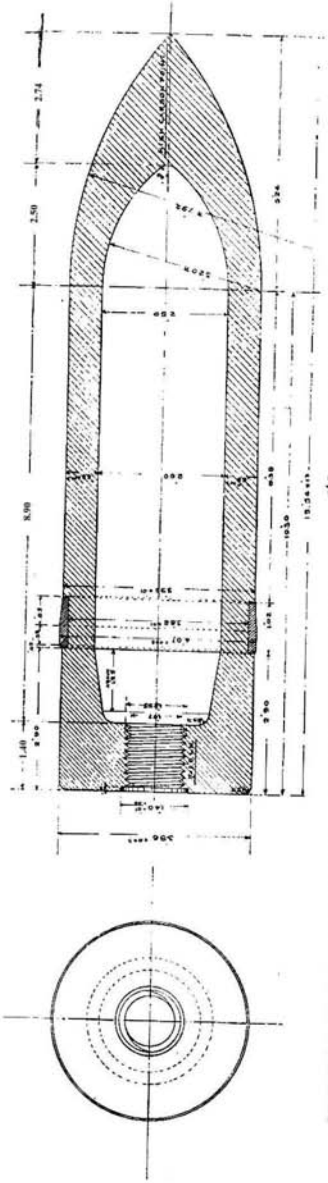


FIG. 1.
COMMON SHELL. Par. 71.

STANDARD TO DATE SEPT. 16, 1897.

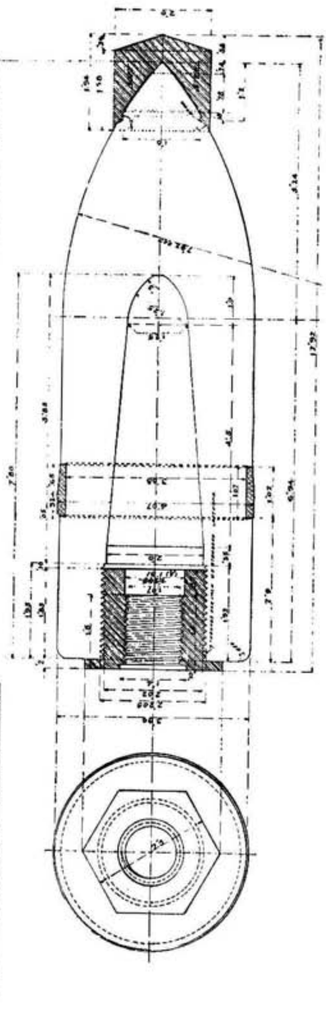
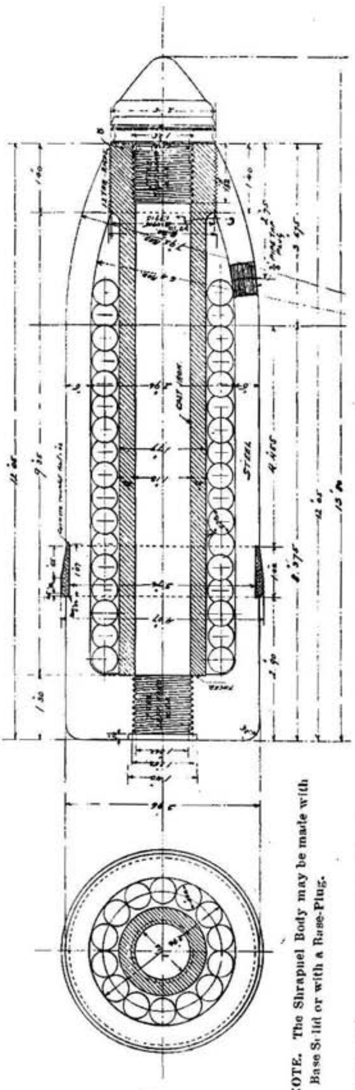


FIG. 2.
A. P. SHELL. Par. 70.



NOTE. The Shrapnel Body may be made with Base Solid or with a Base-Plug.

FIG. 3.
SHRAPNEL. Par. 75.

4-INCH PROJECTILES.

[Ed. some dimensions on the left side of Fig. I, Common Shell have been rewritten for increased readability in this edition. They were too close to the edge of the page to be fully visible after the scan.]

up in the gun or in flight. The remaining shell shall be loaded with ordinary shell powder and exploded, and must give a satisfactory fragmentation without either the base plug or fuse blowing out.

43. **Specifications for Minor Calibre Steel Shell.**—The body of the shell shall be made of steel of the best quality for the purpose, and shall be properly hardened or treated.

44. The rotating bands shall be made of the best quality of seamless copper tubing, annealed and forced into the band scores by hammer or press.

45. The base plug shall be made of steel, and must be a tight fit in the shell. When assembled they must be set home so as to require great force to start them out again.

46. The shell after tempering shall show no signs of flaws or cracking.

47. The band scores must be suitably roughened so as to prevent the bands from slipping.

48. Shell shall be submitted for final inspection in lots of 1000, and each shall have the name of maker and the year of its manufacture stamped on the base. With each lot ten additional shell shall be furnished by the contractor for use in the acceptance tests.

49. One per cent of each lot shall be selected by the inspector for proof firing. Of these, a certain number, to be designated by the inspector, shall be loaded and fused, with their proper bursting charges. When fired, with the service powder charge, through a $\frac{3}{16}$-inch steel plate, all shell must burst properly and break up well. The remaining shell shall be blind loaded to service weight, and shall be fired at a steel plate placed normally to the line of fire and 30 yards from the muzzle of the gun. The material of this plate as used shall have a tensile strength of at least 70,000 pounds per square inch, and its thickness shall be 1 inch for 1-pounder shell, 2 inches for 3-pounder shell, and 2½ inches for 6-pounder shell. All shell must perforate the plate, and none must break or crack so as to open the powder chamber, or develop serious defects of any kind.

50. After acceptance by the inspector the shell shall be lacquered on the interior and oiled on the exterior. A mineral oil or grease

must be used, preferably cosmoline. When finally accepted each shell shall be stamped with the inspector's stamp on the band.

51. **Specifications for Shrapnel.**—The body of the shrapnel must be of cast steel and the powder tube of cast iron, and must be finished to the dimensions shown on drawings approved by the Bureau of Ordnance, and within the limit of tolerances stated thereon.

52. The fuse holes must be tapped, unless otherwise arranged, and the shrapnel banded.

53. The steel used must be of the same quality and grade as that used for cast-steel shell.

54. The castings for the powder tubes must be of good quality, free from defects, and as smooth on the interior as the best iron castings, and rejection for such defects shall be final.

55. The bullets must be uniform in size within tolerances determined by the inspector, and none are to exceed in diameter the dimensions shown on the prints.

56. The shrapnel and all parts, including hidden threads, are to be subject to inspection by the Government inspectors during all the processes of manufacture and to inspection and tests before acceptance; and the contractors shall furnish the inspectors with all facilities for such inspection and tests.

57. The shrapnel of each calibre are to be presented for acceptance in lots of 500.

58. One per cent of each lot presented, to be selected by the inspector, to be tested as follows for acceptance of the lot:

59. When practicable, a lot of fuses shall be tested for acceptance with each lot of shrapnel, and in that case one or more of the shrapnel, loaded and fused and with the fuse set for percussion firing, shall be dropped in an explosion chamber, the fuse wire having first been cut, to observe the character and completeness of burst, and the remainder of the test shrapnel shall be fired over a range with service charges to observe the time action of the fuses.

60. When fuses are not tested in conjunction with the shrapnel, the acceptance tests of the latter will consist of bursting one or more of the selected shrapnel in an explosion chamber, by any suitable means, and firing the remainder, blind loaded, with ser-

vice charges, over a range. Those burst in the explosion chamber must break up well, and those fired over the range must not break or set up in the gun; their flight must be smooth, and their rotating bands must not come off in flight.

61. The powder chambers of the shrapnel must be suitably lacquered, and the balls must be bedded in a suitable matrix, approved by the Bureau.

See Plates II, III, V and VI.

62. **Preparation of Shell for Service.**—The following is a summary of the instructions of the Bureau of Ordnance regarding the preparation of armor-piercing and common shell for issue to service:

(a) Only blind shell will be assembled in 1-pounder ammunition for use in sub-calibre practice. These shell are to be brought to standard weight by filling with sand, and the fuse holes plugged with metal plugs, each marked "plug."

(b) All loaded shell except for 1-pounder, 3-pounder and 6-pounder calibres will be loaded with burster bags.

(c) All armor-piercing shell will be loaded with fine black powder and fused, except that armor-piercing shell above 6-inch calibre will not be loaded unless fitted with base cup gas checks. Unloaded armor-piercing shell issued to service will have the fuse holes plugged with metal plugs, each marked "plug."

(d) All common shell (cast iron, cast steel and forged steel), above 6-inch calibre, fitted with base plugs or base fuses, are to be fitted with base gas check covers. Common shell of and below 6-inch calibre will not be so fitted. Cast-iron shell when so fitted may be issued as common shell.

(e) In loading shell having base plugs, great care is to be observed to see that the base plug, after having been given a thin coat of red lead and oil, is set home tight, and that the fuse is set home tight, after being luted with small-arm shellac.

63. **General Remarks on Shells.**—The foregoing specifications and instructions of the Bureau of Ordnance contain nearly all the necessary information regarding service projectiles. Additional information regarding the development of modern projectiles, the action of the steel cap, ballistics, etc., will be found in the chapters on "Armor" and "Penetration of Projectiles," by Lieutenant Cle-

land Davis, U. S. Navy, and the details are shown in Plates I, II, III, IV, V and VI.

64. Radius of the Ogival.—The radius of the ogival in service shells is not fixed, but varies from 2 to 2½ calibres. The Firth-Sterling armor-piercing shell have an ogival head of 2½ calibres. In nearly all other shell the radius is 2 calibres.

65. Base Plugs.—Nearly all shell are fitted with base plugs, but some are cast or forged with solid bases, as shown in the plates.

66. Fuses.—As a rule base fuses only are used, except for shrapnel, which are fitted with Sweet's combination nose fuse. There are, however, some common shell in service fitted with nose fuses, as shown in Plate II.

67. Base Covers.—Nearly all loaded shell of large calibre, both armor-piercing and common, are fitted with base covers (see Plate IV, Fig. 3). The holes for the spanner in the base of the plug are first filled with lead, and a lead disk is then placed over the base of the shell, covering the plug and fuse. A copper disk is then placed over the lead and caulked into the base of the shell, the caulking groove being filled with a lead wire, as shown in the plate.

68. Steel Cap for Armor-piercing Shell.—In order to assist the shell in its attack on hard-faced armor, and to assist in biting into an armor plate, all armor-piercing shell are now fitted with a soft steel cap of the shape shown in Plate IV. The steel cap protects the sharp point of the shell and supports the head on its first impact with face-hardened armor. The method of attaching the soft steel cap is shown in Plate IV. The cap *C*, Fig. 1, Plate IV, is placed in a hardened steel die, *D*, the projectile is then placed on it vertically as shown, and under the hydraulic pressure of a 25-ton ram, *H*, is forced downward until the die is about to touch the projectile. No machine work is necessary, the surplus metal on the exterior of the cap being just sufficient to fill the score in the projectile.

69. Driving or Rotating Band for Projectiles.—The rotating band for all shell and shrapnel is of copper, shaped as shown in the plates, and which is forced into an undercut score on the surface of the projectile, near the base, by hydraulic pressure, after which it is machined to size. The standard band is a few hundredths of an inch larger in diameter than the calibre of the gun, the soft metal being forced to flow into the grooves when the projectile is fired. It is important that the band should not slip, since it is the velocity of rotation that keeps the shell steady in flight and prevents tumbling.

70. **Remarks on Armor-piercing Shells.**—Plates I, II and III show the general details of 4-, 8- and 12-inch armor-piercing shells. The fact that armor-piercing shells now contain bursting charges which make them similar to common shell in effect may result ultimately in the abolition of the common shell. The weight of the armor-piercing shell is the same as the common shell of that calibre.

71. **Remarks on Common Shell.**—Common shell have been made of cast iron, cast steel, and forged steel. Cast-iron shell will not be manufactured hereafter, and cast steel will be replaced by forged steel except for small-calibre guns. The forged-steel shell being tough and having good penetrating power, has sometimes been called "the semi-armor-piercing shell." The term common shell is preferred, however. Plates I, II and III show the details of three sizes of common shells.

72. **Bursting Charges for Common Shell.**—The following are the approximate weights of the bursting charges of small-grained black powder for common shells:

Gun.	Weight of Shell.	Weight of Bursting Charge.
1-pdr. and 37 mm. R. C.	1 lb.	250 grains.
47 mm. R. C.	3 lbs.	600 grains.
3-pdr.	3 lbs.	900 grains.
6-pdr.	6 lbs.	1450 grains.
4-in.	33 lbs.	2 lbs.
5-in.	50 lbs.	3 lbs.
6-in.	100 lbs.	3½ lbs.
8-in.	250 lbs.	10 lbs.
10-in.	500 lbs.	30 lbs.
12-in. Cast Steel	850 lbs.	60 lbs.
12-in. Forged Steel	850 lbs.	36 lbs.
13-in. Forged Steel	1100 lbs.	50 lbs.

73. High explosive shells have not been issued to service, but the subject is under consideration and is touched upon in the chapter on "Penetration of Projectiles."

74. It has been proposed to place smoke-producing materials of different colors in the different calibres of shells so that the bursting of the shells would indicate, by the color of the smoke, where each calibre falls. This plan might be of use in bombard-

ments to discover the correct range and to show what shell strike over or short.

75. **Shrapnel.**—Both cast iron and steel shrapnel have been issued for guns from 4- to 8-inch in calibre, but in future steel shrapnel only will be issued.

Plates II, III, V and VI show the details of shrapnel of three different calibres. It will be seen that the body of the shrapnel is made of steel of comparatively thin walls and that the details are different for the several calibres. Sometimes the bursting charge is in the point, sometimes in the base, and again in the central tube.

The number of balls varies with the calibre; in the 4-inch shrapnel it is about 270, and in the 5-inch, about 360, of .52 inch diameter. The 6-inch shrapnel has about 210 balls of .82 of an inch diameter.

76. **Fuse for Shrapnel.**—Sweet's combination time and percussion fuse for shrapnel is described in Chapter 27.

77. **Shrapnel for 3-inch Field Gun.**—The following is a description of the shrapnel for the 3-inch field gun:

It consists of a thin cylindrical body about two-tenths inch in thickness, with a cast-iron head, containing the cavity for the bursting charge, a threaded hole for the fuse, and a base plug, also of cast iron. (See Plate V.) Within the body of the shrapnel are packed 135 balls, ½ inch in diameter, which are held in place by two cast-iron supporting disks, Fig. 2, Plate V, and by six cast-iron separator disks, Fig. 3, Plate V. The separator disks are cut radially into five sectors. The fuse screws into the fuse hole in the cast-iron head.

78. **New 3-inch Shrapnel.**—The latest 3-inch shrapnel is shown in Plate VI.

79. **The Bursting Charges of Shrapnel.**—The bursting charges, as compared to shell of the same calibre, are very small, a few ounces only, the amount being just sufficient in each case to crack the walls of the shrapnel, allowing the balls and fragments to be carried forward by the remaining velocity at the instant of bursting, the cone of dispersion being due to the small bursting charge and the impinging of the balls on each other. The charges are as follows: 4-inch, ⅓ pound; 5-inch, ½ pound; 6-inch, ¾ pound, approximately.

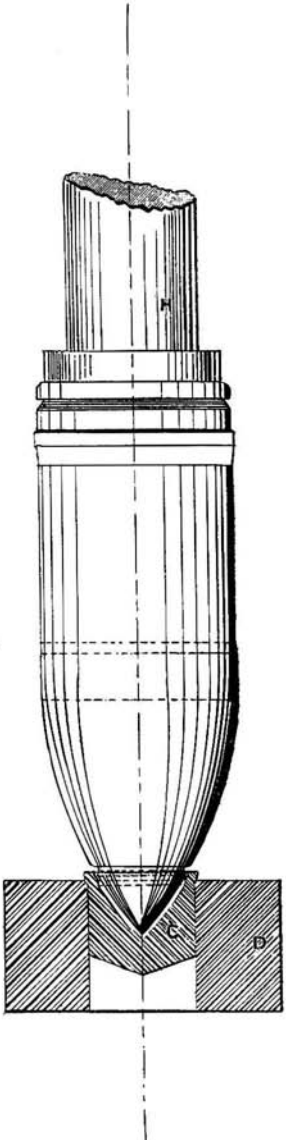


FIG. 1.
METHOD OF CAPPING ARMOR PIERCING SHEEL. Par. 68.

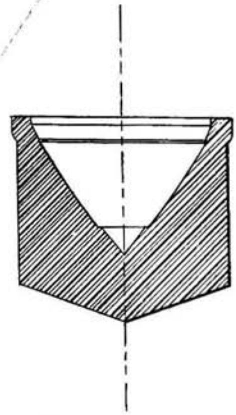


FIG. 2.—STEEL CAP. Par. 68.

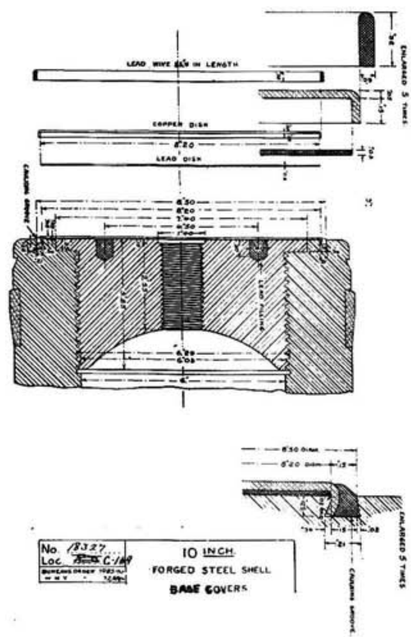


FIG. 3.
BASE COVER FOR SHELLS. Par. 67.

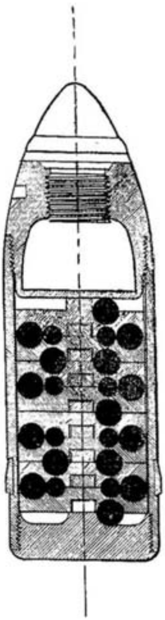


Fig. 1.

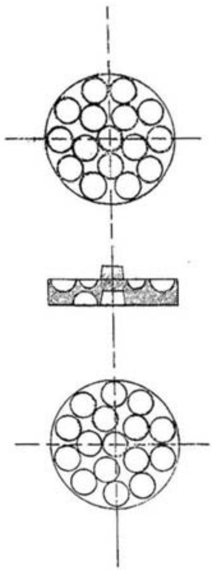


Fig. 2.

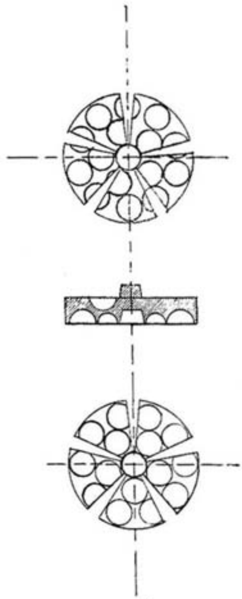


Fig. 3.

3-INCH SHRAPNEL FOR R. F. FIELD GUN.

CHAPTER XXVII.

FUSES.

1. **The Navy Base Percussion Fuses** are shown in Plate I, Figs. 1 and 2, and the action of the fuses is as follows: The shock of firing causes the inertia of the plunger to break the wire holding the plunger, and on impact the plunger flies forward and explodes the primer cap. Fitted with these fuses, shell of 4-inch, 5-inch and 6-inch calibre are exploded by passing through ¼-inch steel plates, while the 1-, 3-, and 6-pounder shell explode on passing through three-sixteenths inch plates. The larger shell require somewhat thicker plate than ¼-inch to explode them. All base fuses have a left-handed thread.

2. The short fuse, Fig. 2, for minor calibre shell, differs from the long fuse used in large shell in having no magazine, and the base of the fuse cavity is conical instead of cylindrical.

3. **Safety in Handling.**—It has been found that a drop of 30 feet upon well supported half-inch steel plating does not arm these fuses, but that a drop of about 12 feet upon a heavy armor plate does. Consequently, while, under usual conditions, a fuzed shell dropped from a considerable height will not explode, it is advisable to take great precautions against dropping one. As the greatest velocity with which a shell can be rammed home does not equal that due to even a small drop, there can be no danger whatever that the shock of a shell bringing up on the compression slope will cause the fuse to be armed.

4. **Frankford Arsenal Fuse.**—The Frankford Arsenal base percussion fuse, of which a large number will be issued to service, is shown in Plate II, Fig. 1. The action is simple and requires but little explanation.

The igniter plunger (7) rests against the rear end of the fuse cavity, and the sleeve (6) against the forward end. The plunger and sleeve are held together, with the point of the former clear of

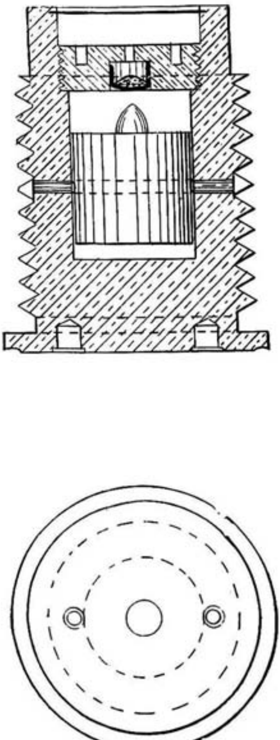


FIG. 1.

FIG. 2.

NAVY BASE PERCUSSION FUSES.

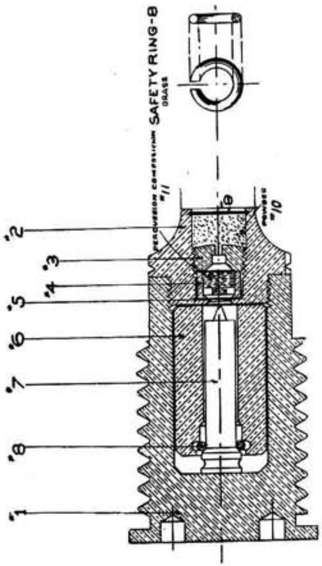


FIG. 1.

FRANKFORD ARSENAL FUSE. Par. 4.

1. Body.
2. Closing cap screw.
3. Primer closing screw.
4. Primer.
5. Restraining disk.
6. Igniter plunger sleeve.
7. Igniter plunger.
8. Safety ring.
9. Closing disk (power chamb r).
10. Powder.
11. Percussion composition.

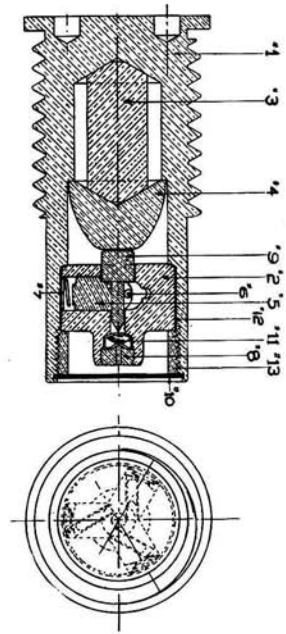


FIG. 2.

MERRIAM FUSE. Par. 6.

the restraining disk (5), which covers the percussion composition, by the split safety ring (8). This is the position of safety.

When the shell starts from its seat the shock of discharge carries the sleeve to the rear, opens out the safety ring and forces it back into the groove around the rear end of the plunger where it springs into place and again locks the sleeve and plunger together, both resting against the rear end of the fuse cavity. When the shell strikes, the sleeve and plunger fly forward against the primer, exploding the latter and igniting the powder in the fuze magazine, from which the flame is communicated to the bursting charge.

5. Broderick Fuse.—The Broderick base percussion fuse for minor calibre R. F. shell is practically the same as the Frankford Arsenal fuse in principle and in action. The magazine is omitted, and the rear end of the fuse cavity is conical instead of cylindrical.

6. Merriam Fuse.—The Merriam base percussion fuse, of which 100,000 have been ordered for issue to the service, is shown in Plate II, Fig. 2.

The *striker* (9) and the *primer* (11) and *anvil* (8) are carried in a block (2) held in the forward part of the fuse cavity by a screw sleeve (13). The flame from the primer communicates with a small powder chamber, the powder being confined by a thin copper disk (10).

The point of the striker is held back from the primer in the block by three radial keys (5) which are pressed against the striker by spiral springs, as shown in the plate. When the shell leaves the gun the centrifugal force due to the rotation of the shell causes the keys to fly back against the springs and unlock the striker, which is then free to move forward against the primer.

The plunger, which gives force to the striker, is in two distinct parts (3 and 4). The rear plunger (3) is designed to cause the fuse to act upon oblique or side impact. Being of smaller diameter than the fuse cavity and its ends being conical where it bears against the cavity and against the forward plunger (4), it is evident that a side impact would cause the plunger to move sidewise and impart a forward movement to the forward plunger (4), driving the latter against the striker (9).

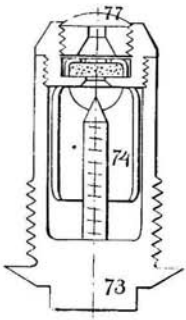
The action upon direct impact will be evident from the plate. The centrifugal locking or safety arrangement and the device for side impact are the distinguishing features of this fuse.

7. **Hotchkiss Fuse.**—The Hotchkiss fuse, Plate III, for small calibre shell, consists of a cylindrical fuse body containing a plunger, and having a small fulminate cap and magazine (76) screwed into its front end. The plunger is a brass cylinder filled with lead (74) and having a stout corrugated steel striker passing through it. The point of this striker is covered by the front end of the plunger, which, in the safety position (Fig. 1) rests against the front end of the fuse cavity (75), while the rear end of the striker projects beyond the plunger and rests against the rear of the cavity. The shock of discharge drives the plunger to the rear along the striker (Fig. 2), the lead holding the two together, leaving the point of the striker projecting from the front end of the plunger. Upon impact, the plunger, carrying with it the striker, drives forward, exploding the cap and communicating the flame to the bursting charge of the shell. (See Plate III, Figs. 1 and 2).

8. **Driggs Fuse.**—In the Driggs fuse, Plate III, the plunger is held back (Fig. 3) against the rear end of the fuse cavity by two tempered steel springs (Fig. 4) having circular lugs which fit into a score around the rear end of the plunger, the forward ends of the springs being joined to a ring which rests against the forward end of the cavity. Thus the point of the plunger is held clear of the cap until the rapid rotation of the shell causes the springs to fly out by centrifugal force so that the lugs are free from the score in the plunger, leaving the latter free to fly forward upon impact. (See Plate III, Figs. 3 and 4).

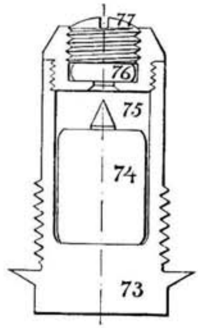
9. **Time Fuses.**—A *time fuse* is one which explodes by its own internal action after a definite time of flight which fixes the *distance* from the gun at which the shell will burst; this interval may be varied within large limits by the operation of "cutting" or "setting" the fuse.

Any time fuse depends upon its train of compressed slow-burning powder; this composition is made as uniform as possible, and, if accuracy is to be attained, equal lengths of it should be consumed in equal intervals of time. When the fire reaches the end of the time train, it ignites the quick powder of the fuse magazine and bursting charge, and the projectile instantly explodes. The time of burning a particular size or variety of fuse depends upon the distance of the point at which the train is lighted from its end.



Position of plunger before firing.

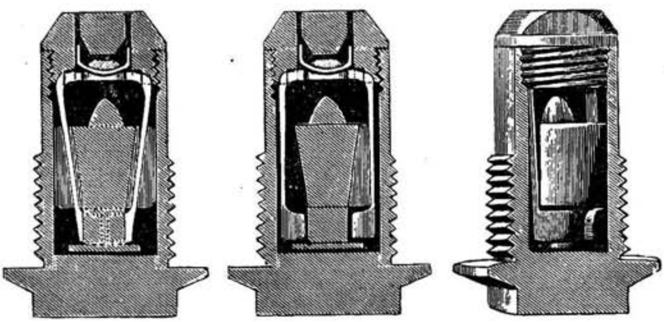
FIG. 1.



Position of plunger during flight.

FIG. 2.

HOTCHKISS BASE PERCUSSION FUSE. Par. 7.

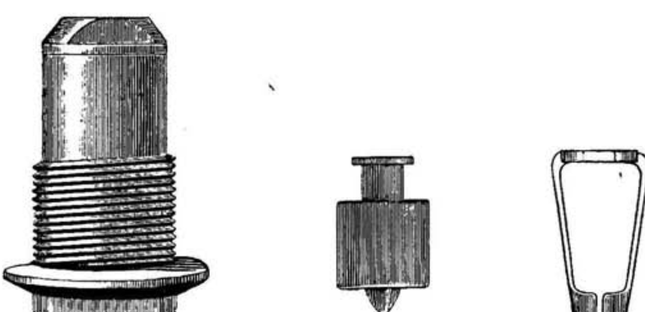


Position of Spring before firing.

Position of Spring during flight.

FIG. 3.

DRIGGS BASE PERCUSSION FUSE. Par. 8.



Plunger.

Springs.

FIG. 4.

FIG. 1.

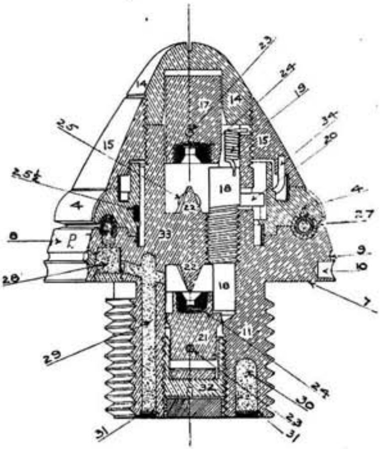
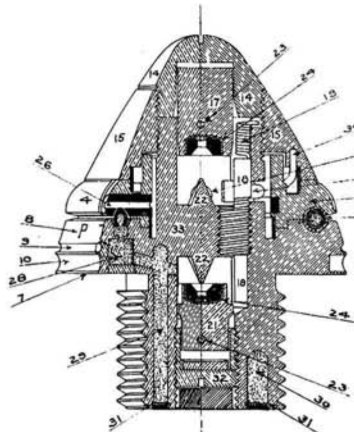


FIG. 2.



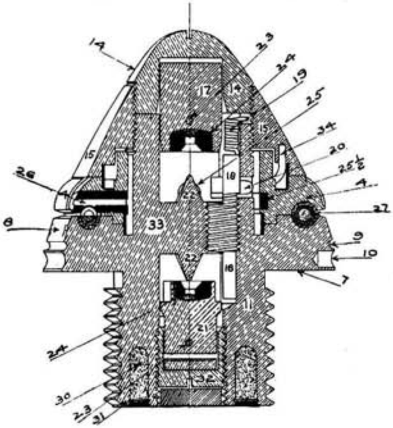


FIG. 3.

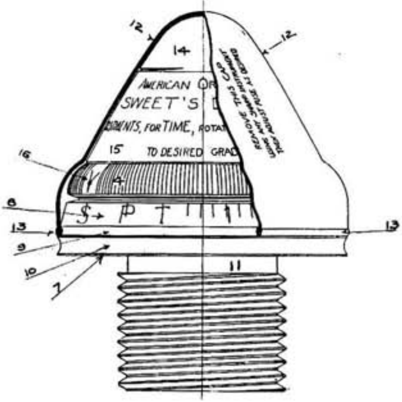


FIG. 4.

SWEET'S FUSE.

The first fuses used for bursting projectiles were time fuses which depended upon the slow-burning powder train; since that time, the only progress, as far as principles are concerned, lies in the method of igniting the time train. These old-fashioned fuses, formerly used with common shell, were ignited by the flame of the gun's powder charge which came into contact with the exposed time train—if it had been "cut." Their bodies were sometimes made of wood, and the time of burning was varied by sawing off a few inches of the end. This method of ignition answered very well, but for modern guns the fuse would have to be in the base of the projectile, and the high powder pressure would crush one of such construction or at least derange it so as to interfere with its working. The modern method of ignition is self-contained, and is in all respects similar to that of the percussion fuses shown in Plate I.

Time fuses are used in the Navy for shrapnel only, and are invariably carried in the nose of the projectile. The one shown in Plate IV is a combination time and percussion fuse now commonly used for shrapnel of all sizes. Figs. 1 and 2 show the same section but with different settings; Fig. 3 is a section a few degrees from the others, while Fig. 4 is a profile showing the graduations.

10. **Sweet's Fuse,** see Plate IV, is a combination fuse, and may be adjusted to act by percussion on striking, or by time. In the latter case, if the time device fails, the percussion feature will cause an explosion just as if the fuse had not been set for time. The fuse may also be set so that it cannot be exploded by careless handling.

11. **The Percussion Feature** of the fuse is like that of the fuses on Plate I; the plunger (21) containing the percussion cap (24) is held by a brittle wire (23); the shock of discharge breaks this and the plunger sets to the rear, arming the fuse; when the projectile strikes, the plunger is carried forward by its momentum, and the cap is exploded by the firing point (22) which ignites the magazine (29) and produces an immediate burst.

12. **The Time Action** is as follows: The shock of discharge breaks the other shearing pin (23) and the time plunger (17), strikes upon the point (22) which explodes the cap (24) and fills

the cavity with hot gas. The flame passes through the hole (25) to an annular space and ignites the ring of powder (25½); the flame is finally communicated through the hole (26) to the time train (27) which burns slowly and finally reaches and ignites the powder in (28) and (29). The hole (26) is in the setting ring (4) and may be moved around with it, thus igniting the time train at the desired point; this comprises setting it for time.

13. **The Safety Lug** (18), screwed into the body of the fuse, suffices to put the time plunger out of action, thus setting the fuse for percussion firing, or to put both plungers out of action, making it insensitive to shock; it is revolved by the action of a stop, on the setting ring, against the small lug (20). In Figs. 1 and 4 the fuse is set at "safety"; in Fig. 3 for percussion firing and in Fig. 2 it would explode, by time, close to the gun.

14. **The Setting Ring** is fitted with pawls which do not permit it to turn in the direction induced by the rotation of the projectile; needless to say, its setting would be changed otherwise. The lead cap (12) protects the fuse from dampness; it is removed before the fuse is set.

15. **Specifications for Shrapnel Fuses.**—Shrapnel fuses shall be made in accordance with drawings approved by the Bureau.

16. The fuse stocks, caps, adjusting ring, and plungers shall be of any good commercial brass composition and shall be finished as well as the best machine methods permit.

17. The time train shall be of suitable composition enclosed in a uniformly drawn or rolled lead tube.

18. The parts of the fuse shall be subject to a visual inspection only, with the exception of the shank thread, which must qualify in approved standard gauges. The inspector, however, shall witness the shop tests of time trains as a means of satisfying himself as to their uniformity.

19. The fuses shall be presented for test in lots of 500, and from each lot five fuses shall be selected by the inspector for test as follows:

20. One or more of the fuzes shall have their percussion elements tested either by dropping loaded and fused shrapnel in an explosion chamber, or by firing through a $\frac{3}{16}$-inch steel plate or its equivalent. The remainder of the fuses shall be fired with service charges over a range to test the time element.

21. For the time test the fuses will, generally, be cut for times between 2 and 8 seconds, and the elapsed time between the appearance of smoke at the muzzle and the explosion of the projectile shall be noted by chronographs or stop watches. The least time noted shall be taken as the true time, and this must not differ more than one-third of a second, plus or minus, from the time for which the fuse was set.

22. The failure of any fuse tested to function properly, or a discrepancy of more than one-third of a second between the set time and the burning time, shall be sufficient cause for the rejection of the lot.

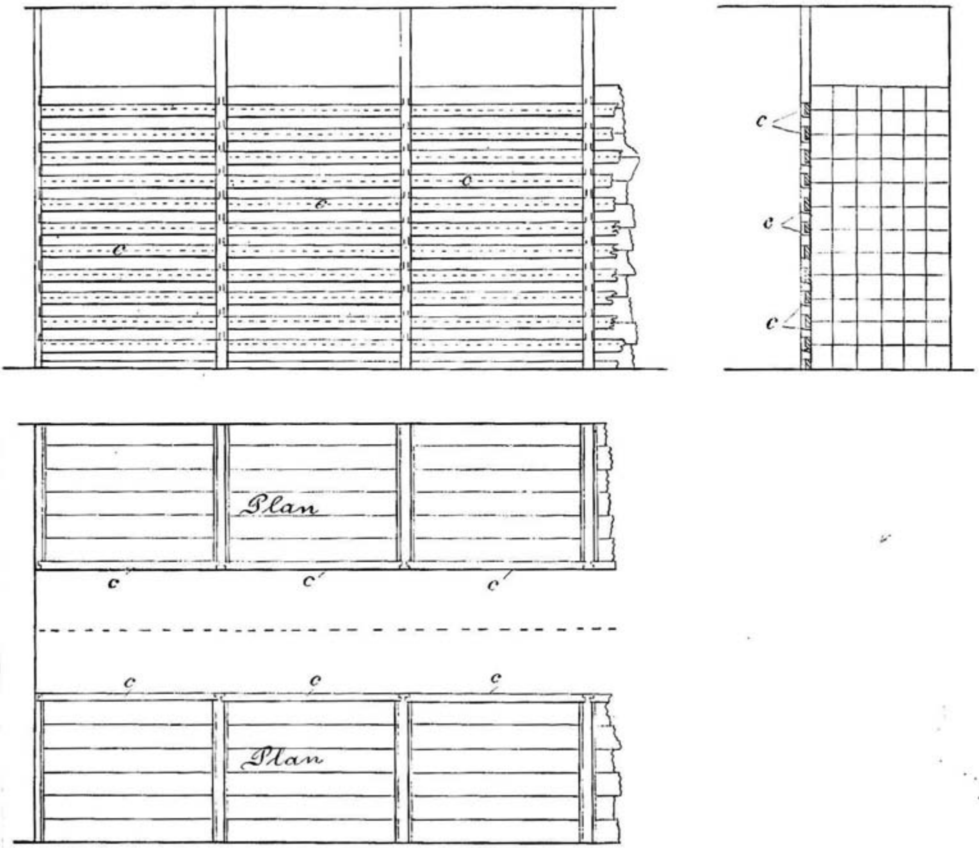
CHAPTER XXVIII.

STOWAGE AND SUPPLY OF AMMUNITION.

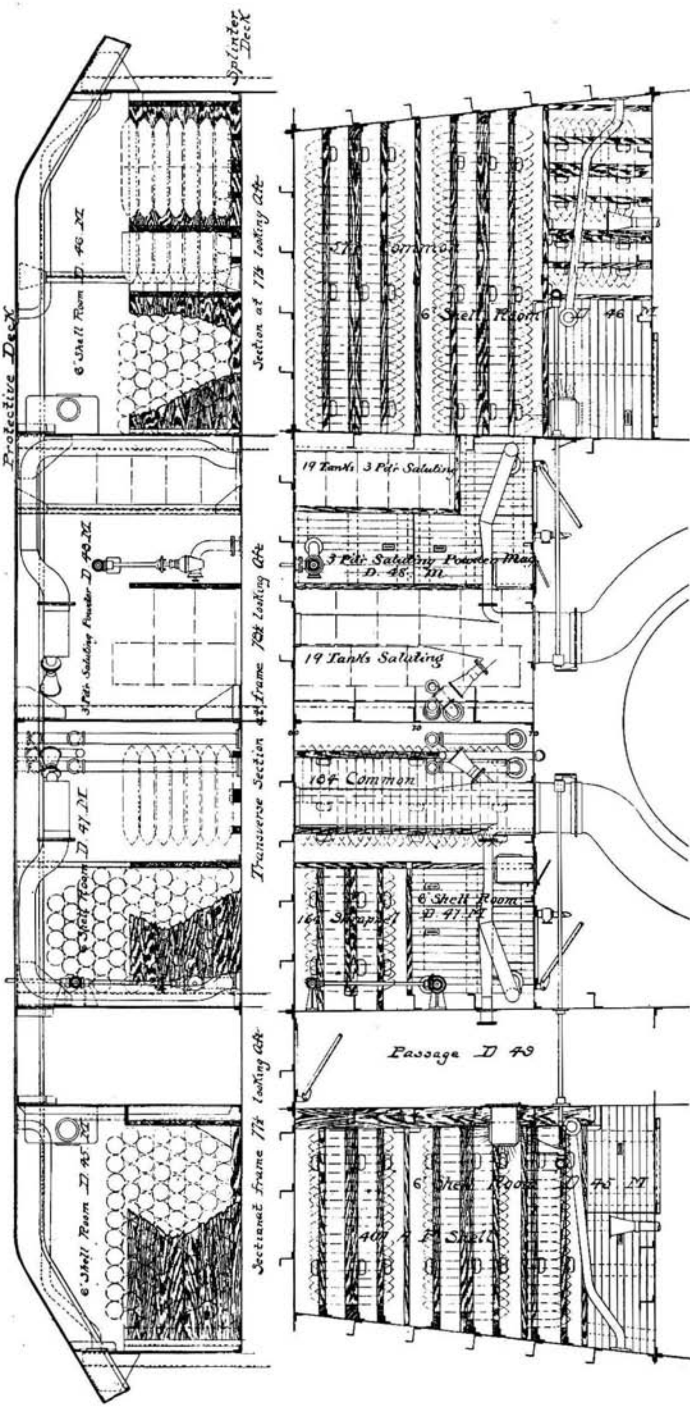
1. With the exception of the detonators and dry gun-cotton primers for torpedoes, all ammunition, of whatever character, is stowed in specially constructed rooms set apart for that purpose alone; a few projectiles are often stowed in racks around the gun emplacements or below decks, where they can be expeditiously supplied to all guns in emergencies. The ammunition rooms are commonly distinguished in name by the kind of ammunition they contain as well as by their regular numbers; for example, compartment A 37 M is one of the forward 12-inch magazines; compartment D 33 M is the "small arms" magazine.

2. **Flooding and Draining.**—All ammunition rooms are watertight compartments and are placed below the water line; to prevent explosions in case of fire below decks, arrangements are made for admitting sea water to each room; such rooms as are unavoidably built *above* the water line have flood pipes leading from the fire main. The flood pipe, of a size sufficient to fill the empty magazine in about twenty minutes, leads from the outer skin of the ship below the water line directly to a flood valve, which is worked either in the magazine itself or from the berth deck. A spindle leads from the valve to a plate on the berth deck and ends

in a square section on which is shipped a large key for turning the valve; the key or wrench is kept near at hand in a locked rack, the key of which is kept with the magazine keys. The deck plate is stamped with the name and the compartment number it floods and an arrowhead indicates the direction that opens the valve.



STOWAGE OF 4-INCH, 5-INCH AND 6-INCH R. F. AMMUNITION BOXES.



6-IN. SHELL ROOMS OF U. S. S. MAINE.

In addition, a specially shaped plate, with a red ground, secured to the beam above, gives the same information (see figure). The air escapes from the magazine through the exhaust ventilating duct; if none is fitted, a special escape pipe is provided to allow the room to fill. Those compartments flooded from the fire main have relief valves to prevent the accumulation of a pressure that would make the bulkheads collapse.

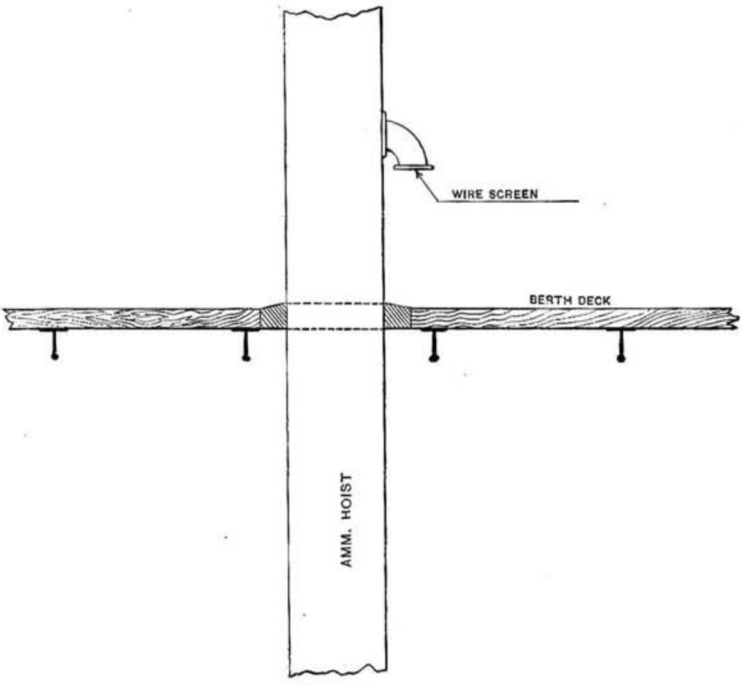


FIG. 1.

Ammunition rooms in the hold drain into bilge wells, from which suction pipes lead to drain manifolds. Upper compartments sometimes have individual drain pipes to drain wells or lower compartments; in other cases, they can be freed of water, that happens to find its way into them, only by portable pumps.

3. **Ventilation.**—The adoption of a smokeless powder which, in the process of manufacture, is colloided with a very volatile liquid, makes the subject of ventilation a very important one; the ether

fumes are inflammable and must be carried off and, in addition, the powder must be kept cool. To this end, every ammunition room is fitted to receive, directly from the ship's artificial ventilating system, a supply sufficient to renew the air once in about eight minutes. A natural exhaust pipe of greater area than the supply duct is placed in each room as far away from the supply as possible; the upper end is carried up at least above the berth deck and terminates in a gooseneck covered with wire mesh. When ammunition hoists open directly into the magazine, the trunk of the hoist itself is used for natural exhaust ventilation (see figure); a gooseneck outlet, covered with wire mesh, is fitted at a height at least above that of the berth deck. Piping in ammunition rooms is generally of brass.

4. **Lighting.**—Each magazine and shell room is lighted by one or more light boxes, of standard Navy pattern, which throw light in three directions through round ports covered with double glass plates. The boxes are water-tight and are separate compartments opening *only* from the deck above or from some passage or compartment outside the magazine. The light boxes each contain incandescent lamps and are arranged to burn candles if the others fail; in the latter case, enough water to cover the bottom is introduced.

5. **Stowage, Location of Magazines, etc.**—The ammunition rooms, as a rule, form two groups, one in each end of the ship, next forward and abaft the engine and boiler spaces. To the greatest extent practicable, the ammunition compartments are below the water line and are always beneath the protective deck for protection and for facility in flooding; their arrangement must be such that the contents may be gotten out and sent to the guns expeditiously. If the groups of magazines, etc., contain any rooms that are next to boiler or engine rooms, they are separated from such sources of heat by double bulkheads, separated by a narrow air space which has an outlet to the upper deck. The problem of location varies greatly for the different designs of ships. In large ships which have splinter decks, the two groups of ammunition rooms are connected by long wing compartments on this level, called the ammunition passages; many of the rooms open on these passages, which are just inside and above the machinery spaces,

and they are particularly useful in *supplying* ammunition to the battery. There is sometimes a third group of magazines about midway between the two main groups which open on the ammunition passages and supply the waist guns; these rooms are small and are called the "ready" or auxiliary magazines.

The ammunition rooms of turret guns open into a common handling room, beneath the turret, from which the hoists convey their contents to the guns. For other magazines and shell rooms the same plan is followed where space permits; the ammunition passages are really handling rooms. The shell room doors swing into the handling rooms and are kept open while projectiles are being supplied; but the magazine doors are kept closed and the charges are passed through small openings in them which are in turn closed by shutters; this arrangement is to prevent, as far as possible, an explosion in the handling room from reaching the powder. When there is no space for handling rooms, the hoists open directly into the magazines and shell rooms; it is, in this case, usual to place the hoisting motors and controlling panels outside, to obviate any possibility of an explosion by the ignition of ether fumes from electric sparking. All magazines are floored with ash gratings; the wood used in the racks and bins for the ammunition is of non-fireproof yellow pine.

6. Rapid-fire ammunition is stowed in its boxes in bins in which the charges of the same character are kept separate; thus, in a 3-inch magazine, one bin will contain armor piercers, another common shell, etc. Also the different calibres are stowed in separate magazines; miscellaneous ammunition, such 1-pounder, .30-calibre machine-gun, rifle and revolver ammunition is stowed together. These magazines are frequently called "fixed ammunition rooms"; the boxes are piled in tiers as is most convenient in transferring to the hoist. The sides of the bins are formed from battens shipping in vertical channels (see Plate I).

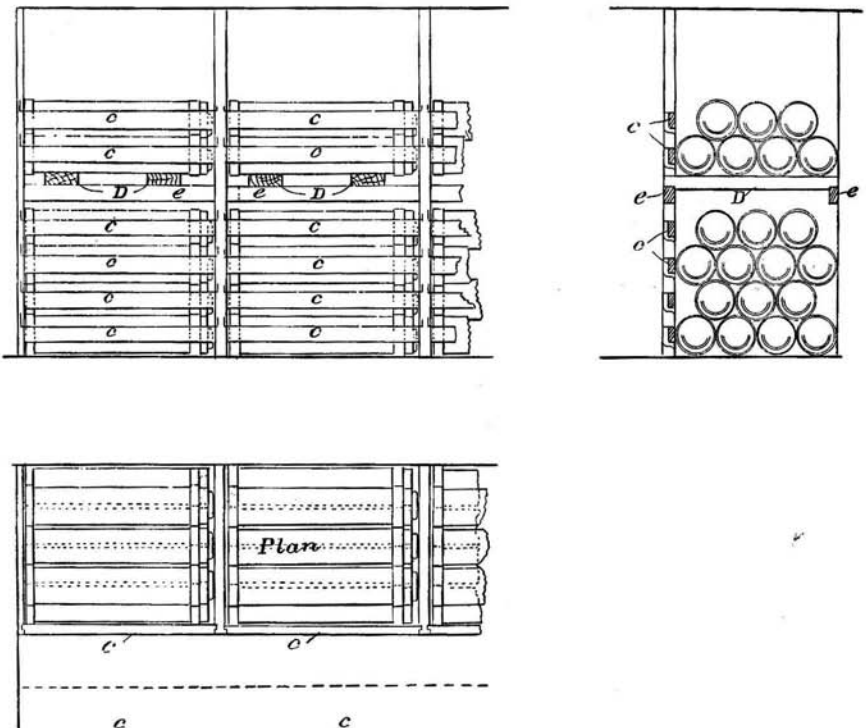
Projectiles for other than R. F. guns are stowed in separate shell rooms. The bins are strong and the projectiles are stowed in bulk in tiers, the same kinds being left together. If there are two rows in the same bin, they are stowed base to base, and, in any case, the bins are lined with wood against which the sharp noses bring up (See Plate II). Overhead rails, for the cars of the differential lifting purchases, lead from the bins of the large calibre shell rooms through the doors to the hoists; smaller projectiles are transferred by hand. In the few ships in which hand whips only are used, the projectiles are often stowed with straps running longitudinally around each and seized together to form an eye at the nose, into which the whip hooks; this is a convenient, though expensive, way of handling projectiles during shipment. All 10-, 12- and 13-inch projectiles are shipped in strong boxes which are removed before stowing in the shell rooms.

Powder tanks are also stowed in bins, usually on their sides (see Plate III). The older cases are not strong and, as shown, can be stowed only a few tiers high; in this case, horizontal wood battens (D) support the upper layers. Wooden battens bound together by brass rings run along the sides of the new tanks and so strengthen them that they may be piled up to the deck beams. Tanks should be stowed so that their contents can be removed without disturbing them; it is usual to arrange them, particularly those for the turret guns, with their heads to the passage. The bins are built up from stationary vertical channels and rolling boards, which are removed to get at the tanks. Bins are arranged in the different magazines with a view to accessibility in supplying powder to the hoist and, where necessary, alleys are run between them. While the ship is rolling, projectiles, powder tanks and charges are more secure if stowed parallel with the keel, but the tanks and charges should be perpendicular to the passages.

The ammunition rooms of small ships are simply arranged, in two groups, in the hold forward and aft. Of this type the "Baltimore" carries the following ammunition:

TOTAL STOWAGE.

In Magazine..	6″ Shells	2160 R'd's.
On Deck	6″ "	240 "
In Magazine..	6″ Charges	2400 "
" " ..	3″ Amm.	459 Boxes (Including 9 Boxes 3″ Field Gun Amm.).
" " ..	3 Pdr. Amm.	244 Boxes
" " ..	1 " "	40 "
" " ..	30 cal. Machine Gun	50 "
" " ..	30 " Ball Cartd'g's.	100 "
" " ..	30 " Blank "	10 "
" " ..	30 " Gallery Practice	10 "
" " ..	38 " Ball Cartd'g's.	10 "
" " ..	45 " " "	5 "
" " ..	Common Powder	19 "
" " ..	Primers	1 "



STOWAGE OF 6-INCH POWDER TANKS.

Page 342b
BACK of Plate III,
Chapter XXVIII,

Faces Page 343.

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This ammunition is handled by one secondary battery hoist and four 6-inch hoists at each end of the ship.

7. The stowage and means of getting up the ammunition necessary for the large battery of a battleship is a more intricate problem. Plate V shows the plans of the new "Maine" as regards the stowage and supply of ammunition; her battery consists of four 12-inch, sixteen 6-inch, six 3-inch (50-calibre), two 3-inch field guns, eight 3-pounder, six 1-pounder and two Colt automatic guns. The allowance and possible capacity of all kinds of ammunition is given in the following table (pages 344 and 345).

The magazines and shell rooms are in three groups—one around the base of each turret and a smaller one in the waist; all are below the protective deck, the top or crown of which is a little above the water line.

The waist group comprises two 6-inch charge and shell magazines, designated the "ready" or auxiliary magazines, on each side at the level of the splinter deck. These rooms, four in number, open on the ammunition passage which is on the same level. The other two groups are on three flats—splinter deck, platform and hold.

The 12-inch ammunition rooms (see Plate IV), all on the platform deck, open into the handling rooms at the same level. The powder charges are distributed among eight magazines in the forward group and the same number aft; the projectiles are carried in two shell rooms forward and two aft.

Besides the 6-inch auxiliary magazines in the waist, there are in the hold five other magazines for 6-inch charges—three forward and two aft. A few 6-inch projectiles are stowed in the auxiliary magazines and around the gun emplacements, but the bulk of them is carried in five shell rooms in the fore hold and three on the splinter deck aft. Some 6-inch charges are stowed in the saluting powder magazine.

The 3-inch and 3-pounder ammunition stows in two fixed ammunition rooms forward and two aft—all on the splinter deck. One-pounder ammunition and a small amount for 3-pounders and Colt automatic guns is stowed in two magazines on the forward splinter deck. Small-arm ammunition has a room by itself just abaft the after 12-inch magazines.

Name.	Comp't.	Location.	Side.	SUMMARY OF STOWAGE. 12" Amm.					6" Amm.						Fixed Amm.																		
				Tanks.	A. P. Capped.	Common Shell.	Shell Dummy.	¼ Charge Dummy.	Charge.	A. P. Capped.	Common Shell.	Shrapnel.	Shell Dummy.	Charge Dummy.	3" (50 Cal.) Fixed Ammu.	3" (50 cal.) Dummy Cart'dges.	3 P'd'r Fixed Ammu.	3 P'd'r Saluting.	3" Field Gun, Fixed Ammu.	1 P'd'r Heavy Fixed Ammu.	1 P'd'r Heavy Feed Boxes.	3 P'd'r Drill Cart'dges.	1 P'd'r Drill Cart'dges.	30 Cal. Rifle Ball Cart'dges.	30 Cal. Rifle Blank Cart'dges.	30 Cal Rifle Dummy Cart'dges.	38 Cal. Revolver Ball Cart'dges.	45 Cal. Rifle Ball Cart'dges.	22 Cal. Rifle Ball Cart'dges.	Tanks 3 P'd'r Saluting Powder.	Torpedo War Heads.	Submarine Mines.	(30 Cal.) Colt Automatic.
For'd 12" Magazine	A. 33 M.	Plat DK 20-22	S	15																													
" 12 "	" 34 "	" " 20-22	P	16																													
" 12 "	" 35 "	" " 20-23	S	26																													
" 12 "	" 36 "	" " 20-23	P	26																													
" 12 "	" 37 "	" " 23-27	S	65																													
" 12 "	" 38 "	" " 23-27	P	65																													
" 12 "	" 42 "	" " 28-30	S	16																													
" 12 "	" 42 "	" " 28-30	P	13																													
After 12 "	D. 19 "	" " 70-72	S	14																													
" 12 "	" 20 "	" " 70-72	P	14																													
" 12 "	" 21 "	" " 70-73	S	42																													
" 12 "	" 22 "	" " 70-73	P	42																													
" 12 "	" 23 "	" " 73-77	S	49																													
" 12 "	" 24 "	" " 73-77	P	49																													
" 12 "	" 27 "	" " 78-80	S	15																													
" 12 "	" 28 "	" " 78-80	P	15																													
For'd 12 Shell Room	A. 39 "	" " 27-30	S		24	36	4	8																									
" 12 " "	" 40 "	" " 27-30	P		24	36																											
After 12 " "	D. 25 "	" " 77-80	S		24	36																											
" 12 " "	" 26 "	" "	P		24	36																											
For'd 6 Magazine	A. 21 "	Hold 23-27	S						286					15																			
" 6 "	" 25 "	" 20-30	S						771																								
" 6 "	" 26 "	" 20-30	P						760																								
After 6 "	D. 11 "	" 70-80	S						749																								
" 6 "	" 12 "	" 70-80	P						673																								
Midship 6 Aux. Magazine	B. 47 "	Sp'l DK 41-47	S						73		80																						
" 6 " "	" 48 "	" " 41-47	P						73		80																						
" 6 " "	" 49 "	" " 47-53	S						136		64	24																					
" 6 " "	" 50 "	" " 47-53	P						136		64	24																					
For'd 6 Shell Room	A. 19 "	Hold 20-23	S							108	61	49																					
" 6 " "	" 20 "	" 20-23	P							108	61	49																					
" 6 " "	" 22 "	" 23-27	P							85	317	293																					
" 6 " "	" 23 "	" 27-30	S							126	165	91	16																				
" 6 " "	" 24 "	" 27-30	P							126	241																						
After 6 " "	D. 45 "	Sp'l DK 77-80	S							407																							
" 6 " "	" 46 "	" " 77-80	P								571																						
" 6 " "	" 47 "	" " 78-80	S								184	164																					
3 P'd'r Saluting Powder Magazine	" 48 "	" " 78-80	P						38									19												19			
For'd 3" & 3 P'd'r Magazine	A. 47 "	" " 23-27	S												99		171																
" 3 " 3 " "	" 48 "	" " 23-27	P												99	12	112		18														
After 3 Magazine	D. 45 "	" " 73-77	S												132																		
" 3 "	" 46 "	" " 73-77	P												198																		
Small Arms Magazine	" 33 "	Plat " 80-83	S																					150	15	5	13	10	12				
1 P'd'r & 3 P'd'r Magazine	A. 47 "	Sp'l " 20-23	S														20			40													
1 " " 3 " "	" 48 "	" " 20-23	P																	32		4	3										20
Torpedo War Heads	" 6 "	Hold 11-13	P																												48		
Submarine Mines	" 8 "	" 13-16	P																													13	
Possible Stowage				482	96	144			3695	960	1888	694			528		303			72													
Allowance of Amm				480	96	144	4	8	3200	960	1920	320	16	15	528	12	300	19	18	67	..	4	3	150	15	5	13	10	12	19	48	13	20

Page 344 (&345)a
BACK of revolved
double page.

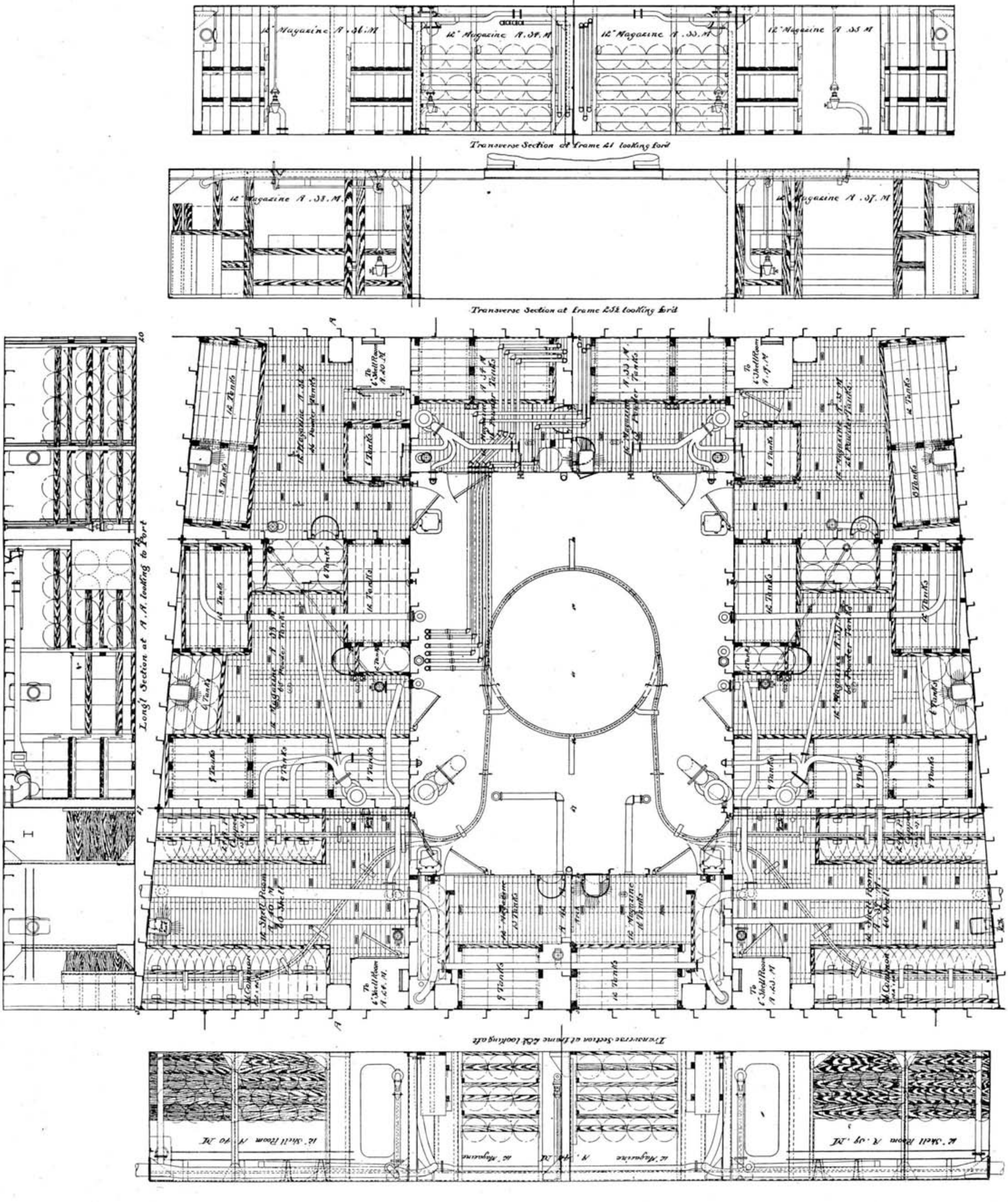
This page has been added to maintain proper pagination when this work is printed on a duplexing printer.

It is needed because pages 344 & 345 which were a "tipped in" table in the original have been rotated 90deg to print full size on a standard letter sized page.

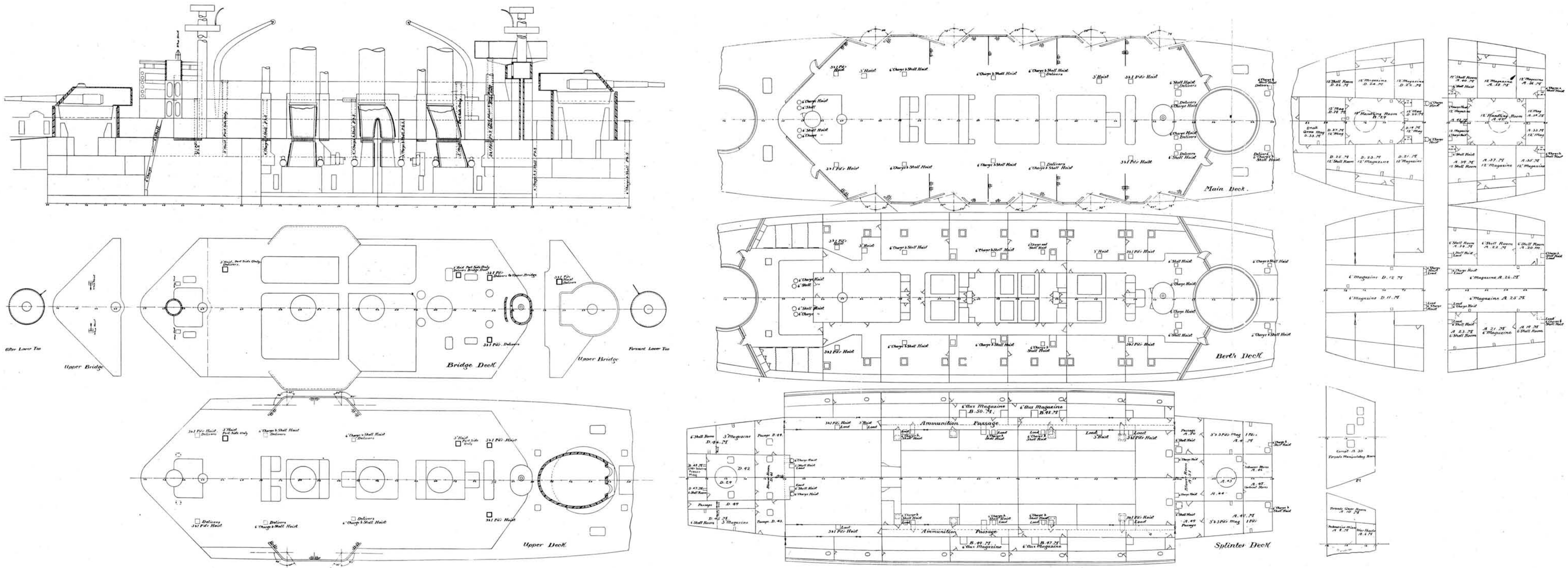
The "Maine" has two under-water torpedo tubes in a compartment, which also stows the allowance of torpedoes, on the platform deck forward of the magazine group; underneath it on the port side are the two gun-cotton magazines (see plate). The ammunition passages on the splinter deck may be utilized to stow extra projectiles and, with proper precautions, a supply of charges as well, but they should not be kept there for a long period.

8. Ammunition Supply.—In the efficient use of a ship's battery in action, the supply of ammunition is next in importance to the correct use of her guns; the excellence of the gun pointers and crews will avail nothing unless they can receive the ammunition in exactly the proper way. Save for a few projectiles, it is unsafe to stow any ammunition near the guns; in fact, we have seen that it is imperative to stow it in definite places, *below* the water line, which are a long distance from some of them. The problem, then, which varies in its intricacy in each class of ships, is to maintain a supply of ammunition to each gun—firing several rounds per minute—as fast as it is needed, without allowing it to accumulate on deck, as, for instance, when the gun, to which a particular chain of supply leads, is silenced. All practicable precautions against powder explosions from the enemy's fire must be enforced.

Obviously, the simplest and surest solution of the problem is to install a magazine and shell room directly beneath each gun, with hoists leading upward to it. This would involve placing a line of magazines along each side, extending the whole length of the machinery spaces at least, which cannot be carried out because many rooms would be too near sources of heat and the space and weight is not available, anyhow; these necessary restrictions as to weight and space are responsible for transforming the comparatively simple problem of gun installation on shore, where space and weight are unlimited, into an exceedingly complicated one. The ideal arrangement of individual magazines and hoists is, in general, attained only for turret guns which, as it happens, are mounted over spaces available for magazines; the tendency, however, is to provide a hoist for each main battery gun and a sufficient number for the smaller pieces; the hoists cannot lead very obliquely, and for some of them ammunition must be transported



FORWARD 12-INCH MAGAZINES AND SHELL ROOMS OF U. S. S. MAINE.



AMMUNITION STOWAGE AND SUPPLY SYSTEM OF U. S. S. MAINE.

by hand over considerable distances, both below decks and at the guns; however, it is the best that can be done, and the same degree of incompleteness is present in all naval ships.

Ammunition stowage and supply is a factor to which the designer devotes much thought and care, but when he has exhausted his ingenuity and the finished ship possesses the best possible system, the matter of efficient *supply* is still only partially taken care of; by far the more important part is concerned with *personnel* rather than with materiel. It remains, for those charged with the duty—the "Powder Division," containing many good men and many not suitable for work at the guns—to manipulate the machinery of supply to the best advantage. The best thought of those officers in direct command is needed right at this point and complete success will come only when all the details have been minutely and patiently worked out. Care in stationing every man according to his fitness, small, readily-made changes, improvisations, etc., will often give good results from a manifestly imperfect system if the desire to make the best of it exists—and there is room for the exercise of a large amount of that sort of spirit in some of our ships.

9. Ammunition hoists for turret guns were described in a previous chapter. Hand whips for getting up ammunition are relied upon in some of the older ships and, for a few supply chains of minor importance, in later designs. In all other cases, a power hoist, which works somewhat like grain lifts in elevators, is employed. Plates VI and VII show a 5-inch R. F. hoist; the same general system is used for Q. F. charges and projectiles, secondary battery ammunition boxes, etc.

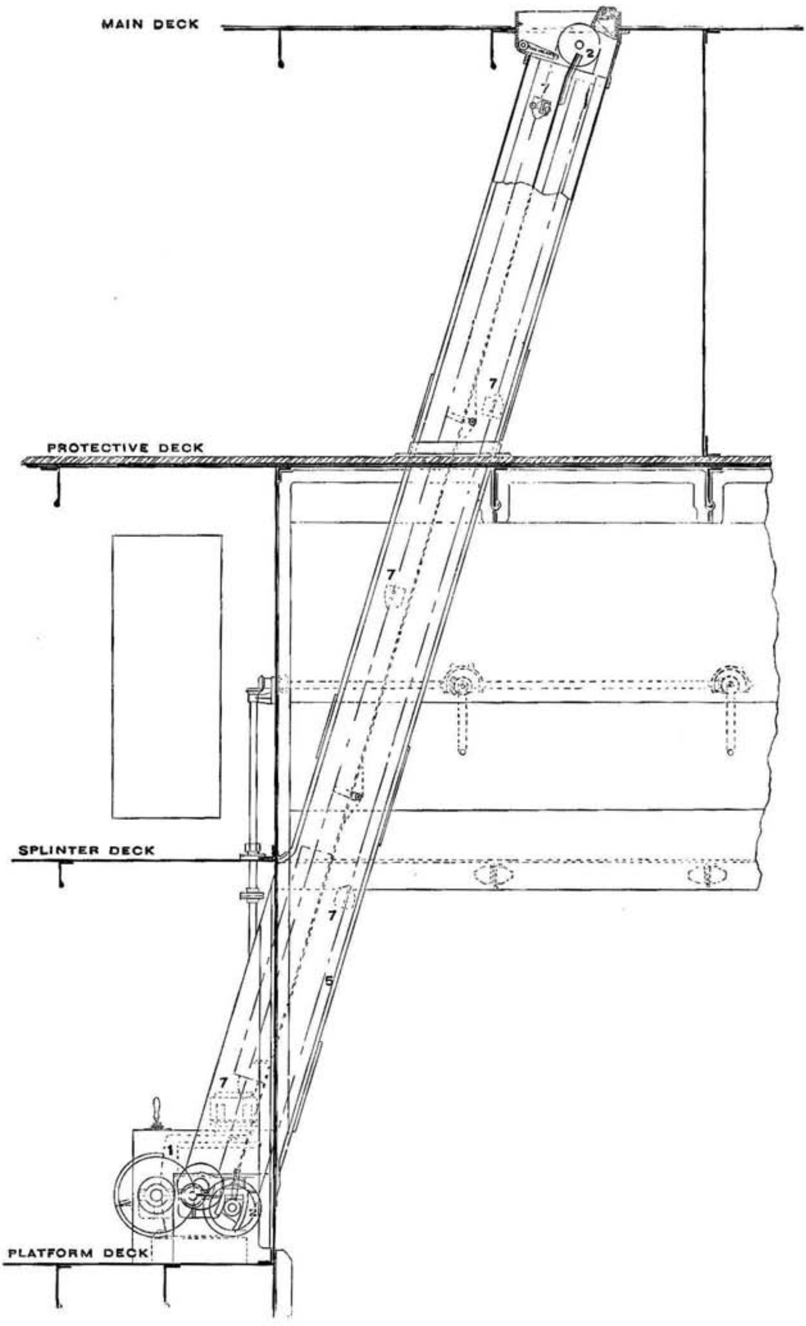
A steel trunk (5) extends from the main deck through the protective and splinter decks to the platform on which the magazines for 5-inch R. F. ammunition are situated. The trunk has two compartments, divided by a partition in the direction of its length; at each of its upper and lower ends a pair of sprocket wheels (2), which carry endless sprocket chains, are fitted. Attached to the sprocket chains are five carriages (7), fitted with rollers, which support the ammunition boxes. Power is applied by suitable gearing from an electric motor (1) to the axle of the lower pair of sprockets, or hand power can be used from a deck above.

At the lower end of the trunk is fitted a loading table (3) on which the ammunition boxes are first landed on end; guides (4), at the sides of the trunk, insure accurate placing of the boxes. The boxes are picked up by the carriages as they pass the table and rest on the carriages and against the partition between the compartments of the trunk. Just above the protective and splinter decks, pawls (6) are fitted which are tripped as the boxes pass and drop back into place as the carriages pass, thus preventing the fall of an ammunition box below the pawl, in case of accident. A pawl (6) with a light spring is attached to the front side of the trunk at the upper end to assist in tipping the ammunition box on the rollers at the top of the trunk; the carriage passes the upper sprocket wheels, pushes the box on to the deck, and then continues down the other compartment of the trunk on its return to the magazine.

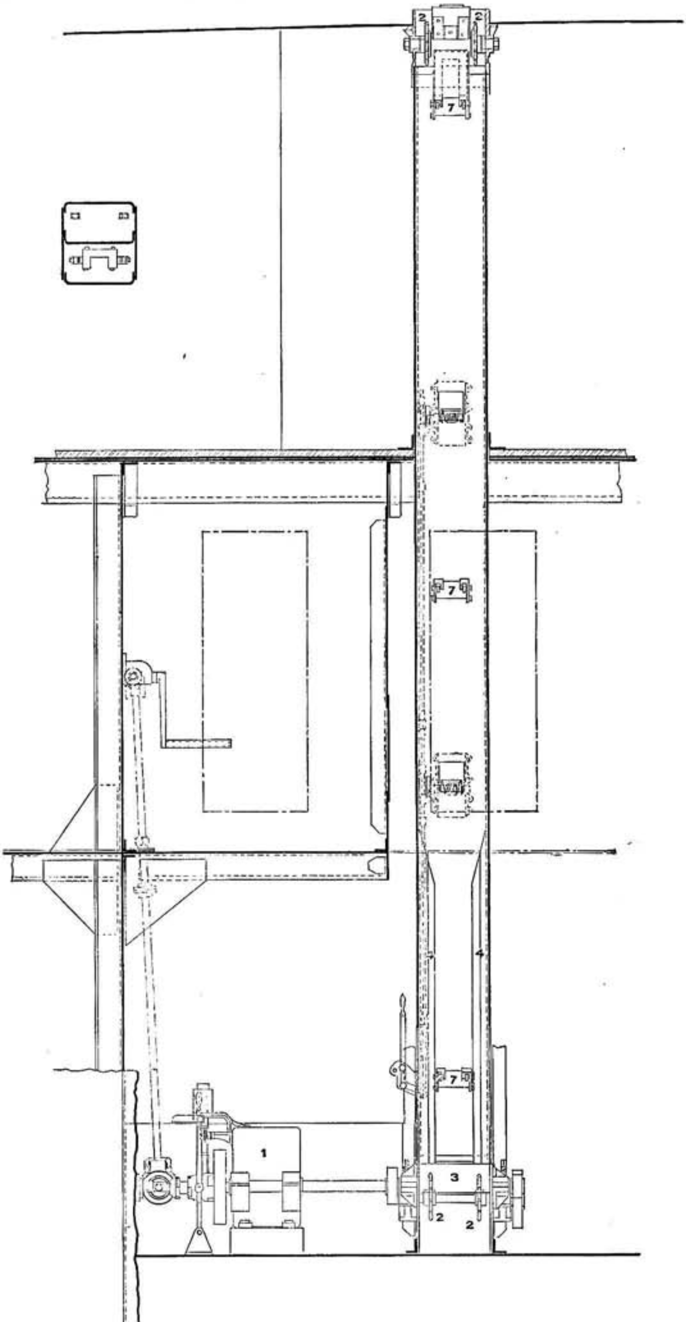
By this arrangement, when one box has just started from the magazine, one is half-way up the trunk and one is about to be delivered on the main deck; two carriages are on their way down to the magazine.

10. The supply system of the "Maine" is shown in Plate V. The hoists for the 12-inch guns lead upward from the handling rooms as previously described; those for the other kinds of ammunition are of the same general type as the 5-inch hoist of Plates VI and VII.

The four 6-inch guns on the upper deck are each supplied by a charge and shell hoist which loads in the ammunition passage and delivers near the gun it supplies. The forward pair of main-deck 6-inch guns (which, being well forward of the turret, do not appear in the plate) also each have a charge and shell hoist which leads from the forward end of the forward 6-inch magazine group and delivers on the main deck at some distance from the guns. In addition to the six already mentioned, there are ten 6-inch pieces mounted in broadside on the main deck within the citadel. Ammunition is supplied to these guns by two charge and shell hoists which lead from the ammunition passages and deliver at about the center of the battery, and by four charge and four shell hoists leading from the forward and after 6-inch magazines and shell rooms and delivering at each end of the citadel. It is not likely



5-INCH AMMUNITION HOIST, PORT SIDE, LOOKING OUTBOARD.



PORT SIDE LOOKING FORWARD

Mark.	Name.	Description.	Material.	Remarks.
1	Motor	To specification		3¾ H. P. at 375 revls.—Shunt wound, 160 volts
2	Sprockets	9,659" Pitch-diam.: 12 teeth	Cast-steel	
3	Loading-table		Naval brass	
4	Guides		Wood	
5	Trunk		Steel	
6	Pawl		Cast-steel	Fitted with spiral brass spring
6	Pawls		Cast-steel	
7	Carriages	Fitted with brass rollers	Cast-steel	Number of carriages on each hoist

that both sides of a ship will be engaged at the same time—at least not for a long period—and all hoists of the unengaged side may be utilized at need for the supply of the engaged guns.

The 3-inch ammunition is delivered to its guns on the bridge deck by two hoists leading from the *port* ammunition passage and delivering at that level. On each side are two hoists for sending up 3-pounder and 1-pounder ammunition in its boxes; these four hoists are all loaded in the ammunition passages. The after ones deliver on the upper deck; ammunition for the guns on the after bridges and in the top is hoisted from the upper deck by hand whips. The starboard forward hoist delivers on the bridge deck and the port one on the upper bridge; from here it is whipped up to the top by hand.

11. A handling table, with accessories, for 8-inch turrets is shown by Plate VIII. In many of the earlier turrets of this size one hoist was originally fitted by which the single car was hoisted to a crane in the turret and then swung over to the loading position. It was found that ammunition could not be supplied with sufficient rapidity and the system was unsatisfactory for other reasons as well. Because of the restricted size of the turret and ammunition tube it was not possible to substitute two independent hoists, but the arrangement finally adopted has resulted in a much higher rate of fire.

The tracks for the ammunition cars lead to the center of the turret and at a half-way point, between the turret and handling room, the tracks spread sufficiently to allow the two cars to pass each other, one car (loaded) coming up while the other (empty) passes it going down, both being operated by the same wire rope and a single electric motor. The car being at rest, the projectile is pushed out of the shell compartment on top of a table *A* (see Plate VIII), and brings up by the base against a stop at the rear end of the table. The projectile, *M*, is then rolled into side rests, N, on the top of plates, *B*, which pivot at the lower end, *C*, to the turret floor, and which are allowed to swing off from the table, a distance controlled by the chain, *g*, bringing the projectile opposite the bore of the gun, *E*. The projectile is then shoved home by the rammer. The powder charges are removed from the car by hand and passed to the loader who places them in the chamber.

By this arrangement, with a projectile in each of the pair of guns, three on the table and side rests, and one in the loaded car, six projectiles are ready for use. Overhead cranes are done away with and the supply of ammunition is much more rapid and more easily handled.

12. **Communications for Battery Control.**—The electric system of communications which has been adopted for U. S. naval ships is shown diagramatically by Plate IX. The order indicators which are installed at the guns and at their principal ammunition supply stations are brass boxes with round pieces of ground glass set in their fronts. The orders are printed on these glasses in heavy black letters and in a pocket behind each is an incandescent lamp of low candle power, the glow of which, when lighted, shows through and thus indicates the order transmitted. This shows clearly in darkness, and, while of course the orders on all the glasses, lighted or not, can be plainly read in daylight, those which *are* lighted are the plainer and mistakes in reading cannot occur. The lamps have each an individual leading wire and a *common* return (see heavy line) running to the transmitter in the conning tower; the leads of each indicator are enclosed in an ordinary pipe conduit. The current is taken from the dynamo at the voltage of the ship's lighting circuit.

The *transmitter*, in the conning tower, is a regular switchboard with the standard orders written down its middle. Its switches are arranged so that an impossible order cannot be transmitted; thus the two upper orders may be transmitted to every indicator, but the guns cannot be ordered trained on bearings *not* in their arcs of fire; similarly, shrapnel can be ordered only for those guns for which they are provided. The several indicators, moreover, will only show such orders as apply to the stations they are installed in.

The indicator of each supply station is connected in parallel with the indicators of those guns which receive their ammunition from that station. Such indicators show only the orders to commence and cease firing and the kind of ammunition to be sent up. In many cases, provision is made for transmitting orders to the magazines and shell rooms directly from the batteries to which they belong; this will prove useful in the case of a breakdown in

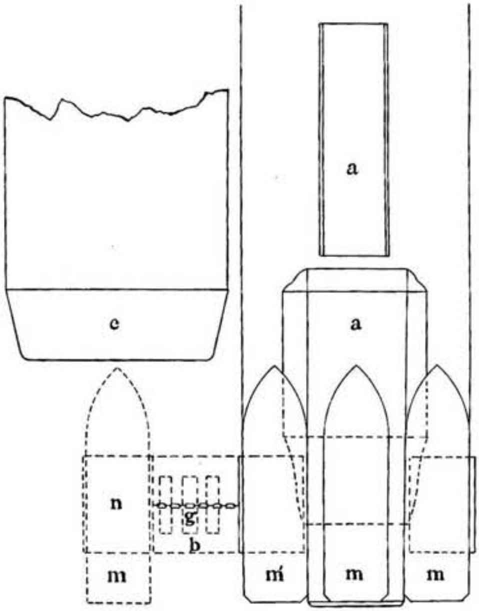


FIG. 1. TOP VIEW.

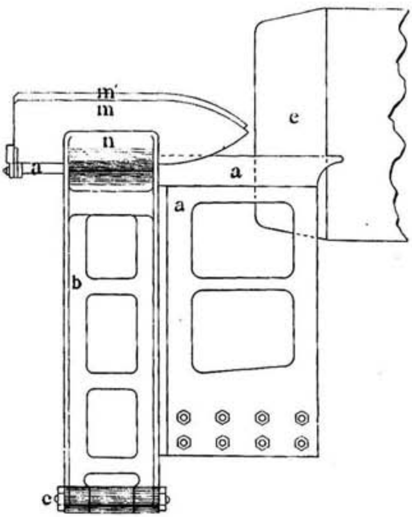


FIG. 2. SIDE VIEW.

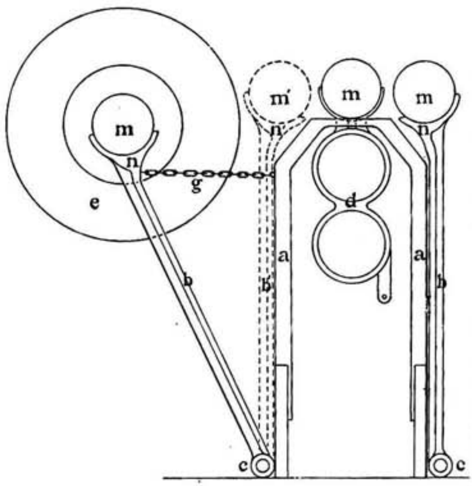


FIG. 3. REAR VIEW.

UPPER END OF AMMUNITION HOIST FOR 8-INCH TURRETS.
["INDIANA TYPE"]

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Faces Plate IX,
Chapter XXVIII,

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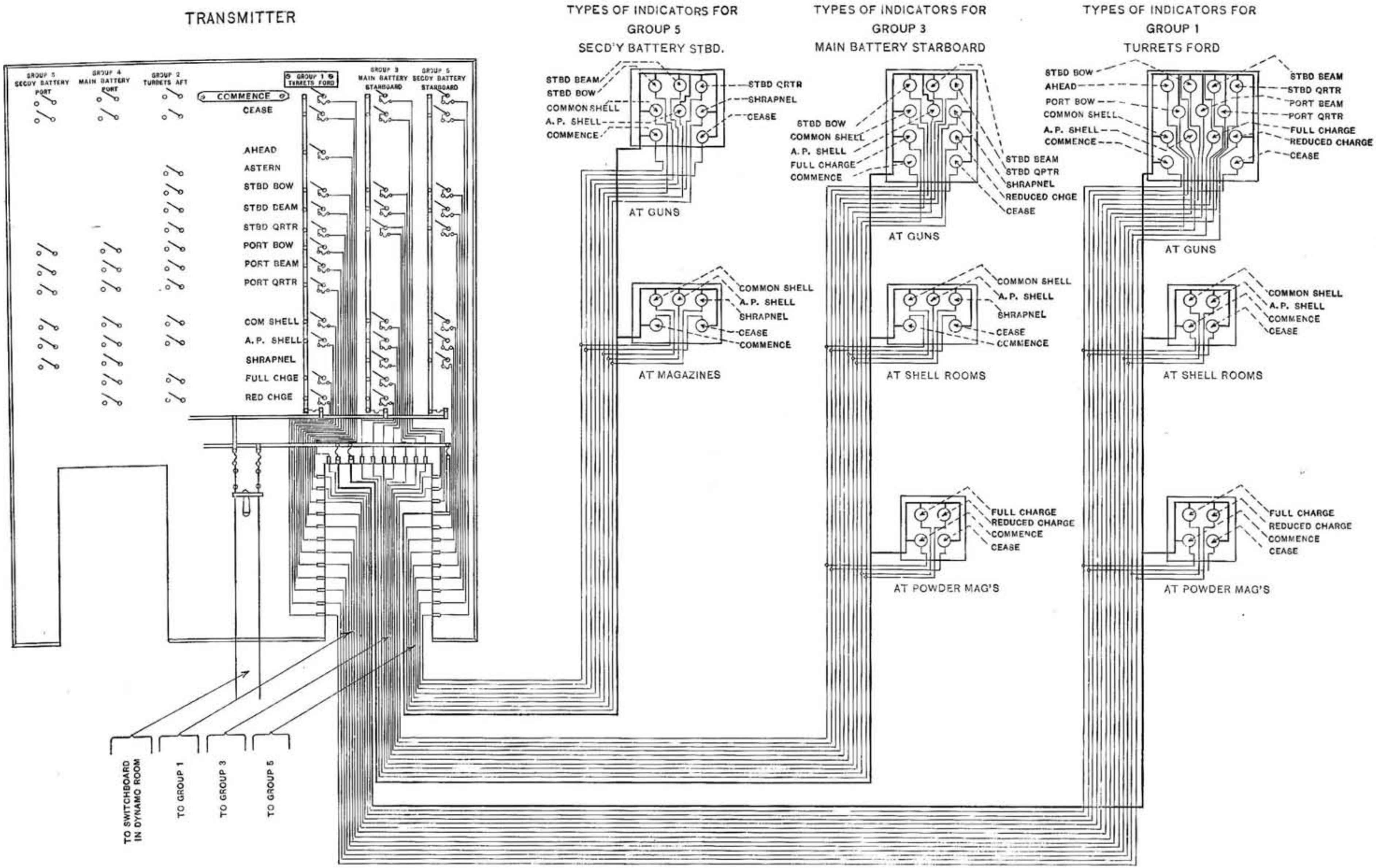

DIAGRAM OF ELECTRIC COMMUNICATIONS.

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the connection to the conning tower. Everything about the systems is as positive in its action as an electric device can be. Orders may be transmitted as long as current can be fed to the lamps; the latter are sensitive only in same degree as ordinary ship's lamps.

CHAPTER XXIX.

ARMOR PROTECTION FOR SHIPS AND GUNS.

By Lieutenant Cleland Davis, U. S. Navy.

1. **Historical.**—In so far as it is of record, John Stevens, of Hoboken, New Jersey, was the first to propose the use of armor for the protection of vessels of war. In 1812, he designed a vessel whose battery was protected by inclined armor. This plan, however, like nearly all innovations, was not seriously considered. The Stevens family then began a series of investigations and experiments with armor that extended over many years, and in 1842, Robert L. Stevens submitted a report to a committee of Congress containing the results of these experiments, being deductions concerning the laws of the resistance of armor and the penetration of projectiles. These results were of great value to naval architects, and the principles therein set forth are to this day, many of them, applied in naval construction.

In 1854, Congress appropriated money for an ironclad on the Stevens design, and construction was begun, but the vessel was never finished. The development of the gun, however, in energy, range and accuracy, and the introduction of explosive shell rendered the use of armor imperative, and thus we see the construction in 1855 immediately after the laying of the keel of the Stevens Battery, by France and England, of armored batteries and ironclad vessels. This marks the adoption, generally, of wrought iron armor. The United States quickly followed.

Still further improvements in "Ordnance," especially the adoption of the rifled gun, made it apparent that wrought iron armor applied to vessels of war was of little avail against improved projectiles fired from rifled guns, so that strenuous efforts were made to increase the resisting power of armor, with the result that *compound armor* was developed in England, and *all* *steel armor* in France. The efficiency of these two types was about equal. The former had greater resisting power, but the tendency of the steel face to flake off over considerable areas made it unsatisfactory. However, the two about held their own until 1889 when the introduction of nickel into steel materially increased its toughness and power of resistance, so that homogeneous nickel steel plates showed marked superiority over the compound type. Almost immediately thereafter, in 1890, the Harvey process was developed in the United States. The success of this process marked the greatest advance in the history of armor, and it was soon adopted by all the naval powers. The Krupp process, which followed in 1895, effected an improvement over Harvey, though the principle of resistance remained the same.

During all this time numerous experiments were made in the effort to produce novel types that would effect a saving in weight and cost of armor. Target structures of almost every conceivable description were made and subjected to ballistic test. There were homogeneous cast iron and wrought iron plates, and built up targets of every description, including sheets of metal bolted together and presented flat or edgewise; alternating layers of metal and wood; of metal and rubber disposed in various ways, and of springs behind solid plates and between the laminations of built up plates. The targets were fired at vertically, and inclined at various angles.

These experiments demonstrated the following general principles:

1. That, to be efficient, armor must be homogeneous as to mass, so as to concentrate the resistance.

2. That armor should be rigidly attached to the structure, and that devices such as springs or rubber cushions do not add to its resisting qualities, but are in reality a source of weakness.

3. That inclined armor, designed to deflect the projectile upon impact, is more efficient for purposes of protection (when the angle of inclination is greater than the biting angle of the projectile) than vertical armor of equal weight, but when the angle of inclination is not greater than the biting angle, vertical armor of equal weight is more efficient. The introduction of the cap

has not altered this principle. Considering the plate as opposed to capped projectile, the biting angle is reduced to about 20°.

2. Resistance of Face-hardened Armor.—Modern hard-faced supercarbonized armor is the logical development of the principles of compound armor. With the advent of the modern armor-piercing projectile it was recognized that to be defeated the projectile must be made to expend its energy upon itself. In other words, the resistance must be so concentrated as to greatly reduce the velocity of the projectile in a short space. The ideal armor plate, therefore, would be composed of a metal homogeneously hardened so as to make it as hard, if not harder, than the projectile itself, and at the same time so tough as not to be shattered upon impact of the projectile. But this was then, as it is now, metallurgically impossible of attainment. Thus the idea of *compound armor* was evolved, which consisted essentially of a high-carbon steel face and a wrought-iron back. It was manufactured by casting steel upon wrought iron, the latter being heated and otherwise prepared to make as intimate a union as possible. This was a distinct advance upon the homogeneous wrought-iron armor, and compound armor was immediately adopted by nearly all the leading powers. The limitations of manufacture, however, made it practically impossible to obtain an intimate union between the two metals and so prevent flaking off of the steel plates, and caused the compound type to be superseded by homogeneous steel and homogeneous nickel-steel plates in the latter part of the 80's. Advance in the art of manufacture of steel enabled the manufacturers to produce steel of what was then considered a very superior quality.

The application by Mr. Harvey of the well-known process of cementation to homogeneous steel plates quickly followed, and the result was the perfection of the compound armor principle, namely, *an integral plate supercarbonized to a considerable depth, giving an extremely hard, elastic face, bound together and supported by a tough back, having a minimum tendency to crack.* The action is as follows: when the point of the projectile strikes the face of the plate, the hard inextensible surface does not immediately give way, but there occurs an elastic or diaphragmatic dishing, in diameter equal to about three times the calibre of the projectile. The stress of impact is thus distributed over a considerable area, and the concentrated resistance works to suddenly stop the projectile and causes it to break up through its own inertia. Krupp armor has exactly the same ballistic characteristics as that produced by the Harvey process. Its superiority is due to its composition, which makes it susceptible to treatment that improves the ballistic qualities. For example, Krupp armor has a greater affinity for carbon than the manganese nickel-steel used in the Harvey process, so that although the cementation may be accomplished in exactly the same way, carbon will be absorbed to a greater depth in Krupp than in Harvey plates, giving a greater depth of hard face in the former and thus increasing its resisting powers accordingly. Another point of superiority is a less tendency to crack in Krupp plates.

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.

Theory of the Cap.—The introduction of the cap which is now fitted to all armor-piercing projectiles materially reduced the resisting power of hard-faced armor. For so simple a device, its effect is marvelous. It is efficient only against hard-faced armor, and it is a question whether its action has been satisfactorily explained. The most plausible theory is as follows: When the mass, consisting of projectile and cap, meets the hard face of the plate, the latter is elastically dished and the resistance concentrated. The cap is strong enough to transmit the stress of impact, and at the same time the projectile proper is not stopped suddenly as is the case with an uncapped projectile; it continues to advance through the cap, its passage through the latter being comparatively easy, and when the point reaches the plate it finds the latter already dished, perhaps, to its elastic limit. The resistance then becomes purely local, and the effect is similar to the impact of an uncapped projectile against a homogeneous plate, save the flow of displaced metal to the front which occurs in the latter.

3. General Discussion.—The prime function of armor as applied to vessels of war is to keep out shell, and the qualities sought to be obtained are first, resistance to penetration, and second, a minimum tendency to crack. With modern methods of securing armor the importance of the latter is not so great as formerly. It is, however, an element of weakness in that it makes the plate more vulnerable to the next hit, so far as resistance to perforation goes.

The question of racking effect on the structure of the ship and on the machinery, main and auxiliary of the vessel is not now considered. Proving Ground experiments have shown that the shock of impact is dissipated by work on the projectile, or is absorbed by the armor plate and its supports.

4. Method of Securing.—Wood backing is used for the purpose of insuring a good fit and to provide a sufficient length of armor bolt. It is being gradually reduced in thickness, and the tendency is to discard it altogether. In battleships of the Virginia class, and in subsequent designs, it has been given up for barbettes. It is not used for conning tower armor, signal tower, interior armor, or gun positions outside the casemate, except turrets. The four-inch side and casemate armor of the St. Louis class is being fitted without backing, the plates being disposed vertically, 8 feet wide and about 17 feet long, extending from the armor shelf to the port sill.

5. Armor Bolts.—The following table shows the size of bolt for each thickness of armor:

Size of bolt.	Thickness of armor.
1.5 inches	To and including 5 inches.
2.0 inches	From 5 inches to 9 inches.
2.4 inches	From 9 inches to 13 inches.

Armor bolts are so spaced as to provide one bolt for every five square feet of surface, so far as the framing behind armor will permit, except in the case of 3-inch armor for which one bolt for about six square feet of surface is used.