place the centers in the lathe to favor the scant side in order that the piece may true up on finishing.

7. Machining the Jacket.—The jacket is placed in the lathe with forward end to the face plate and there clamped, and an adjustable center placed in the rear end, and so thrown as to bore to the best advantage. A rest bearing and a recess for a clamp (used to lift the jacket in assembling) are turned on the outside near the rear end. The steady rest is put in place and accurately adjusted, the rear center is removed and the screw box and step, if any, is accurately bored to within one-tenth of an inch of finished size. The position of the jacket is reversed, and a rest bearing is turned on the forward end. The jacket is now bored to the finished diameter called for on the drawing. The boring requires three bits; 1st, a hog bit which brings the bore to within four-tenths of an inch of finished diameter; 2nd, a rough packed-bit bringing the diameter to within three-tenths inch finished size; and lastly a "finish" packed-bit to full size. An accurate entrance for the hog bit is first opened, using an ordinary turning tool. The bits are freely lubricated with oil, in fact the bore becomes a trough for oil, being stopped up at the rear end. The front end is faced off true to within one-tenth inch of the finished length of the jacket, and the inner edge is rounded to 0.2-inch diameter to give an easy entrance over the tube when shrunk on. (In case there is no shoulder on the tube as with some smaller guns, the jacket is faced off to neat length.) The jacket is then rough turned to within one-tenth inch of finished size, using two cuts, first a roughing cut with a round nose tool, second a smooth cut with a flat nose tool. The jacket is now removed from the lathe landed on skids, and examined carefully for defects such as scores, tool marks, cracks, sand splits, etc., by the assistant inspector using the "electric bore searcher." Plate I. This consists of two hollow rods, *E* and *F*, carrying a head which supports a mirror, *A*, inclined at 45° with the axis of the bore, and a pair of carbon points, *B, C,* the wires from which lead through the rod *F* to the binding posts *H, K*. A hood, *D,* is fitted in rear of the carbon point, *C,* to obscure the light from the observer. The points are adjusted by wheel, *M,* on the inner rod, which moves the carrier of the carbon, *C*. A photographic camera can also be used on the rod to obtain views of defects developed in the bore during manufacture. The rods are graduated to inches and tenths, so that the location of any injury or defect can be determined.

The bore is carefully stargauged for each inch of length, commencing at the front end, to the nearest one-thousandth of an inch, the points of the gauge being reversed when bottom of bore is reached, then stargauge withdrawn, and readings taken. A record is preserved in the rough manufacture book. All fillets are tested with fillet gauges. The neat length is measured and divided into four lengths which are marked with fine cuts or a punch, and the outside diameters taken. These points serve the



ELECTRIC BORE SEARCHER.

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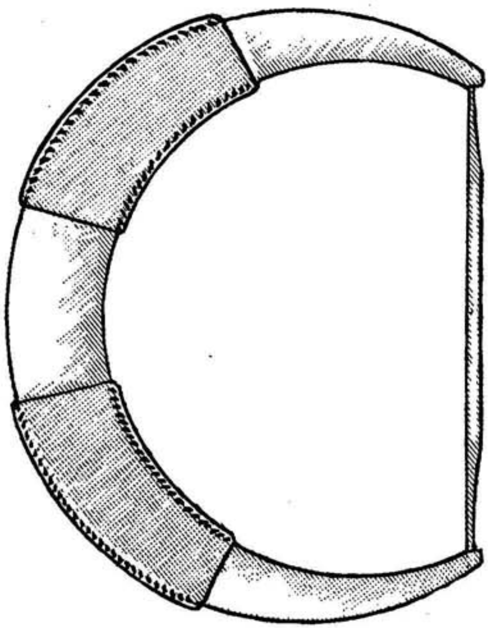
purpose of determining whether, after heating and assembling, the piece has recovered longitudinally, whether contraction has been uniform, or to determine the extension of the jacket, if any.

8. A Shrinkage Sheet for the jacket is now prepared by the assistant inspector for the use of the workman in turning the tube. A blue print with no dimensions, showing the tube and assembled parts, called the "shrinkage sheet," is provided for this



Snap Gauge. Par. 8.

purpose. Each gun has one such sheet on which is written, with soda or acid, the numbers of the different forgings making up the gun, the date when the shrinkage dimensions are written for each part, with the initials of the assistant inspector and superintendent of gun factory. To the diameters of the jacket's bore, as shown by the stargauge, is added the assigned shrinkage for the jacket, and these are marked off in lengths corresponding to those in the jacket. A steel point for each separate diameter is made and accurately tested in the measuring machine. By these the work-men set their crescent-shaped *snap gauges,* for trying the diameters of the tube when turning for shrinkage. These points are all verified by the assistant inspector, and the length in inches and thousandths is stamped thereon. The same thing is done in the case of hoops. In this connection it might be said that all fillet gauges made by the gauge maker are of steel plate, and the radii are stamped on for that gun or part of gun. These gauges should also be verified.

9. Boring and Turning the Tube.—The tube is placed in the lathe, breech end to the face place, adjustable center in muzzle end, having due regard for any minor defects or warping. Steady rest bearings are turned so that it may be bored true and at the same time leave enough metal above the finished drawing size to true up. The steady rests are then put in place and center removed. The tube is now bored, beginning at the muzzle end, using two and sometimes three bits, one hog bit and two packed bits. The first cut brings the diameter to within one-half inch of full size for any gun of and above the 8-inch, and three-tenths inch for smaller calibres; the second and last cuts, one-quarter and two-tents inch respectively. The hog bit, about four calibres in length, must have a long and accurate bearing first bored with the ordinary tool. The muzzle is faced off true. While the boring is going on, etc., rough turning is also done, bringing the diameter to one-tenth inch of shrinkage size. The first bit (hog or packed, either can be used), having passed through half the length of the tube, the latter is reversed in the lathe and the other end is bored. This reduces the chance of the bit running out. (In calibres below 8-inch, for relatively short guns, the bit is run all the way through, but should the bit start to run "out" the position in the lathe is reversed.) It is usual to draw out the roughing bit twice for each half length of the tube for guns above 8-inch. The packed bit, or bits, are then passed *all the way* through the bore from one end. It is found that in boring it is best to revolve the tube as rapidly as the metal of the bit will allow, and use a moderate feed (5 or 6 inches an hour). After each cut the bore is examined with a light for defects. The other end of the tube is faced to neat length. After boring, the tube is electric lighted and inspected in the same manner as for the jacket, and stargauged from the muzzle end. The tube is then transferred to the "shrinkage turning lathe," muzzle end to the face plate, on centers, and also steady rests; top braces being used in the case of long tubes for small guns where springing may occur. (This lathe is only for smaller guns, being one which is in good order and allows no spring.) The shrinkage surface for the jacket is now turned, the last cut being taken with a broad, flat nose tool (1 inch to 2 inches wide), to insure a smooth, accurate surface. This turning requires a very good mechanic, as the tolerances are only one-thousandth of an inch. The shrinkage sheet above mentioned is used. When the shrinkage surface is completed, the lengths for different diameters are laid off, and the assistant inspector of ordnance carefully calipers the diameters, checks the lengths. inspects fillets and shoulders, and looks out for defects. The tube and jacket are now ready for assembling.

10. Balance Rod for Testing the Bore of Guns, or Long Tubes.—This machine is used to ascertain whether or not a bit is running true, or so that the inside will be true with the outside and hence the thickness of the walls the same on all sides. It is inserted in the bore at intervals of about one-third of the tube's length. If the rod, when in place and properly adjusted, shows no movement at its rear end while the tube is revolving, it can be assumed that the bore is concentric with the bearing surfaces on which the tube is turning; but if there is any movement to the rear end of the rod, the amount of such movement will indicate the eccentricity of the bore, at the point where the front end of the rod is in contact with the bore; in this case the centers are thrown, and the bore trued up with a bit of slightly larger diameter.

11. Preparations to Assemble the Jacket.—The tube being ready, clamps are placed on it at the center of gravity and it is lifted by the overhead crane and placed in the "shrinking pit," muzzle end down (some of the later guns, as 5-inch, Mark V, have the jacket shrunk on from the muzzle end, hence the tube would be placed breech down in the pit), accurately plumbed so as to stand vertical, and held within the holes in the two heavy movable tables by four large screws, the muzzle resting on the lower plat-

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form. A water pipe is run up through the tube to within a few inches of the top, to carry off the waste water used in cooling the tube. The water is admitted into the bore of the tube from the lower platform.

12. **Expanding the Jacket** is accomplished by heating it in a hot-air furnace. The clamps are placed in the recess on the rear end of the jacket, the latter is lifted by the overhead crane and lowered into the furnace, forward end down (except for jackets assembled in the reverse manner, as the 5-inch, Mark V), where it rests on a platform or pedestal, and the furnace top is placed on. The expansion should be gradual and uniform, and never exceeds five one-thousandths (5/1000) of an inch for each inch of diameter of the heated piece (this rule applies to all parts). For the 13-inch jacket, then, the expansion will amount to 0.06-inch; others in proportion. From time to time, near the end of the heating, the expansion of the bore is tried by means of cross points placed on a long steel rod entered through a door in the furnace top. The cross points are set for a diameter very slightly in excess of the required diameter. The jacket must not be heated beyond a black heat, or about 600 degrees, nor should it be subjected to any heavy blows while so heated (this rule applies to all parts). Time, then, is the factor to get the desired expansion without overheating. The 12-inch, Mark III, jacket (13-inch about the same) remains in the furnace about 30 hours, about 14 of which are required for raising the temperature up to 575 degrees Fah., which is maintained for sixteen hours. For smaller guns, the furnace being hot, less time is necessary.

13. **The Hot-Air Furnace for Jackets** (6-inch and above) is a vertical cylinder built in sections, to suit the particular lengths of jackets, and made of fire brick and asbestos. Heated air flows through a large pipe from the air heating furnace to the bottom of the hot air (jacket) furnace, passes through openings, up and around the jacket, and out through a large pipe in the top section, the overflow being regulated by a damper. The temperature of the furnace is shown by a pyrometer let in the furnace cover.

The air-heating furnace is a rectangular brick structure containing a system of pipes through which air is forced by a blower and thence to the hot air furnace. The air is heated by means of a number of *aerating burners* at the base of the furnace; crude petroleum is used, being delivered as a spray by means of compressed air. The jacket being in place, the burners are lighted, and when the pyrometer registers 575 degrees Fah., all but three burners are cut off, so that an even temperature can be maintained.

14. Shrinking on the Jacket.—The jacket having been expanded, the hot air is shut off, furnace cover removed, and the jacket is lifted out of the furnace by means of the overhead travelling crane. The bore is again tried with cross points and then wiped clean, using a wet muslin sponge on the end of a rod, after which the jacket is swung vertically over the tube and accurately centered over the latter. The jacket is then slowly and carefully lowered over the tube, being guided by men having asbestos gloves and wet cloths on their hands, until it brings up at the proper point on the tube. During the lowering, the jacket is turned first one way and then the other about its axis, to prevent galling or abrasion should there be an imperfect centering. If any difficulty arises in lowering, and the jacket does not go on smoothly and easily, it should be immediately lifted off, the operation suspended and the jacket allowed to cool, an examination being made for galls, abrasions, or other causes likely to interfere with the process. It is well to test the bore of the jacket with the cross points, to see whether the fault is due to cooling and consequent contraction; and should this be the case, and no galling is observed on the tube, the jacket is put in the furnace again and heated until the proper expansion is again obtained. The cross points should be verified. Water is turned on and allowed to circulate through the bore of the tube, to hasten cooling. The weight of the jacket renders it unnecessary to use a spray of water over the point where the junction is made on the shoulder of the tube. It is usual to try the heat of the jacket's exterior at the top, middle and bottom, before assembling, by rubbing on it strips of alloys which melt at different temperatures, the temperature for lead being considered 600 degrees.

15. To Starguage the Tube for Jacket Compression.—After the jacket is quite cold (and it is usual to wait not less than 16 hours for guns over 8-inch in calibre, and from 2 to 8 hours for others), the assembled tube and jacket are lifted from the shrinking pit and landed on skids. The bore of the tube is then carefully stargauged at each inch of length from the rear end to a point under the front end of the jacket, and the measurements recorded in the manufacture book. The diameters being compared with those taken before assembling, the amount of compression due to the grip of the jacket is ascertained, and should the results be abnormal the matter is referred to the Bureau. The lengths of the jacket between the marked points, and also the outside diameters, are then recorded, to note the condition as to recovery from longitudinal expansion and to ascertain the extension of the jacket. In the case of small guns, it is usual to strike the jacket (when cold) several heavy blows with a sledge-hammer, to relieve any tensions (the existence of which is shown by audible reports).

16. Boring the Hoops.—The hoops are bored as nearly as possible to the drawing dimensions, while the jacket is being bored, or at any convenient time. As a rule the *short* hoops of guns of and under 6-inch in calibre use a special, cylindrical chuck made of cast iron nearly the length of the tube, which is bolted to the face plate of the lathe, the hoops being centered thereon by means of radial set screws. In this case the hoop is bored, rear end faced off and fillet turned, using two packed bits, except for very short hoops, which use an ordinary bar tool in the lathe tool head. Longer hoops, such as the D hoop of the 6-inch, Mark IV, gun, are bored just like the jackets. For guns of 8-inch calibre and above, the hoops are fixed by clamp screws within cylindrical rests which form a part of the lathe, and instead of using packed bits, or ordinary bar tool, in the lathe tool head, there is a boring bar provided having one or more cutters fitted with what might be called a "star feed," that is, during each revolution the tool is set along a predetermined amount. In this case the hoop remains fixed; the cutting tool revolves. The metal of the bore of hoops (except the long chase hoop forward of the jacket in the case of more modern guns) is inspected before removing from the machine, as it would be difficult to rechuck should any defect be found requiring another small cut. The *front* ends of chase hoops and the rear ends of jacket hoops are not faced to neat length until after assembling. All fillets and shoulders are tried with what are called "profile gauges," made of sheet steel (this also applies to shoulders on any exterior parts of the gun). Hoops are stargauged from the rear end (chase hoops) for each one inch of length; electric lighted, etc., as for jackets.

17. **Assembling Hoops.**—The assembled tube and jacket is now placed in the lathe, upon centers in the ends of the tube, muzzle end to the face plate, a rest bearing turned at the rear end of the jacket, a steady rest then placed, and the rear center removed. The screw box is trued up for a center, jacket faced off to within 0.1 to 0.15-inch finished length, and then center placed in the rear end of the tube. It is usual in the larger guns to face the screw box for a length 0.2-inch greater than the drawing. The gun is reversed in the lathe and a rest bearing turned in the forward end of the jacket. The chase (of the tube) is now turned to shrinkage diameters for the chase (or tube) hoops, in accordance with the *bored* diameters of the hoops plus the shrinkage, using the "shrinkage sheet" already mentioned, and exacting inspections as for the shrinkage for the jacket.

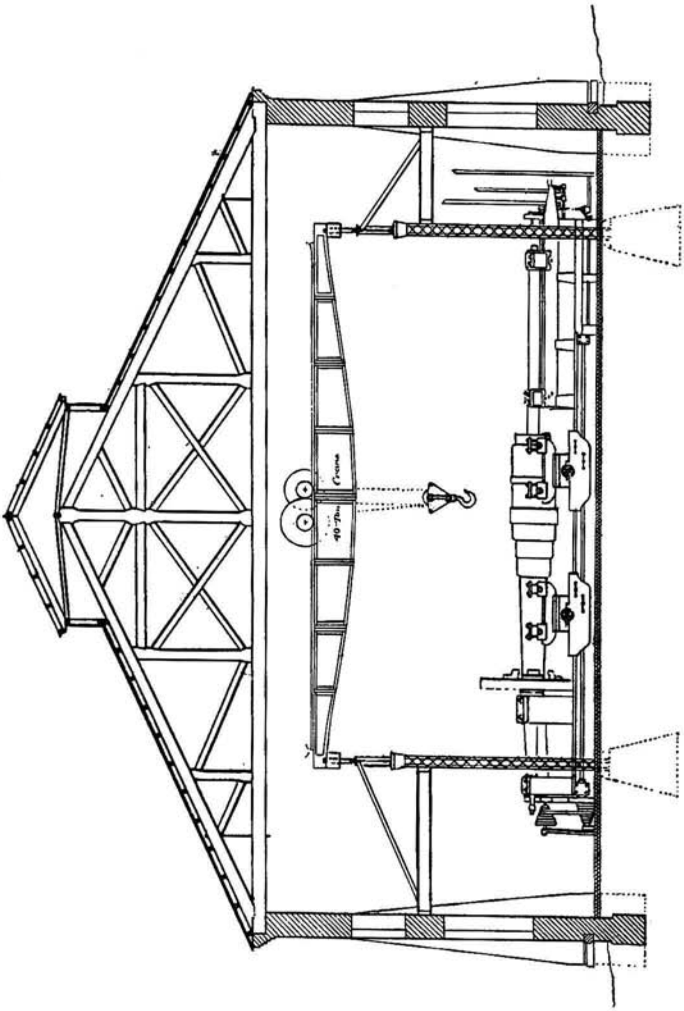
The first chase hoop for all guns of and below 8-inch in calibre is assembled with the gun in the pit (breech end down, secured as for assembling the jacket) in the same manner as for the jacket, except that a spray of cold water is turned on at the joint to hasten cooling at that point, so as to obtain a close joint. The spray is given by means of a perforated copper ring (generally two rings) surrounding the gun and connected to the water system. In the case of long hoops, such as the D hoop of the 6-inch Mark IV gun, or E hoop of the 6-inch Mark VI gun, where the contraction of course is considerable, the contraction is followed up by means of a heavy iron yoke placed over the hoop and constantly forced down against the upper end of the hoop by means of long tie rods and nuts. The pressure is kept up for about twelve minutes, when the lower end of the hoop has taken a firm hold of the tube. All other chase hoops are shrunk on with the gun horizontal, lying on skids. The heated hoop, after being wiped out and tested with cross points, is brought to the gun by an overhead crane hooked into a clamp ring, or in the case of very small hoops, brought by men in a bearer and slipped over the muzzle, held in position by means of wood braces passing from the face of the hoop to a cross head carried by a rod through the gun, and set up by nuts at the breech of the gun. The gun must be properly supported by a screw jack at the muzzle during the cooling. Cold water spray is used at the joint.

Chase hoops for all guns above 8 inches in calibre and those forward of the first chase hoop of the latter, are put on with the gun horizontal. A second hoop is never shrunk on until the gun is quite cold.

All chase hoops for 10-inch, 12-inch and 13-inch guns are put on while the gun is in the lathe. The hoop has a clamp band placed at its center of gravity for lifting, and when hot is lifted by the crane, inspected with the cross points, wiped out with a wet muslin sponge, then carried by the crane to the gun on the lathe, and slipped over the muzzle to its seating, the gun being supported by steady rests. To follow up the contraction, and hold the hoop in place, a wood brace is placed on each side between the hoop and back head of the lathe and kept screwed up, while the usual spray of cold water is turned on at the joint. Chase hoops other than tube hoops, if any, as for heavy guns, are next assembled. The center in the muzzle end of the tube is replaced and the shrinkage surface and hoop are turned on the front end of the jacket and rear end of the first chase (tube) hoop. The tube locking (or chase locking) hoop is then assembled as before. The shrinkage surface and hoop are next turned over the shoulder on the jacket and rear end of the previous hoop, and the jacket locking hoop is assembled. In the case of the 13-inch guns the screw thread for the chase "guard hoop" forward of the last tube hoop is cut, and the thread having been cut in said hoop, the latter is screwed on. While the shrinkage surfaces for the chase hoops are being turned, the body of the jacket is worked down close to shrinkage dimensions for the jacket hoops, provided the lathe has a second tool carriage, which is the case for the lathes used for heavy guns.

The tube is now stargauged for compression from the muzzle end, under the chase hoops, record noted as in the case of stargauging after assembling the jacket.

18. The Jacket Hoops are next assembled. The gun is reversed in the lathe (with its muzzle to face plate), a rest bearing



TRANSVERSE SECTION OF 8-INCH GUN SHOP,
Showing Gun in Lathe.

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is turned on the jacket locking hoop, and a steady rest put in place in the case of heavy guns. The shrinkage diameters for the jacket hoops are next turned on the jacket. During this operation the chase hoops are worked closer to the finished dimensions. For 6-inch R. F. guns having no jacket locking hoop, the shrinkage diameters for the chase locking hoop and all jacket hoops are turned at once, so that all hoops other than the first chase hoop are successively assembled, first the chase locking hoop with the gun horizontal on skids, afterwards the jacket hoops with the gun in the pit muzzle down. This may also hold true for the 8-inch guns. In the case of the 6-inch, Mark VI gun, the final hoop put on is the locking hoop, which is screwed over the rear end of the chase locking hoop and the front end of the B (or forward jacket) hoop, after complete shrinkage. The jacket hoops for all guns above the 8-inch are then assembled in a similar manner to the chase hoops, beginning with the forward one, the gun being horizontal in the lathe.

The 12-inch, Mark III gun, having an outer jacket called D hoop, forming a fourth layer over the chamber, is next turned for said hoop, and the latter shrunk on.

The final hoop assembled for 13-inch and 12-inch guns is the outer locking hoop, which screws over the juncture of the front jacket hoop and the chase locking hoop. This may be deferred to the next operation, when the gun is finished.

The rear end of the tube is now stargauged for the total compression of the bore under the jacket hoops, and record made as before. The gun is now completely assembled, and the next operation is to "finish the gun," which includes finish-boring, chambering, finish-turning the outside, rifling, chasing and slotting screw box, lapping the bore, and fitting the breech mechanism.

19. **Finish-boring.**—The gun is now placed in the boring lathe with breech end to face plate on centers, and two rest bearings are turned, rests put in position, and muzzle center removed. The gun is now finish-bored, using two packed bits, the last cut being about 0.03-inch on the diameter. Great care must now be exercised to insure boring the tube straight, and the "balance rod" previously described is used to test the accuracy at 10, 15, 20 and 25 feet from the muzzle in the case of 12-inch (and 13-inch) guns.

20. Finishing the Outside.—In the case of heavy guns, the outside is finish-turned while being finished-bored. Smaller guns (6-inch and below) are not finished on the outside until after finish-boring, for the reason that should the bit fail to follow exactly the hole already in the tube, and "run out of line," the outside would not be symmetrical with the inside; and another reason is, that the fast speed found best for boring is not the best for fine turning. In fact, the outside may be finished any time after finish-boring. Should the gun have trunnions, the gun is placed in lathe, breech end to face plate, and screw thread cut for trunnion band, which is then screwed on. For guns screwing into a sleeve, the left hand thread is chased. Care is necessary so that when the sleeve is screwed on it will bring up firmly against the shoulder provided for it. Special gauges are made to show the starting point of the thread, and when finished is tested by screwing on a bronze sleeve gauge, in length and diameter the same as the service sleeve. When home, the register line should agree with the top line on the gun. In turning to finish dimensions the mechanic is furnished with a drawing of the finished gun, with "points" for setting snap gauges, graduated rods for lengths, and profile and fillet gauges. The gun should be inspected in the lathe before removing.

For 12-inch and 13-inch guns the outside is finished while finish-boring; the thread for the outer locking hoop is chased, and after finish-boring is completed the locking hoop is screwed on, having removed the muzzle center. The muzzle is faced to its proper length and all lengths determined. The gun is now reversed in the lathe (muzzle to face plate), suspended between centers in each end of the tube, and the surface for a rear steady rest trued up if necessary. The steady rest is then adjusted and rear center removed. The breech is faced to exact length, and rear end of gun sloped off to the rear in guns requiring it. The screw box may now be bored to finished size and length. A steel rod of the exact length of the screw box, and a steel point of proper diameter, are furnished the mechanic to work by.

21. Chambering.—The gun is now chambered. For 6-inch to 13-inch guns having the ordinary chambers, the latter is bored, using, first, a hog bit; second, a (rough) packed bit; third, a