rounded shape and smooth surface; a light powder more easily than a dense one.

Smokeless powder is not ignited as easily as black or even brown powder, and for this reason an *ignition charge* of the former is used for each charge of smokeless.

26. Inflammation and Combustion.—When grains of powder are united to form a charge, and fire is communicated to one of them, the heated and expansive gases evolved insinuate themselves into the interstices of the charge, envelop the grains and ignite them one after another.

The propagation of ignition is called *inflammation,* and its velocity, *the velocity of inflammation.* It is much greater than that of combustion, and it should not be confounded with it. When powder is burned in an open train, fine powder inflames more rapidly than coarse; such, however, is not the case in firearms, owing to the diminution of the interstices. If a charge were composed of mealed powder, the flame could no longer find its way through the interstices, and the velocity of inflammation and combustion would become the same. The ignition charge used with smokeless powder serves not only to ignite the powder but to increase the velocity of inflammation.

Now, supposing one grain or particle alone be ignited, it will first be inflamed over its whole surface, and the progressive combustion will take place from the exterior to the interior. Its *rate of combustion* will therefore depend upon both its shape and size, leaving out entirely, for the present, the question of density and hardness. A grain of spherical or cubical form will expose less surface to ignition in proportion to its volume than one of an elongated or flat shape, and will consequently require a longer period for the combustion of its entire mass; the larger the grain also, the longer will be the time required for its combustion.

Looking, then, at one grain of powder by itself, we may say that the larger it is, and the more nearly its form approaches a sphere, the longer will its combustion take and the slower will be the evolution of the gas. When, however, we come to regard the action of an aggregation of such particles, as in the charge of a gun, the *rate of ignition* of the whole charge is also affected by the size and shape of the grain.

The part of the charge first ignited is that near the vent, and the remainder is inflamed by contact with the heated gas generated by the combustion of this portion, so that the rate of ignition of the whole mass will be regulated by the greater or less facility with which the gas can penetrate throughout the charge, which is itself dependent upon the shape and size of the interstices between the grains. If the grains be spherical and regular in form, the interstices will be comparatively large and uniform, and the gas will penetrate the mass with facility; again, the larger the grains, the larger the interstices between them. If, on the other hand, they be flat or flaky and irregular in shape, the passage of the gas will be more difficult, and the rate of inflammation of the charge will be reduced.

We see, therefore, that the considerations which affect the more or less rapid combustion of an individual grain of gunpowder, also affect the rate of ignition of a charge of such grains, but in an opposite direction; so that a form of grain which will individually burn rapidly, may offer an increased resistance to the passage of the heated gas through the charge, and thereby retard its ignition, while a grain which will burn more slowly may allow of the charge being more rapidly ignited. In the case of perforated grains, however, the rates of ignition and combustion are both increased by the perforations.

By varying the size and shape of the grain alone, a powder may therefore be obtained, a charge of which shall be ignited rapidly throughout, but burn comparatively slowly, or one which will be ignited more slowly, but when once inflamed burn very rapidly. It is necessary to draw a clear distinction between a rapidly igniting and a quickly burning powder.

27. **Velocity of Combustion.**—The velocity of combustion is the distance passed over by the surface of combustion in a second of time, measured in a direction perpendicular to this surface.

The velocity of combustion varies with the purity, proportions, trituration, or incorporation of ingredients, density, and condition of the ingredients, also with the pressure and temperature under which the powder is burned.

28. **Effect of Temperature on Combustion.**—The heat developed increases with the charge, and as the velocity of the gases

increases with their temperature, it is therefore evident that a large charge is consumed quicker than a small one; it is also true that the quantity of heat absorbed by the surface of the bore is much less sensible when the charge is great than when it is small; that is, the heat absorbed is proportional to the surface, or the square of the calibre of the gun, and the heat developed increases as the cube of the calibre.

29. **The Resistance of the Projectile.**—When the projectile offers a great resistance its motion in the bore is less rapid, and it evidently follows that the inflammation takes place in a space which diminishes as the resistance increases. The smaller this space, the more heat is generated, the higher the temperature of the gases, and the greater their velocity; and there follows from all these causes a train of effects which accelerates the inflammation and combustion of the charge.

30. **The Point of Ignition.**—When a quantity of powder is contained in a closed space all the sides of which offer an equal resistance, it is evident that the complete inflammation will be quickest when the fire is applied to the center of the charge.

In cannon, however, the force developed does not meet with the same resistance in all directions; the projectile yields as soon as sufficient force acts upon it; and as the combustion of the powder requires a definite interval of time, it follows that a great part of the charge is not consumed until after the displacement of the projectile.

Now, the position of the interior orifice of the vent may influence the time required to displace the projectile, and this influences the inflammation of the charge. For example, with the regulation vent, it is the rear part of the charge which first takes fire; the inflammation is communicated to the adjacent parts and promptly reaches the projectile; the gases expanding displace it, and the inflammation takes place in a larger space than that at first occupied by the charge.

31. **Density.**—The density and hardness of the grains of powder are of quite as vital importance as their size and form, in determining the rate of ignition and combustion of a charge.

By density is meant the quantity of powder actually present in a given bulk.

It is important that this quality should not be confounded with hardness. A substance may be very hard and yet be of a low density. A powder with a very hard surface may be really less dense than another the surface of which is softer. Of course, very high density cannot be communicated without producing a considerable degree of hardness; but powder can be made hard without rendering it very dense, by pressing the dust in a comparatively dry state.

32. **Hardness** seems to bear a direct relation to the power exerted in compressing, while density does not. Black powder dust, at a high degree of moisture, say six per cent, can be made very dense by application of moderate pressure, while that of 1 per cent can only be brought to the same point in density by the exertion of enormous force. Of the two, the latter will be the harder powder.

The action of gunpowder in guns is theoretically treated in works on "Interior Ballistics."

High Explosives.

33. **High Explosives** are used in naval warfare for the charges of torpedoes, submarine mines, for the bursting charges of special shell, and for the destruction of the enemy's resources in machinery, fortifications, buildings, bridges, etc., when necessary and desirable.

There are numerous high explosives, the principal ones being nitro-glycerine, gun-cotton, explosive gelatine, dynamite, picric acid and its compounds, lyddite, maximite, dunnite, emmensite, etc. Of these, gun-cotton, maximite, and dunnite are preferred in the United States for military purposes. Many others are used in Europe, and new forms are being constantly produced for which extravagant claims are made.

34. **Nitro-glycerine** * was discovered in 1847 by A. Sobrero, and is a nitro substitution produced by the action of nitric and sulphuric acids on glycerine. In order to insure stability and reduce its sensitiveness to shock to a minimum, no cheap materials should be used in its manufacture; the glycerine should be above

* *Naval Intelligence Annual*, 1890.

proof, the nitric acid of a specific gravity of 1.5 and the resulting explosives carefully washed to remove all traces of free acid. When ignited in small, unconfined quantities it burns, but with close confinement it explodes either by ignition or when heated to 257° F. It freezes at 40° F., in which state its sensitiveness to concussion and detonation is very much reduced. It can be detonated by shock, gunpowder fuse or detonator, and generates six times as much gas as gunpowder, which is expanded by the great heat produced to occupy thirteen times the volume. It is insoluble in water. Its use is now generally confined to the dynamite and gelatine forms.

35. **Gun-cotton** was first manufactured by Schönbein in 1845, but proved dangerous to handle until it was rendered safe by the method of purifying, pulping, and compressing it. It is produced by the action of sulphuric and nitric acids on cellulose in the proportion of three parts of sulphuric to one part of nitric acid. Under the action of these acids, according to their strength and methods employed, trinitro, binitro, and mononitro cellulose are produced, gun-cotton being the first-named, viz., trinitro cellulose. It is only soluble in acetone; unconfined and ignited it burns away rapidly; struck with a hammer on an anvil a part of it explodes, the remainder being blown away; when heated to a certain temperature it explodes, and when confined or compressed, it explodes from shock, heat, or detonation.

To Mr. E. O. Brown is due the credit of discovering that wet uninflammable gun-cotton is capable of being detonated by a strong detonator, or by an ordinary detonator with a priming charge of dry gun-cotton, the size of which depends upon the percentage of water contained. This discovery greatly increases the value of gun-cotton as a military explosive, not only for submarine work, but also as an explosive for shells; for wet gun-cotton is not affected by shock, will not explode when penetrated by rifle bullets, nor upon shock of discharge when loaded in shells; it is comparatively insensible to sympathetic explosion, and is not exploded by heat. In 1871 the English government tested this last-named quality by burning in bonfires two lots of a ton each, of gun-cotton, containing thirty per cent moisture. In one case the explosive was in disks in a closed tank, and in the other it was divided among eighty closed packages. In both cases the gun-cotton burned away without explosion.

Steps have been taken to coat disks of wet compressed gun-cotton, in order to prevent decomposition by the evaporation of moisture. In 1883 Von Forster and Wolff patented the process of dipping gun-cotton in acetic acids for a few seconds which dissolves the cotton on the surface and forms a coating. But this was found to crack, so they now coat the disk with paraffine, and only treat the hole in this manner to facilitate detonation. Schulhof has patented a so-called weather-proof gun-cotton which is said to possess non-hygroscopic qualities, to be insensible to shock or blow, and to be capable of exploding by detonation or heat of over 300° F. He impregnates dry gun-cotton with molten tallow or mutton fat, getting rid of the superfluous grease by pressure and washing with bisulphuret of carbon and benzine.

The details of the manufacture of gun-cotton are given in the chapter on smokeless powder.

36. **Wet Gun-cotton** is known to be a perfectly safe uninflammable and inert explosive in the absence of a strong detonating force. It may consequently be stored aboard ship, or conveyed and used with land forces, without any special precautions and without the slightest risk from any cause. Its keeping qualities are excellent.

Wet gun-cotton contains about 20 to 25 per cent of water. With a delay-action fuse it has given excellent results as a bursting charge for shells, having been fired through comparatively thick armor plate before exploding. It seems to be superior to the English lyddite in this respect, the latter being more locally violent.

Wet gun-cotton charges for torpedoes are usually made up of small blocks or disks to fit the head. Recently, however, foreign manufacturers have pressed the charge into one solid mold exactly fitting the head of the torpedo, with a hole through the center for the primer.

37. **Gun-cotton in Shell.**—Dry gun-cotton may not resist the shock of discharge of a powder gun under service conditions. Experiments in England from 1864 to 1867 showed that charges of 3 pounds in specially lined shell, when fired with an initial velocity of 1300 f. s., were exploded prematurely; and although

18-pound charges have been successfully fired from a 24-pounder gun, and 6½-pound charges from a 20-pounder gun at the Torpedo Station, it simply indicates the perfection reached in its manufacture at that place.

When wet or saturated with paraffine, gun-cotton is safe for use and will penetrate armor without explosion. When a small percentage of water is used, the detonation produced by impact is of a low order. Wet gun-cotton cannot be ignited by rifle bullets fired into it at short range.

As generally used for explosive charges of shell, wet gun-cotton is compressed into disks and prismatic or cylindrical grains. When used in the latter form, the charges are about one-third less weight, and compactness is produced by paraffine, or mixtures of it and canauba wax, poured in at a temperature of 180° F., a hollow space being left in the axis of the shell for the detonating charge. This detonating charge is composed of a fuse and dry gun-cotton, and must be of sufficient size to produce an explosion of the first order.

38. Gun-cotton for Submarine Mines.—Experiments in England have shown that with a ship of the Hercules type, with double bottom empty, and coal bunkers full, 95 pounds of gun-cotton exploded in contact will sink her; 220 pounds at 30 feet horizontal distance inflicted no serious damage; and 500 pounds at a horizontal distance of 100 feet will probably seriously damage the pipes and machinery. Wet gun-cotton, in addition to the fulminate primer, requires about 1 pound dry gun-cotton disks to cause an explosion of the first order.

39. Blasting Gelatine was invented by Nobel in 1879, and is composed of finely divided nitro-cotton dissolved in nitro-glycerine at a temperature of 100° F., the effect of the combination being to supply the requisite amount of oxygen to insure complete combustion. It contains from 93 to 95 per cent of nitro-glycerine, being more and more gelatinous in proportion to the quantity of nitro-cotton, the thinner being the more susceptible to detonation and liable to liquefy and exudate. When slowly heated it detonates at 400° F. It is less sensitive to blows than either nitro-glycerine or gun-cotton, and requires a strong detonator and close confinement to develop its full force, not being sensitive to detonation by influence. It is unaffected by water, and is more sensitive when in a frozen state. Pure ingredients are essential to insure its stability. It freezes at a relatively low temperature and is then more sensitive to explosion by concussion.

40. **Explosive Gelatine** is blasting gelatine with the addition of a certain amount of camphor, which reduces its sensitiveness. The proportion generally used is nitro-glycerine 89 per cent, nitro-cotton 7 per cent, and camphor 4 per cent. It burns at 570° F., requires special strong detonators or ordinary detonators with gun-cotton or dynamite primers, and is less sensitive than most of the high explosives. It is insensitive to shock, rifle balls having been fired into it at short range without exploding it, and it is believed to be as stable as gunpowder when manufactured of pure ingredients. It is unaffected by immersion in water.

41. **Dynamites** are explosives in which 75 per cent nitro-glycerine is absorbed by some porous substance, thus rendering it safer to handle and less liable to explosion from shock. They are of two classes, viz.: (1) those with an inert base; and (2) those with an explosive or combustible base.

42. **Dynamite No. 1** is the one most commonly used and belongs to the first class, consisting of nitro-glycerine absorbed by kieselguhr, or rotten stone, from which the water and organic matter are driven out, in the proportions of 75 per cent nitro-glycerine and 25 per cent kieselguhr. It can be detonated by shock, and by a metallic gunpowder fuse or detonator, its sensitiveness increasing with the temperature, and it explodes at 360° F. It freezes at 40° F. and remains frozen at a considerably higher temperature, in which state it is insensitive to shock, being unaffected by rifle bullets fired into it, but is more susceptible to explosion by ignition. Great care is necessary in thawing it, as the records of mining accidents show that 95 per cent of them are caused by this operation. Frozen cartridges are not susceptible of detonation, but loose and granular dynamite, even when frozen, can be detonated, its violence being diminished. Compacted it is more sensitive to explosion by ignition than when loose, and water disintegrates it. In tropical countries it loses its strength by gradual evaporation of the nitro-glycerine. Herr

Edward Liebert and Baron von Dahmen have produced so-called safety or non-freezable dynamites. Liebert's invention consists in adding a small per cent of isoamylic nitrate either to the nitro-glycerine itself or to the dynamite, but the substance Dahmen uses is not known. The latter explosive, after being subjected to a temperature of from — 20° to — 15° C. for 24 hours, remained perfectly plastic, exploded with almost as much force as ordinary dynamite, and also by influence. Under ordinary temperatures it is less sensitive to shock than ordinary dynamite and is slightly stronger.

43. **Carbo-dynamite,** invented by Boreland and Reid, belongs to the second class of dynamites, and consists of 20 parts of specially prepared cork carbon containing 90 parts of nitro-glycerine.

44. **Emmensite** was invented in 1888 by Dr. S. H. Emmens and belongs to the picric powders. The compounds bearing the name emmensite all contain a nitrated carbolic acid which is produced by dissolving, at a gentle heat, an excess of commercial picric acid in concentrated fuming nitric acid (50° to 52° C.), the solution, on evaporation, depositing it in yellow prisms. These prisms are heated in a dish until they become semi-liquid, and are then mixed with a mineral salt, some other ingredients being added for special purposes. There are four grades, the best, No. 1, consisting of equal weights of the nitrated carbolic acid, nitrate of soda, and nitrate of ammonia. The cake so produced is then pulverized in a mortar, the smaller the grains the more rapid being the explosive action. When heated it melts into a resinous state without exploding, and a match ignites it with great difficulty. When struck by a hammer on an anvil, or a rifle bullet at short range, only the part immediately in contact explodes, and it has been fired as a projectile from small arms against iron plates without exploding on impact, thus proving its insensitiveness to shock. Its keeping properties have been put to a two years' test without its deteriorating, and when mixed with some substance to act as a reducer it can be used as a propellant. Its specific gravity is said to be 1.8. Although it is hygroscopic, its strength is but slightly affected by repeated saturation with water, and subsequent drying.

Experiments have been made with emmensite as the bursting charges of high explosive shell and it has been generally successful.

45. Picric Acid forms the basis of a great many "ites," no less than thirty being shown in the English "Dictionary of Explosives," and on account of its peculiar qualities it has shown itself to be a very potent instrument in the hands of charlatans for deceiving the uninitiated.

Picric acid is nitrated indigo, and the color of the product is yellow instead of blue. It was used as a dye before it was known to be a high explosive.

At the present time picric acid is made, not from indigo, but from nitrated coal-tar products, and is known chemically as "tri-nitro-phenol."

When pure picric acid is loaded into an armor-piercing shell it will usually detonate by the time the point has penetrated about three inches, although there have been instances where VI shell charged with pure picric acid have penetrated a 5-inch plate.

The addition of dinitro-benzol—a substance similar to picric acid but which melts more easily—renders picric acid less sensitive, and vaseline still further reduces its sensitiveness. For armor-piercing shells a mixture of:

87% picric acid,
10% dinitro-benzol,
3% vaseline,

is sufficiently insensitive, it is claimed, to penetrate almost any thickness of armor with a proper delayed-action fuse.

46. Lyddite.—The English lyddite is a picric acid compound modified with dinitro-benzol and vaseline. Remarkable claims are made for this explosive, and it has been used so extensively by the British that it merits attention. It is claimed that it may be stirred with a red-hot iron, thrown into a furnace or boiled away in a saucepan without explosion. It may be melted in hot water and then poured into shells, where it forms a dense, compact mass, and may be fired through thin armor. When set on fire with a hot iron it will burn while the iron is in contact with it, but the flame will go out when the iron is removed. As a bursting charge it is violent and blows the shell into many very small fragments.

The effect of lyddite against ships is terrific when the shell penetrates between decks. It will be very effective against unarmored or thinly armored ships, but as yet it has not penetrated as much armor as some other high explosives.

47. Lyddite in the Boer War.—The British used lyddite extensively for bursting charges in shell against the Boers. A writer on this subject states: "The lyddite shell has proven one of the distinct disappointments of the war. It has no effect whatever against intrenchments. On exploding, which it almost always does as far as I could judge, it only makes a small hole about a foot deep and two feet in circumference, and breaks into a few fragments. . . . The poisonous gases confined in a close space would be very destructive, but in the open air they are too quickly dissipated to do any injury." Another writer on the same subject says: "The results obtained by the large lyddite shells have been slight. Their effect on men sheltered behind boulders or posted in deep trenches was nil. This was proved at Paardeberg, when 98 pieces of various calibres bombarded Kronje's camp—a square of less than 1000 yards—at 2500 yards' range for eight days and nights, and only put *hors de combat* some 100 men out of 4140. The demoralization produced by the noisy explosion of the lyddite soon passed away, the effect of the shell being so feeble. Boers were seen to be thrown down by the wind of the projectile bursting close by them and even their clothes were torn off, but they got up again without a scratch. *The effect of shrapnel on the contrary was always dreaded.*"

This testimony regarding high explosive shell in the open is significant. In confined spaces, like the decks of a ship, the effect may be very different.

48. Maximite.—Maximite has given such remarkable results as the bursting charge in armor-piercing shells that it may come into general use for that purpose.

The composition of maximite is a secret. It is claimed that it cannot be exploded by ignition or shock, and when heated in an open vessel it will evaporate like water so that the temperature cannot mount to the explosive point. The shells are filled by pouring the explosive into them. Its expansion while solidifying into a dense and solid mass packs it so hard as to prevent the formation of air spaces. The terrific force of the explosion is shown by the regularity and character of the 7000 fragments into which a 12-inch fused shell weighing 1000 pounds has been blown. So far as experimented with maximite appears to have excellent chemical stability and keeping qualities. Shells loaded with it have been fired through armor plates from three to twelve inches thick and either exploded in the plate or just beyond it, showing that it will stand the shock of impact. The fuse used with it is the secret invention of Captain Dunn, U. S. Army.

An account of its action, in the experiments at Sandy Hook, will be found in the chapter on "Penetration of Projectiles."

49. Dunnite.—The composition of dunnite is a secret. As a bursting charge for shells it promises to rival maximite when used with a proper delayed-action fuse.

50. The Use of High Explosives in Warfare.—As the utility of high explosives in warfare is now recognized, the desirability of regulating their sensitiveness is very apparent. The various dirigible and automobile torpedoes carry large charges of explosives, but they are limited as to range and accuracy.

The first successful steps toward accomplishing this problem were where very heavy charges of high explosives were projected at low initial velocities and moderate ranges, as by the Zalinski pneumatic gun; but the use of projectiles so discharged, containing 60 per cent by weight of high explosive is limited to torpedo effect, to countermining, to mortar or high-angle fire against forts and to use against the unprotected sides or exposed decks of ships.

This was a great step, but progress required a still greater advance. Direct fire and penetration are desired; and in order to increase the danger space it is necessary to reduce the height of the trajectory, and therefore increase the initial velocity which increases the range. To accomplish the penetration of modern armor, armor-piercing shell, with very thick walls, must be used; and as the space containing the bursting charge is proportionally reduced, the necessity of a more violent bursting charge than gunpowder; and one that is not so liable to explode by the heat generated before perforation, is evident.

For use against exposed bodies of men gunpowder is still an excellent agent, being less local than the high explosives and not breaking the shell into such small fragments, it being maintained that to disable a man a shell fragment should weight not less than 1 ounce and have a velocity of 500 f. s., which is equivalent to one-eighth foot ton. The high explosive, however, in addition to its great moral effect is capable of throwing pieces of the shattered projectile to the rear, which principle is used by the Germans against men protected by bomb proofs.

As bursting charges for thick armor-piercing (a. p.) shells, or for large demolishing charges in thin shell to be thrown inside fortifications and engineering works, the high explosives are most efficient. But when employed against armored vessels the effect is very slight unless the projectile penetrates a certain distance before explosion, in which case it attains its maximum effect. Charges as high as 500 pounds of gun-cotton have been exploded against the face of vertical armor without producing any material damage, and it is not believed that the heaviest projectile yet fired from the Zalinski pneumatic gun will seriously damage a vessel if exploded in contact with the face of the armored sides.

For use against torpedo boats, Chalon states that high-explosive projectiles from rapid-fire guns are very much more effective than gunpowder projectiles from large guns. He shows that projectiles containing 22 pounds of gelatine dynamite will sink a torpedo boat within a radius of 37 feet of the explosion, and 13 pounds, at 29 feet distance. Hence, the object to be accomplished is to so deaden the explosive that it may remain inactive until the desired moment, when it is exploded by a fuse. This has been effected to such a degree that an initial velocity exceeding 2000 f. s. has been reached; penetration of 12 inches of steel before explosion has been accomplished; and successful delayed-action fuses are now in use.

For use in projectiles the requirements of an explosive are essentially the same as for submarine use, excepting that the quality of being unaffected by water is unnecessary, and its effectiveness is not decreased by being quick in its action; but non-sensitiveness to shock is of the most vital importance.

51. Résumé.—The question of high explosives is by no means definitely settled, but there can be no doubt that they will have very important uses in naval warfare.

For submarine mines, gun-cotton and explosive gelatine seem to give the best results. They are safe and very powerful when exploded under water.

For general naval use, gun-cotton is at present unexcelled. Its stability, safety, and its powerful effect when exploded by a suitable primer all combine to make it most acceptable.

The results obtained in the trials at Sandy Hook, described in the chapter on "Penetration of Projectiles," were apparently very favorable to maximite and the Army high explosive as bursting charges for shells, as well as a triumph for Captain Dunn's delayed-action fuse. No trials abroad have as yet given better results than these.

CHAPTER XXIV.

GUNPOWDER.

Prepared by Lieutenant Joseph Strauss, U. S. Navy.

1. **A Description of the Military Gunpowders** of to-day would, so far as they relate to the propulsion of projectiles, exclude all but smokeless powder. Black powder, which has been in use for nearly six centuries, is little used except for igniting smokeless powder charges, for explosive shell, for primers and fuses and for saluting charges. Brown, or cocoa, powder so named from its peculiar color, came into extensive use some twenty years ago, but is no longer manufactured.

2. **Black Powder** is an intimate mixture of 75 parts of saltpetre, 15 of charcoal and 10 of sulphur. The proportion of ingredients has been varied from time to time during the history of gunpowder, but it is a notable fact that we are using to-day the same relative quantities that were in use at the earliest times.

The ingredients after being incorporated in a suitable mill, are caked and then broken up into granules. Shell powder and powder for fuses and primers are very fine grained; ignition charges for guns up to 6-inch are made up of similar powder; while ignition charges for the larger guns are formed from the large hexagonal prisms or from a single cake of suitable size and shape. Saluting charges are made up of irregularly shaped grains considerably larger than the shell powder.

3. **Brown Powder** has played such an important part in the development of the modern gun that it merits a word in passing. Its composition is similar to that of black powder, except that the proportion of saltpetre is increased and the amount of sulphur is decreased to 2 or 3 per cent; a small amount of sugar about equal to that of the sulphur is also incorporated. The light color is due to the fact that the charcoal used is underburnt.

The incorporated ingredients are formed under heavy hydraulic pressure into regular hexagonal prisms having one or more axial perforations. These prisms are packed into powder bags so as to form a solid mass with the perforations continuous and parallel to the axis of the gun. The result of the peculiar composition of the powder, the size and arrangement of the grains, is to make the mass burn slowly and *progressively*, that is, to increase the ratio of burning surface to weight of unburnt powder as the shell moves forward in the bore. By this means the pressure exerted on the walls of the gun is lessened at the breech and increased at the chase.

4. **Advantages of Smokeless Powder.**—When black or brown powder is exploded in a gun, only about 35 per cent of its weight is converted into gas, the remaining 65 per cent being mainly dissipated in dense smoke, while a portion of it remains in the bore as solid residue. The smoke and residue are entirely inert, and instead of aiding in the propulsion of the projectile, actually reduce its initial velocity by taking away from the expanding gases sufficient force to eject the solid particles from the gun. Thus, taking the 6-inch gun firing a projectile of 100 pounds with a charge of 50 pounds of brown powder, 17.5 pounds of gases are formed which must not only do the work of expelling the projectile at a velocity of 2100 f. s., but 32.5 pounds of solid material must also be expelled, making the projectile weigh, for the moment, virtually 132.5 pounds. Now if the propellant were of a material that could all be turned into a gas of equal force, we would have gained: 1st, the considerable advantage of a less weight of ammunition to stow and handle; 2nd, a greater velocity; 3rd, no fouling of the bore, and 4th, no smoke and an unobstructed view of the target after firing each shot.

These advantages were recognized quite early in the last century, when attempts were made to obtain a substitute for black powder, and gun-cotton was the first material extensively used for the purpose. In order to control its rate of burning, the gun-cotton fibre was spun into threads and then twisted or braided. Considerable success attended these attempts, but owing to irregular ballistic results and other accidents, the use of this material as a propellant was finally abandoned.

5. **Gun-cotton Powder.**—Gun-cotton is of several varieties,

depending upon the degree of nitration the cellulose attains in the process of manufacture. A fairly sharp dividing line may be drawn between the grades of high and low nitration in that the latter are soluble in a mixture of ether and alcohol, while the former are not. In general, this division occurs when the percentage of nitrogen amounts to 12.75; above that point gun-cotton is insoluble. Gun-cotton containing less than 12.75 per cent nitrogen may be perfectly dissolved into a jelly-like substance, which, after the solvent is evaporated off, becomes a hard, tough, translucent mass. In this condition it burns regularly in parallel layers without smoke; it may be pressed into any desired shape, and it cannot be detonated. This material pressed into grains of the required form constitutes the U. S. Navy smokeless powder.

6. Manufacture of Smokeless Powder.—Perfectly clean dry cotton is digested for 30 minutes in about fifty times its weight of a mixture of strong sulphuric and nitric acids. During this time a reaction between the cellulose and nitric acid takes place in which nitryl (NO_2) takes the place of the hydrogen in the cellulose and water is liberated. The function of the sulphuric acid is merely to combine with the water, thus keeping the strength of the nitric acid up to the standard necessary to obtain the proper degree of nitration.

The strength of the acid mixture, its temperature, the duration of the digestion period, the dryness of the cotton and the condition of the mass of fibres as to agglomeration all exert an influence on the resulting product, both as to its nitration and solubility. The digestion is usually performed in a centrifugal wringer, and after its completion the acid is drained off and the gun-cotton is freed from residual acid as much as possible by the revolution of the centrifugal basket. When in this state it is removed from the wringer and "drowned" in a large tank of fresh water, after which it is given a rough washing in fresh water while being revolved in the basket of another centrifugal.

7. Purification of Gun-cotton, Pulping, Poaching.—The gun-cotton is now transferred to large tanks and steamed for two days, the water being changed several times during the process. It is then removed to the *pulping machine,* where it is ground between knives into a fine pulp, the water being constantly changed and sodium carbonate added from time to time in order that any free acid in the cotton may be neutralized. This process generally requires about seven hours.

The pulp is next transferred to large circular vats called *poachers,* and is then steamed and stirred for a period of about two days. During this time fresh water is frequently added, and after a certain period of stirring the pulp is allowed to settle and the top water decanted off. This operation is repeated until all trace of alkalinity has disappeared and the pulp passes the required heat test for stability.

8. Dehydration of Gun-cotton.—Before being capable of solution in ether-alcohol it is necessary to free the gun-cotton from water. To accomplish this it may be first wrung out in a centrifugal which reduces the amount of water to about 25 per cent; or, if partially freed from water, it may be run through a "wet machine," an apparatus used in paper mills for a similar purpose. The latter process leaves 40 or 50 per cent of water in the pulp, but it is nevertheless in good condition for treatment in the dehydrating press. This press consists of a vertical cylinder with a removable bottom over which an inverted hydraulic cylinder is arranged. The overhead cylinder has a piston head which plays in the barrel of the first cylinder below it. The piston is raised and a charge of about 50 pounds of the wet cotton is put in the press. The piston is then forced down under a pressure of about 200 pounds per square inch; this presses out some of the water and leaves the pulp in a compact mass. Twenty-five pounds of alcohol is poured in on top of the pulp, the cylinder is closed and an air pressure of 100 pounds per square inch is admitted over the alcohol. Under this pressure the alcohol is forced to percolate rapidly throughout the mass and has the effect of leaching out the water in its passage through the cotton.

After all the alcohol has been forced through, the cotton is subjected to a pressure of from 2500 to 3000 pounds per square inch in order to squeeze out the surplus alcohol. An amount of alcohol is allowed to remain equal to about 25 per cent of the alcoholized cotton. When in this condition it is only necessary to add ether to the amount of half the weight of the mass in order to provide the necessary solvent.

9. Mixing.—The cotton is next thoroughly ground up in the mixing machine. This apparatus consists of a cast-iron box with a bottom consisting of two half cylinders in which helicoidal steel blades are revolved. The operation of the machine for about an hour serves to thoroughly mix the solvent with the cotton and leaves it at the end of that time in a condition much resembling damp cornmeal. It is removed from the mixer and pressed into cakes weighing about 50 pounds each. The material now has the consistency and appearance of stiff glue or jelly, and is therefore referred to as *colloid*.

10. Pressing.—In order to further complete the solution, the colloid is forced through a thick steel strainer under a pressure of 5000 pounds per square inch. It is again reformed into a cylindrical cake under 200 pounds pressure and is then inserted in the graining press to be formed into grains.

11. Graining.—The graining press consists of a horizontal steel cylinder fitted with a piston operated by an hydraulic press. The colloid is gradually forced through a die under a pressure varying from 4000 to 6000 pounds per square inch, depending upon the size of the grain. The colloid issues in a continuous grain which is chopped into lengths usually about twice the diameter, and is then ready for the dry house.

12. Form and Size of Grain.—The size of the powder grain varies with the calibre; the larger the gun the larger the grain; in general terms, the lineal dimensions of grains of similar form are in direct ratio to the calibres of the guns in which they are employed. As compared to the old forms of powder, smokeless powders produce relatively large volumes of gases per unit weight of material, yet they burn away more slowly; the result is that grains of smokeless powder for a given calibre are smaller than those of the black and brown varieties.

Naval smokeless powder is translucent and varies in color from a light lemon to a deep brown, almost black. These variations in color depend generally upon variations in the process of manufacture, and possibly upon the water used. The material possesses a marked degree of toughness, which operates to render the powder regular and progressive in action and prevents the unconsumed portion of the charge from crumbling or disintegrating in the gun, under the influences of heat and gas pressure due to those portions of the charge already consumed.

The form of grain in use for the .236-inch small arm is the flat rectangular; for the .30-calibre Krag it is in the form of small short cylinders; for all other calibres the multi-perforated cylinder is at present employed, there being seven holes through each grain. Some powder for 1-, 3- and 6-pounders has been in the form of thin ribbons about 2 inches long and ½ inch wide. The perforations of cylindrical grains are for the purpose of keeping the burning surface practically constant, thus securing the quality of progressiveness which is of prime importance.

When smokeless powder is employed in the form of a sphere or a cube, the cube burns smaller in all directions; consequently the surface upon which the flame is operating is rapidly diminished in all directions and the quantity of gas diminishes. If, however, the powder is formed in long strips, the amount burning from the ends is immaterial; consequently the reduction only takes place in one direction—that is, in the thickness, and therefore the reduction of the burning surface is much less rapid than in the case of spheres or cubes. For this reason powder that is formed in flat strips, or in long tubes, is more *progressive;* that is, it evolves equal quantities of gas in equal intervals of time. In the case of the multi-perforated grain, the burning surface decreases from the outside and increases from the inside. This form is, therefore, the most progressive of all.

13. **Drying the Powder** is accomplished in buildings fitted with trays with wire net bottoms, air being admitted underneath the trays; or the powder is placed in large bins through which warm air is forced by blowers. For powder of the large calibres five or six months are required to dry out the solvent down to 3.5 per cent. It is extremely difficult to reduce the volatiles to a lower point in thick-walled grains; in powders for the minor calibre guns the volatiles are reduced to about 2 per cent in a month or six weeks of drying.

The diameter of the grain is reduced about one-third and the length shortened one-tenth as a result of the drying. After tests have shown the powder to be dry enough, it is carefully blended and then packed in air-tight cases ready for shipment and proof.

14. Ballistics of Smokeless Powder.—An example of the ballistic value of smokeless powder is shown in the fact that in a 6-inch 40-calibre gun, 20 pounds of navy smokeless gives a velocity of 2000 f. s. with 10.8 tons pressure, whereas 45.5 pounds of brown powder are required to produce the same velocity, while the resulting pressure is 15 tons. With brown powder, 2100 f. s. is the greatest velocity obtainable in the 6-inch 35-calibre gun, while the smokeless easily produces a velocity of 2300 f. s. with less pressure and a charge weighing 25 pounds. The 12-inch 35-calibre gun gives a velocity of 2100 f. s. using 425 pounds of brown powder. Exactly half this weight of smokeless will produce the same velocity.

In general, the new type large-chambered guns of 40 and 50 calibres length require a charge of smokeless weighing about 40 per cent of the weight of the projectile. In the 12-inch 40-calibre gun this charge gives a velocity of 2800 f. s.; in the 6-inch 50-calibre gun the velocity for such a charge is 2900 f. s. These velocities would be impossible with black or brown powder.

It is certain that the powder is absolutely progressive in its burning. When small charges are used with consequent low pressures and rates of burning, it frequently happens that partially burned grains are recovered in front of the muzzle of the gun. In all cases it has been observed that the outside diameter has been reduced and the inside diameter of the perforations increased in exactly equal amounts. The walls may be reduced to the thinness of paper, but the general structure of the grain remains intact.

15. The Ignition Point of smokeless powder is about 185 degrees C, and notwithstanding that this is lower than that of brown or black powder, the material is less inflammable, and the charge requires a starting or ignition charge of black powder. High pressures are sometimes produced when the charge is ignited imperfectly, and it is therefore necessary to fill the chamber with a burst of flame so that ignition may take place simultaneously throughout the mass. In the 12-inch gun, one or two pounds of black powder are sufficient to supply the necessary amount of flame, and this is divided equally among the four powder bags, the ignition powder being placed at the bottom of each bag.

16. Nitro-glycerine Powders.—There are practically but two kinds of smokeless powder in use to-day, the powder described above and which is classed as a *gun-cotton powder,* and another class known as *nitro-glycerine powder,* which is made of a mixture of gun cotton and nitro-glycerine.

17. **Cordite and Ballistite** are the two best known examples of nitro-glycerine powders. The former consists of a mixture of 58 parts of nitro-glycerine, 37 parts of trinitro cellulose, and 5 parts of vaseline. Acetone is used as a solvent, and the resulting composition, after the acetone is evaporated out, has the consistency of very hard beeswax and varies in color from a dark yellow to brown. *Ballistite* is very much the same kind of powder. The action of cordite, as compared with gun-cotton powder, is very brusque, hence, the powder is pressed out into solid cords and the charge is made up of bundles of these cords. By this means, the ratio of burning surface to weight of powder is less than it would be were the grains provided with longitudinal perforations; but this entails the loss of the quality of *progressiveness* which obtains with a multi-perforated grain. Hence, guns using cordite cannot attain the high muzzle velocity that can be had with gun-cotton powders.

18. **Advantages and Disadvantages of Nitro-glycerine Powder.**—Cordite possesses a considerable advantage in that a very much lighter charge is required for *ordinary velocities* than is required with gun-cotton powder. Besides this, its power admits of the grains or cords being arranged in a uniform way in making up the charge, which, other things being equal, would give more uniform ballistics. It is, however, extremely sensitive to heat and cold, the velocity dropping with its temperature, and its pressure rising under the reverse condition. A very strong objection to its use lies in the fact that the rifling is rapidly eroded, causing an increasing and permanent loss of velocity that finally compels the relining of the gun. One more objection obtains with nitro-glycerine powder, and that is, that the nitro-glycerine exudes, or evaporates out, and impregnates the powder bag; thus the danger from free nitro-glycerine is added to the disadvantage of a powder with a decreasing velocity and variable pressure.

Powders of this class have been made with only 25 per cent of nitro-glycerine. They were brittle, and gave very erratic and sometimes disastrous results, and in general have been abandoned, although the great consideration of reducing the weight of the charge for field guns has led to further experiments.

19. Erosion.—Erosion of the bore seems to depend upon the amount of heat imparted to the metal. As might be expected, when the work is so largely increased, smokeless powders raise the temperature of the gun to a much higher point than do black or brown powders. As has been stated, nitro-glycerine powders are very objectionable in this respect, and in the thinner-walled guns where the firing is very rapid and sustained, considerable erosion takes place even with the navy smokeless powder.

Special gas checks have been devised abroad, which prevent the escape of the gases beyond the rotating band of the projectile. This of course preserves the uniformity of the velocity within limits, but does not prevent the ultimate erosion and consequent disabling of the gun.

20. Pressures and Velocities.—Both the pressure and velocity vary directly with the weight of charge, when the charge is not too small to prevent sufficient pressure being developed to burn up all of the grains before the shell leaves the bore, or, when the charge is not so large as to give pressures exceeding 17 or 18 tons. At that point there seems to be a deflection in the pressure curve, and a small increase in the charge may produce a very great pressure. The residual volatiles contained in the smokeless powder act as a deterrent, and if they are permitted to escape after the powder has been proved and a charge assigned, excessive pressures will result. It is, therefore, of great importance that the charges be always kept hermetically sealed; and conversely, it is necessary to protect the powder from the deposition of moisture on its surface or it will become "slower" and fail to give the designed velocity.

21. Stability.—Certain tests for the stability of nitro-cellulose powders are given which depend upon the fact that decomposing powder evolves the fumes of nitrous acid. In these tests the powder is heated above the atmospheric temperature to a point where all powders, no matter how stable, would eventually decompose. The *time* between the beginning of the heating and the appearance of the first signs of decomposition is taken as a measure of the stability. Instability is generally caused by insufficient purification of the gun cotton of which the powder is made; but subjecting the powder to direct sunlight, or permitting it to sustain an abnormally high temperature for a protracted period will cause any powder to decompose.

22. Effect of Instability on Pressure.—Instability does not manifest itself in *higher pressures* in the gun. On the contrary one would look for *lower pressures* in a powder that had lost considerable oxygen and nitrogen. A strong odor of ether in the charge is often erroneously taken as an indication of decomposition. But it may be of no importance whatever, as a very minute quantity of ether is sufficient to strongly impregnate the atmosphere of a large room.

23. Tests for Stability.—In making the tests for stability, it is necessary to observe such directions as are given, with the greatest care and accuracy. All of the tests now known are entirely empirical and if the standard method is departed from in the slightest particular the value of the test is nullified.

CHAPTER XXV.

PRIMERS, EXPLODERS, CARTRIDGE CASES, DISTANCE PIECES, POWDER BAGS, IGNITION CHARGES, AMMUNITION BOXES AND POWDER TANKS.

Primers.

1. The primer of any gun or firearm is the specially constructed device which, when exploded by the direct action of the firing mechanism, ignites the powder charge by its flame of discharge and fires the gun. The primer, for R. F. ammunition, is in the center of the base of the cartridge case; for B. L. and Q. F. ammunition it is placed in the firing lock and its flame travels through the mushroom stem to the powder charge. There are at present three varieties of primers in use: *percussion, electric,* and *combination* primers.

2. **Percussion Primers** are those containing a sensitive explosive which is fired by the jar or friction resulting from the blow of the firing pin or hammer. The explosive in commonest use is fulminate of mercury which explodes by percussion, by friction, by the electric spark, by heating to about 300 degrees or by contact with concentrated nitric or sulphuric acid. It is extremely sensitive, particularly when mixed with sand or ground glass, and is very sudden in its action, though its explosive force is, weight for weight, not much greater than that of gun powder. It is the best known substance for detonating dry gun cotton; equal weights of much more violent explosives will, when substituted for it, often fail to produce an explosion of the first order. For use in primers, the fulminate is usually mixed with nitre, mealed powder or other substances to moderate its explosive properties.

The simplest example of the percussion primer is the well-known "cap" shown in Fig. 2, Plate II. The end of the outer case is bent inward to form an anvil against which the fulminate is forced by the blow of the firing point; the percussion and the friction of the particles on each other cause an explosion, the flame from which passes through the small holes in the anvil and ignites the powder. The cap is "vent sealing," on the same principle as the cup gas check, and, unless it is pierced by a too violent blow of the firing point, there will be no "blow back" of gas. The cap shown by Fig. 2 gives enough flame of discharge for small arm cartridges but not for larger ammunition; for the latter purpose the primer comprises a small magazine of mealed black gun powder, a very inflammable substance, which multiplies the effect of the cap.

The percussion primer used in all 1-, 3- and 6-pdr. ammunition is shown in Fig. 1, Plate I; the magazine contains 42 grains of powder and is closed by a paraffined paper wad.

The percussion primer, shown in Fig. 1, Plate II, was formerly used in main battery R. F. ammunition; that employed in all 3-inch, 50-calibre, ammunition is similar to it. These primers are driven into the primer pockets of the cases before the powder charge is put in. The use of B. L. percussion primers will be discontinued.

3. **Friction Primers,** still supplied in a few instances for the impulse charge of Whitehead torpedoes, were for a time used in B. L. guns as an alternative for the B. L. percussion primers. They contain a roughened wire running through the fulminate and ending in a loop at the rear end; the firing lanyard is attached to this loop and, when it is sharply pulled the roughened wire is drawn out creating friction enough to explode the fulminate.

4. **Precautions.**—All ammunition containing fulminate primers is sensitive to shock and must be handled with great care. A swinging breechblock should not be closed too forcibly, as its blow on the base of the cartridge case may give shock enough to fire the primer and cause a premature explosion with disastrous results. The jar given by closing the breechblock in an ordinary manner, on an empty chamber as it happened, has been known to explode a fulminate primer in the firing lock.

5. **Electric Primers,** containing no fulminates, superseded the percussion primers of main battery guns, as being safer, more reliable in themselves and because they materially reduced the firing interval. A R. F. primer which came into extensive use is

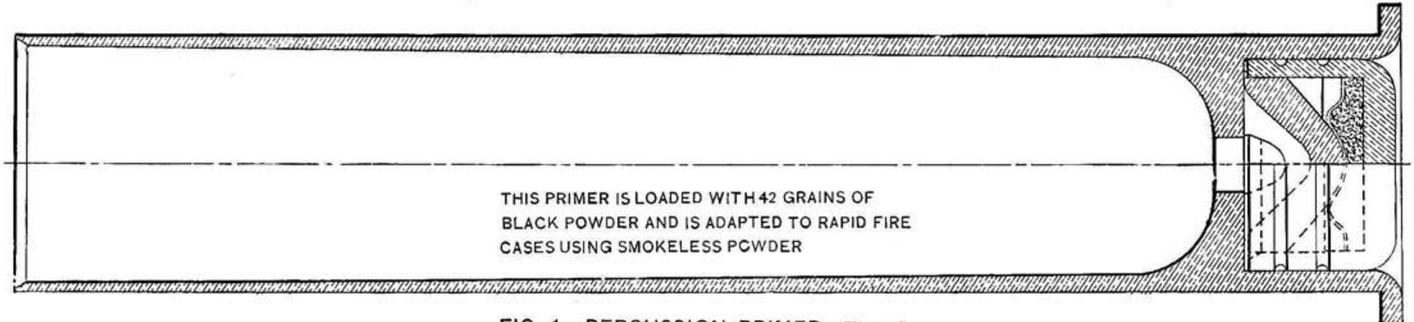


FIG. 1. PERCUSSION PRIMER. Par. 2.

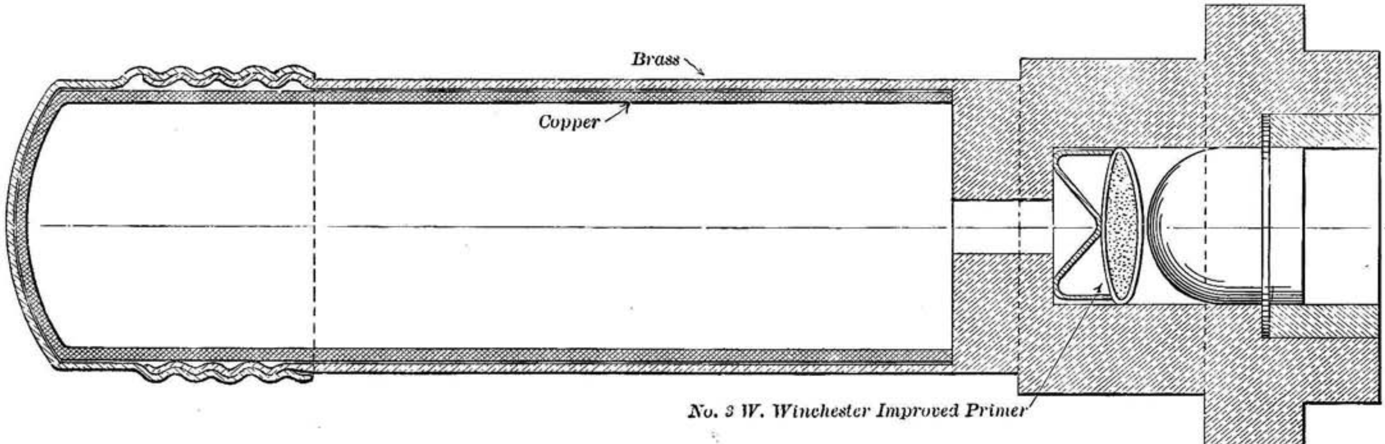


FIG. 2. EXPLODER FOR WHITEHEAD TORPEDO. Par. 7.

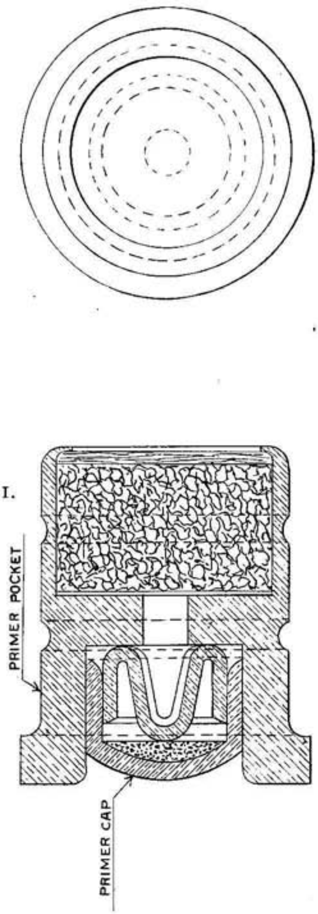


Fig. 1.

PERCUSSION PRIMER FOR 4-INCH, 5-INCH AND 6-INCH R. F. CARTRIDGE CASES. Par. 2.

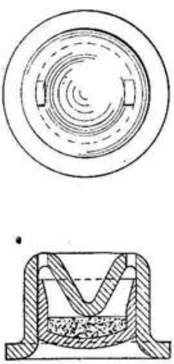


Fig. 2.

PRIMER CAP FOR PERCUSSION AND COMBINATION PRIMERS. Par. 2.

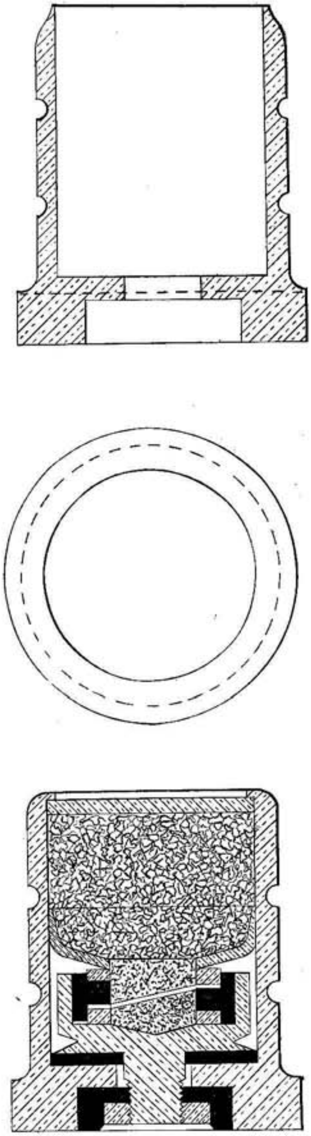


Fig. 3.

ELECTRIC PRIMER FOR 4-INCH, 5-INCH AND 6-INCH R. F. CARTRIDGE CASES. Par. 5.

POCKETS FOR PRIMERS.

	Percussion.			Electric.		
	Dim.	Plus.	Minus.	Dim.	Plus.	Minus.
Total length	.745	.015	.000	.760	.000	.015
Diameter of powder chamber.	.489	.003	.000	.4865	.000	.001
Diameter of counterbore.	.3445	.000	.0005	.344	.0005	.000
Depth of counterbore	.300	.002	.000	.117	.000	.003
Depth of powder chamber	.345	.015	.000	....	....	....
Diameter of flash hole	.100	.005	.000	.158	.003	.000
Stud—diameter	....	....	....	.450	.000	.003

shown in Fig. 3, Plate II. In outward form, it is exactly like the percussion primer of Fig. 1. The firing point rests against a portion which is insulated by vulcanite and air spaces from the main body of the primer but is electrically connected to it by a thin platinum wire, the *bridge*, which, as shown, runs to the checking cup. The current flows from the insulated firing point, over the bridge to the primer, thence through cartridge case, gun and mount back to the firing battery. When the current is admitted by the firing key, the bridge instantly becomes hot, fires the wisp of dry gun cotton and mealed powder around it which in turn ignites the primer magazine and thus the main powder charge. It is to be noted that it is the heat generated in the bridge and not an electric spark that effects the explosion; the firing battery and one end of the bridge are grounded and the return is through "earth."

Electric B. L. primers, with ground return and also some having double leading wires, were supplied; but all are now being replaced by combination primers.

6. A Combination Primer is in itself on electric primer and a percussion primer, combining the functions of both in one case. As long as all the mechanism and attachments are intact these primers are used electrically and the percussion feature is the alternative; the firing mechanism, as we have seen, is arranged to work in either manner.

Combination primers are furnished for B. L., Q. F., and R. F. guns of the main battery; the different varieties as shown in Plate III. Fig 1 is the R. F. "drive" primer and Fig. 2 the R. F. "screw" primer; the only difference between them is in the way of attaching them to the cases; in general, screw primers are for the largest calibres and drive primers for the others. The B. L. and Q. F. primer is shown in Fig. 3. The details are clearly shown and require no description if the principles of simple electric and percussion primers are known; all of them are vent sealing. When firing by percussion the cap is not directly struck by the firing pin but by the point of a plunger forced inward by its blow.

These primers have given great satisfaction in service—it is to be kept in mind that they contain fulminate and the precautions

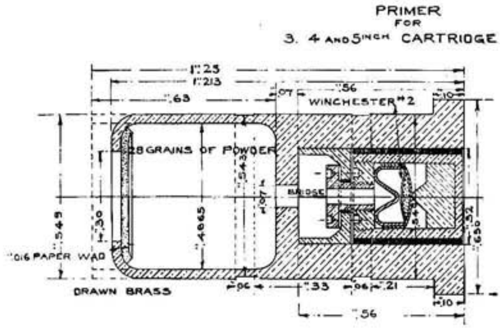


Fig. 1.

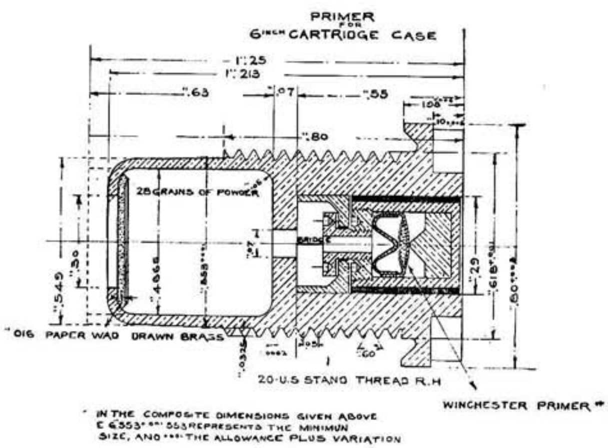


Fig. 2.

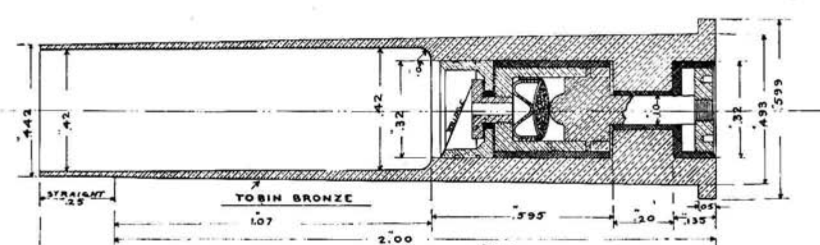
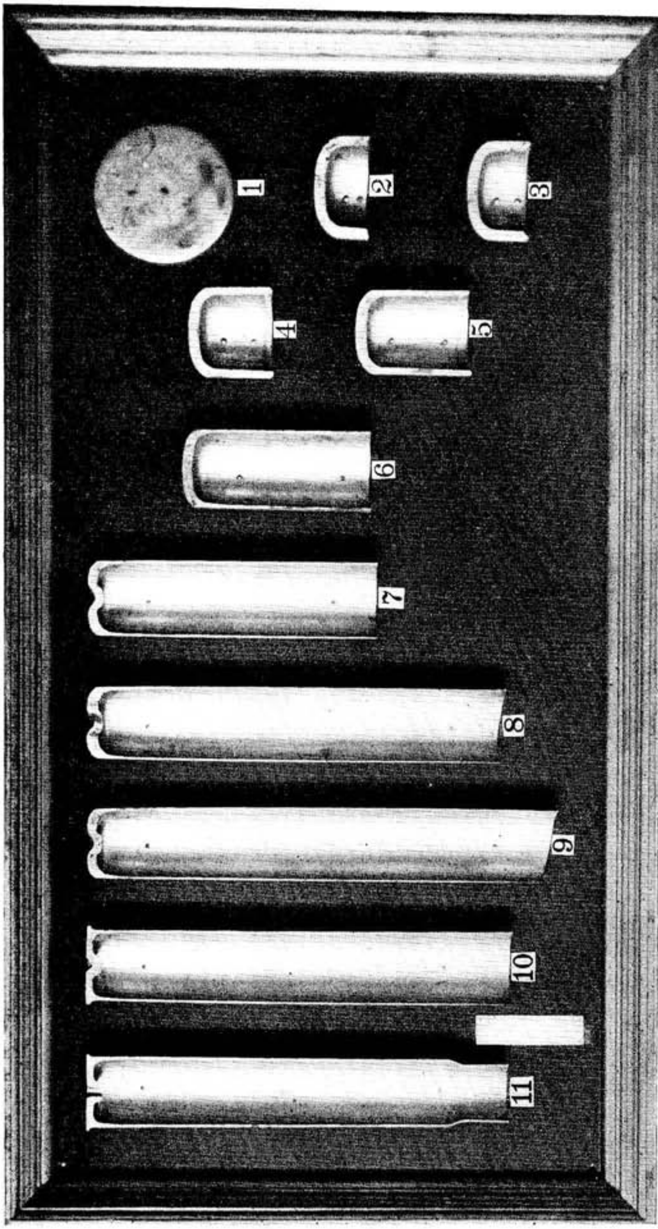


Fig. 3.

COMBINATION PRIMERS.



STEPS IN MANUFACTURE OF CARTRIDGE CASES.

needed in the use and handling of ordinary percussion primers are called for.

7. **Exploders** are the devices which detonate the gun-cotton charges of torpedoes—for Whitehead torpedoes, they correspond, perhaps more nearly to *fuses* than to primers. The Whitehead exploder is shown in Fig. 2, Plate I; it is carried in the war nose and is fired by percussion. When the torpedo strikes, the firing pin of the war nose drives in the small striker which is held in place ordinarily by a brittle shearing pin as shown. This striker explodes a cap which in turn fires the 35 grains of fulminate in the attached copper magazine; the *dry* gun-cotton primer is detonated by the exploder and in turn detonates the main charge of *wet* gun cotton in the warhead.

The exploder for the service gun-cotton mine is of the same size and shape as the above but is fired electrically. There are two leading wires from the firing battery to the primer which, within the latter, are reduced to a thin bridge; the explosion is caused by heat as in the simple electric primer.

8. **Metallic Cartridge Cases.**—The metal is 70 parts Calumet and Hecla copper and 30 parts zinc. It is cast in slabs from which disks, called "blanks" are cut, and each blank is then put in a vertical press and forced through a die by a plunger forming the first cup. This process is repeated once or twice according to the size of the case, and the second or third cup is then placed in horizontal draw presses and forced through successive dies by plungers, its length being gradually increased and its thickness diminished to the desired dimensions.

The case is then taken to an indenting machine which puts a dent in the center of the head of the case, thus raising a portion of metal on the inside of the head to provide a seat for the primer.

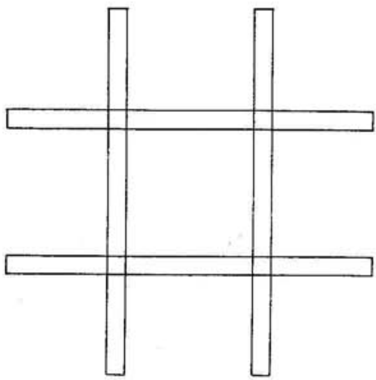
The case is then placed in a vertical heading machine which strikes a blow and forces the metal into a die to form the head, and it is next placed in a lathe, turned to exact dimensions, guaged and stamped.

After each drawing the case is annealed by heating in a furnace and cooling slowly. Scale is removed by acid. Plate IV shows the successive steps in drawing the case from the first cup.

9. **Primers for Cartridge Cases.**—These are described under

the head of "primers." They are always counter sunk a short distance below the head of the cartridge case for safety in handling. Sometimes failure to explode the percussion primer has been attributed to its being counter sunk too far. It is more likely that such failures are due to insufficient throw of the firing pin in electric or percussion firing, or to injury to the pin.

10. **Fit of Shell in Cartridge Case.**—The base of the shell should fit tightly and be perfectly secure in the cartridge case in fixed ammunition. When the shell is loose there is danger and delay in loading, and the space in the cartridge case being increased, the ignition charge may work away from the primer and cause hang or missfires.



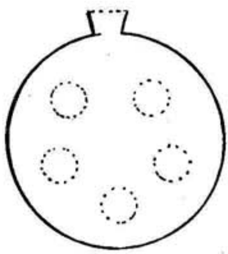
PASTE BOARD DISTANCE PIECE.

11. **Distance Pieces for Cartridge Cases.**—The space between the powder and the base of the shell in 3-, 4-, 5-, and 6-inch cartridge cases was sometimes filled with excelsior. This made smoke and was objectionable. To replace the excelsior, *distance pieces*, made by crossing and locking four pieces of pasteboard, are used. The distance piece can be cut to any length desired.

When the powder is confined in a bag the distance piece extends from the tie end of the bag to the base of the shell. When no bag is used a wad is placed over the powder and the distance piece extends from the wad to the base of the shell, or to the cover of the metallic cartridge case in case there is no shell.

12. Powder Bags.—Powder bags for charges of smokeless powder are made of unbleached muslin, two thicknesses at the bottom, and with chafing bands at each end. They are stiffened by longitudinal strips and circular bands of tape, the latter being securely tied around the bag. *It is most important that the bags should be stiff and that they should fit the chamber.* The powder should be well shaken down and the bag tied tightly above the powder, extra material being cut off the tie end. Stiffening tape is sometimes omitted from the powder bags for small calibres. To this there is some objection.

Charges which are flabby, or loosely put up, cause trouble and serious delay in loading. For this reason it is well to examine, and, if necessary, re-tie charges before sending them up. This precaution may be taken in anticipation of target practice or active service.



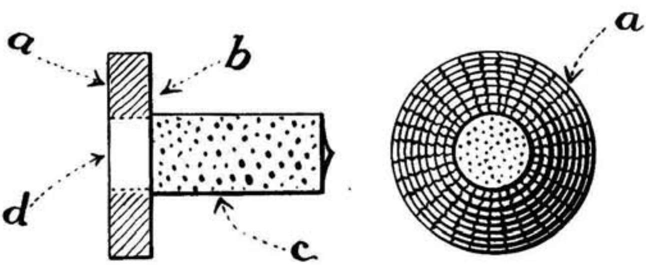
IGNITION POCKET FOR Q. F. CHARGES. Par. 14.

A circular piece, about 4 inches in diameter in the case of large bags, is usually cut out of the center of the bottom and a piece of *scrim* is sewed in through which the flame from the primer penetrates to the ignition charge. The bottom of the bag is sometimes strengthened by six radial strips.

13. Ignition Charges for Large Calibre Powder Bags.—The ignition charge for 8-inch, 10-inch, and 12-inch charges consists of seven grains of black prismatic powder cemented together with a thick solution of shellac and alcohol, and placed upon the scrim at the bottom of the bag and inside a small cylindrical pocket which is sewed to the bag around the scrim on the inside. The mouth of the pocket is then secured, thus holding the ignition grains close against the scrim in the center of the bottom. The powder is then poured in on top of the ignition charge, shaken down well, and the bag tied tightly. (See Plate V, Figs. 1 and 2, 10-inch ignition charge. Bureau of Ordnance Blue Print, 18999.)

14. Ignition Pocket for Small Calibre Powder Bags.—For powder bags of 5-inch and 6-inch quick-fire guns, a flat circular pocket of muslin with a filling hole for small grained black powder, is sewed to the bottom of the bag on the inside close against the scrim.

In order to keep the pocket flat and prevent the powder from falling down to one side away from the central line, five small circles are stitched through the pocket as shown in the sketch.



IGNITION POCKET. Par. 15.

a, a. pulp disk. b. scrim. c. powder pocket. d. hole in disk.

The flame from the primer passes through the scrim in the bottom of the bag, penetrates the ignition pocket and ignites the black powder which in turn ignites the smokeless powder which is poured in on the top of the pocket. It is important that the powder should be well shaken down and the bag tied tightly.

15. Ignition Charges for Metallic Cartridge Cases.—There are three different kinds of ignition charges in use, or proposed, for metallic cartridge cases.

In the first form an annular disk made of pulp, with scrim over the opening, is used, a small muslin pocket being sewed to the scrim and the latter glued to the disk. The pocket is filled with small grained black powder and then tied securely. The disk is then dropped into the cartridge case, the primer projecting into the hole in the disk toward the scrim, and the smokeless powder without a bag is poured into the cartridge case on top of the ignition pocket (see sketch)

In this form it is evident that the pocket may become displaced, throwing the ignition charge out of line with the primer and causing miss or hangfires.

16. Ignition Grains.—In this form, which is preferable to the preceding, the charge of powder is confined in a bag which is placed in the cartridge case. The ignition charge is composed of from one to three grains of black prismatic powder secured together and sewed to the cartridge bag on the inside of the bottom immediately over the scrim. An annular papier maché disk about ½-inch thick and nearly equal in diameter to the powder bag is secured to the bottom of the latter on the outside. This disk serves to stiffen the bottom of the bag and to hold the ignition grains opposite the primer which projects through the hole in the disk nearly to the scrim. This form for 6-inch case is shown in Plate VI. (See Bureau of Ordnance Blue Print, 18861.)

17. Ignition Disks of Black Powder for Cartridge Cases.—The latest form of ignition charge, to be used in cartridge cases where no bag is used to confine the charge, is shown in Plate VII. (Blue Print No. 19475.)

A paste board or pulp disk, of section shown in the figure, is placed in the bottom of the cartridge case and held firmly in position by the primer which fits tightly in and projects through the hole in the center of the disk. A cake of black powder, pressed into the shape shown in the figure, with seven .2-inch holes parallel to the primer, is cemented to the disk by a thick solution of shellac and alcohol.

In a later design the pulp disk is increased in diameter to that of the inside of the case to still further prevent all chance of displacement, and thus ensure the ignition cake being held opposite the primer.

18. Fixed Ammunition Boxes.—For the 4-inch and 5-inch R. F. guns each round is in a box by itself. The boxes are made of poplar wood with a becket at one end, the cartridge being held by corner wedges, and one side of the box being easily removed by cutting the three lashings which hold it in place, as shown in Plate VIII.

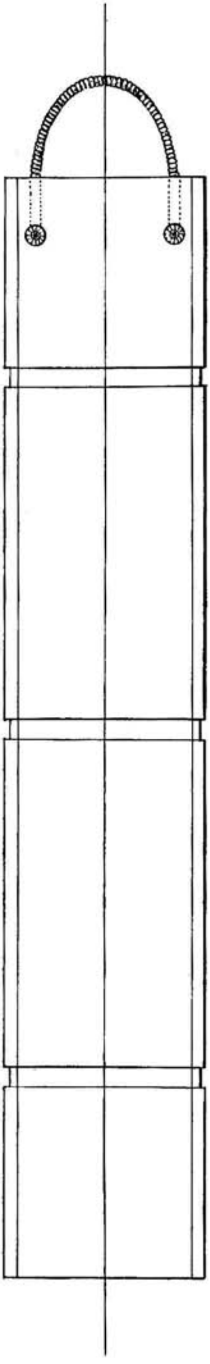


Fig. 1.

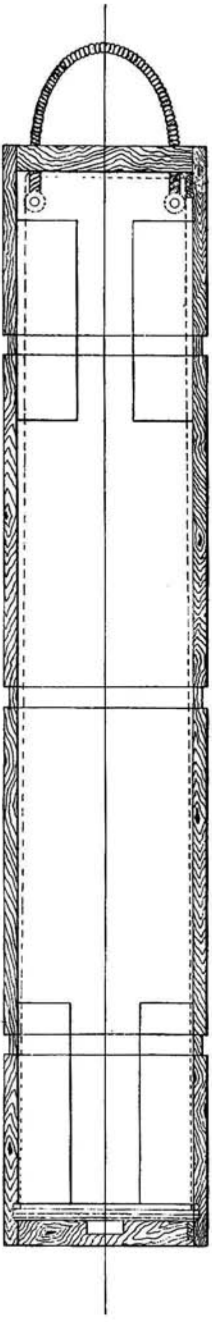


Fig. 2.

WOODEN FIXED AMMUNITION BOX FOR 4-INCH AND 5-INCH AMMUNITION.

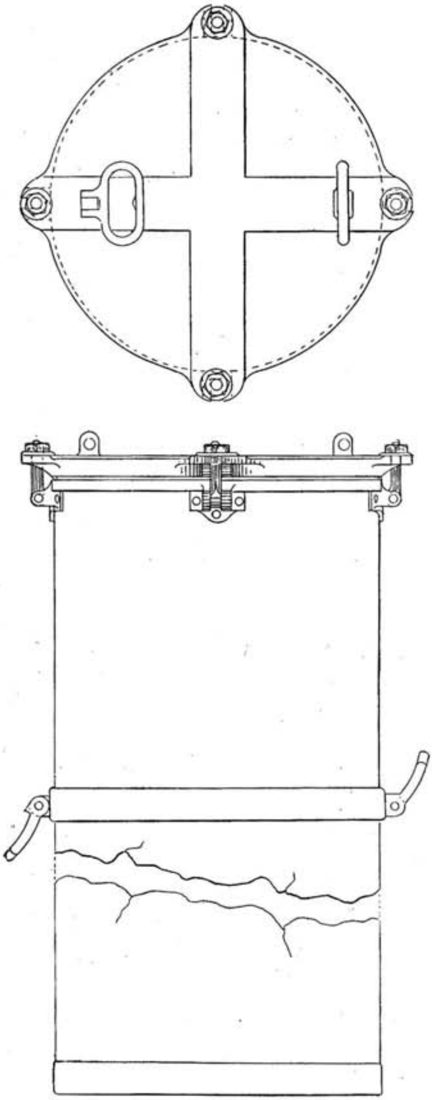


Fig. 1.

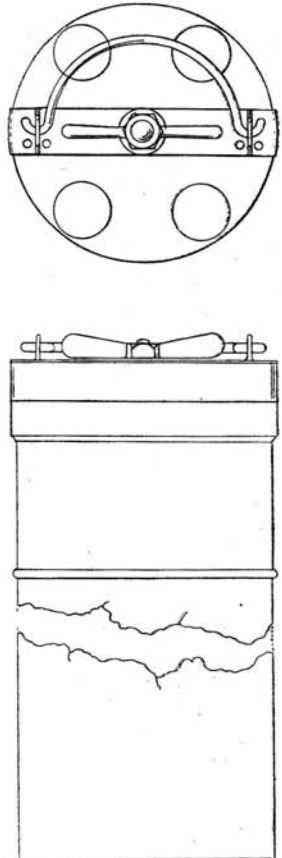


Fig. 2.

POWDER TANKS. Par. 23.

These boxes are painted to indicate the projectile, as follows:

Armor piercing .... All black.
Steel, common .... All lead color.
Shrapnel ....All white.

Boxes for drill cartridges are half white and half black.

19. Fixed Ammunition Boxes for Minor Calibres.—The fixed ammunition for minor calibres R. F. guns is placed in chests, the number of rounds for each being as follows:

1-pounder (light and heavy)	60	rounds
3-pounder	16	"
6-pounder	11	"
3-inch field gun	17	"
3-inch field gun (new)	8	"
3-inch 50-calibre R. F.	4	"

These chests are painted as follows:

Armor-piercing rounds........Black, white letters.
Steel, common rounds.........Lead, red letters.
Cast iron, common rounds.....Red, black letters.
Shrapnel rounds..............White, black letters.

Blind 3-, 4- and 5-inch boxes, red band 12 inches deep at each end and both ends red.

DRILL CARTRIDGE.

20. Drill Cartridge for Small R. F. Guns.—For exercise or for target practice using small-arm ammunition, a drill cartridge of the same general shape as the regular cartridge is provided. It has a metallic base and point, and in the axis a short length of a rifle barrel, calibre .45, is inserted. The body of the drill cartridge is a hard, close-grained wood.

Drill cartridges are packed in chests painted half black and half white, the dividing plane being parallel to the ends of the chests.

21. Drill Cartridges for 4-inch and 5-inch R. F. Guns are the same in shape and size as the regular complete cartridge, and similar in design to those for the secondary battery, with the same provisions for sub-calibre practice with .45-calibre ammunition.

22. Boxes for Metallic Cartridge Cases.—Metallic cartridge cases, when separate from the shell, are stowed in boxes made of poplar wood. The boxes have corner wedges at the ends to keep the cases from moving, and are stowed in bins in the magazines. There is a strong becket in one end of each box with which to handle it.

In the New Orleans and Albany, the metallic cases were not kept in boxes originally, but were stowed in racks in the magazines and sent up in leather buckets to the guns.

23. Powder Tanks.—The tanks for the powder charges of heavy guns are shown in Plate IX, Figs. 1 and 2. They are made of copper. The covers for 12-inch and 13-inch tanks are secured by bolts, as shown in the plate, and close down on rubber washers. For smaller calibres the cover goes on with a bayonet joint and is secured by a wing nut and disk upon a ground seat without washer.

In recent designs the tanks are protected by vertical wooden battens held in place around the tank by three copper bands, and the cover for all but the largest calibres has a raised rim to protect the handle and wing nut from injury.

Care should always be taken not to tear powder bags in removing them from the tanks. Such accidents are dangerous and have caused delay in loading during target practice. If the bottom of the bags are torn the ignition charge may be spilled or thrown out of line, thus causing hangfires.

24. Drill Charges for Q. F. Guns.—The drill charge for a Q. F. gun consists of a bronze tube with a flange at each end, the space around the tube and between the flanges being filled by longitudinal strips of wood segmental in section. The flanges are connected by small brass rods which also serve to keep the wooden strips in position.

Drill charges will be of the same weight as the powder charge of the gun for which they are supplied.

CHAPTER XXVI.

PROJECTILES.

1. Manufacture of Armor-piercing Projectiles.—Material selected for the melting operation is first prepared in convenient size to be shaken in a plumbago crucible which has a capacity of about 90 pounds of steel contents and weighs in itself about 30 pounds. The melting furnace is of the Siemens gas regenerative type, with a capacity of 30 to 48 or more pots, in several holes, each of the latter holding six pots.

2. The filled pots are lowered at one time by means of hand tongs into the melting holes and in about four hours are ready to teem or pour. The molds are of cast iron and are cylindrical in form, being split in two lengthwise, and the bottom of the mold following generally the curvature of the shell point; the extreme point end being continued in a square projection, which later serves as a hold for the tongs in the hammer forging.

3. The pots are pulled out of the furnace by means of hand tongs and the fluid steel surface carefully mopped to remove floating impurities, and then, by means of other hand tongs, the teeming is accomplished by pouring pot after pot slowly into the top of the prepared mold, the stream of molten steel never being allowed to stop for an instant until the proper weight of steel to make the required ingot is contained in the mold.

4. When the steel has solidified, and before losing its heat, the rings are stripped from the mold and the red-hot ingot is exposed and at once removed to the reheating furnace (coal-fired reverberatory), near the forging hammer. The latter is of the ordinary type of steam hammer and has a striking blow of 16 tons.

5. The forging dies are formed to follow the curves desired in the finished shell, and the ingot is given a uniform reduction therein so that the forging, as completed, is from ½ to ¾ inch larger in diameter dimensions than is required in the finished shell.

6. A heat treatment next follows to take out all hammer stresses and to prepare the steel in suitable condition for machining; this operation takes a week's time, after which the forgings are removed to the machine shop and after being centered in a special machine are chucked in a special turning machine and the outside metal removed, leaving the shell surface finished completely, with the exception of the swell of the point (the bourrelet), which is left full.

7. The shell is now removed to the cutting-off machine, where the top of the ingot is cut off and the serial number is transferred to the band score.

8. The shells are next chucked in a special machine and the boring out of the chamber cavity accomplished.

9. After cutting the score for the cap on another special machine, the shell is ready for the hardening process, which is secret.

10. In the meantime the steel for the base plug has been cast and forged into round bars, which are cut into blanks, and these later threaded and finished in turret lathes, the finished plugs awaiting the hardened shells.

11. Ballistic selection is made by the inspector from the completed lots as they come from the hardening operation, and after the Bureau has signified its acceptance, the shells are chased to receive the base plug, the base receives its markings with steel stamps, the shell is ground on its bourrelet to within specified tolerances, the copper band is hammered and pressed into the band score, and the shell again chucked in the lathe for turning the band. The hydraulic press then secures the soft steel cap to the point of the shell and completed lots are given the official inspection and stamped with the acceptance stamp, after which all that remains is to box and load in cars for shipment.

The copper for bands and small brass fuse plugs is prepared elsewhere, and so is generally the soft cap, these being furnished the manufacturers.

SHELL, A. P.

	6-inch.	8-inch.	12-inch.
Length:			
Without cap.........inches......	18.82	25.82	40.31
With cap............inches......	19.76	27.00	41.37
Weight:			
Without cap........pounds.....	98.00	250.00	848.00
With cap............pounds.....	103.00	257.20	868.40

12. **Specifications for Armor-piercing Shell.**—Designs of shell may be submitted for the Bureau's approval, or the Bureau's drawings may be used. If drawings are submitted, the exterior dimensions and tolerances must correspond with the Bureau's drawings in respect to diameter of body, of band, and position of band. In case the Bureau's drawings are accepted, the shape of the interior cavity may be changed, if desired, subject to the Bureau's approval.

13. The shell must be of domestic manufacture and must be finished to the dimensions shown on the drawings approved by the Bureau within the limits of tolerance stated thereon. The cavities must be concentric with the exteriors and of ample capacity to insure a satisfactory fragmentation when the shell is burst with black powder.

14. The right is reserved by the Bureau to alter the shape of shell not in course of manufacture should it develop at any time that such alteration is desirable. All such changes are to be made at the expense of the contractor.

15. They must be made of the best quality of steel, and must be sound and free from cracks, blowholes, and all other defects seriously affecting their resistance and value as projectiles; this condition to be determined by the Government inspectors.

16. At the specified distance from the base a groove or band score is to be turned for the rotation band with the necessary roughening to prevent the band from turning on the shell. The rotation band must be of the best quality of copper, must be properly pressed into the before-mentioned band score, preferably by hydraulic pressure, and must then be finished to the dimensions shown on the approved drawings.

17. If fitted with base plugs, a forged steel base plug with external thread fitting closely in a corresponding thread cut in the base of the shell, and with an internal thread to take the fuse, is to be set home in each shell, the exterior threads of base plug and interior threads in the shell being first coated with red lead. This base plug must fit gas tight. The Bureau reserves the right to have the shape or dimensions of the base plug changed at any time, which shall be done without extra charge.

18. Shell of 8-, 10-, 12-, and 13-inch calibres must have an an-

nular groove turned in the face of the base, to be of the dimensions prescribed by the Bureau for fitting base covers.

19. All shell must be capped with caps of soft steel furnished by the contractor, fitting into a score cut or ground around the head and being secured in place by proper methods approved by the Bureau.

20. Maximum and minimum gauges will be furnished for the fuse hole.

21. All shell must be thoroughly cleaned, the cavities carefully coated with a suitable lacquer.

22. The shell shall be subject to Government inspection during all the process of manufacture, and the contractor shall furnish all necessary facilities to the Government inspector to enable him to properly perform his duties.

23. Except when specifically provided to the contrary, all tests, measurements, etc., shall be made at the expense of the contractor, under the supervision of the Government inspector and with the contractor's gauges and instruments.

24. Chemical and physical tests may be made for the purpose of insuring uniformity in each lot, and the requirements shall be as follows:

(a) A specimen from each forging or casting shall be analyzed for carbon, chromium, or other hardening element, and as shown thereby, the carbon percentage of no shell in any lot shall vary more than ten one-hundredths of 1 per cent from the mean carbon percentage of the entire lot, and the chromium percentage or percentage of other hardening element in no shell in any lot shall be less than that fixed by the contractor as a minimum percentage suitable for the class of shell constituting the lot.

(b) Transverse specimens may be taken from the base of three shell of each lot after annealing, and, as judged by their test, all the shell of each lot shall be of substantially uniform quality of metal.

25. After final treatment and before submission to ballistic test, each shell shall be subjected to an internal hydraulic pressure of 500 pounds to the square inch, and any shell which develops unsoundness, holes, or cracks, or leaks around base plug will be rejected.

26. The shell shall be presented for acceptance completely finished, except banding, lacquering, and capping, in lots of 500 3-inch, 400 4-inch, 400 5-inch, 250 6-inch, 250 7-inch, 250 8-inch, 200 10-inch, 200 12-inch, and 200 13-inch.

27. The ballistic test for acceptance shall be as follows: Three shell shall be selected from each lot; shall be banded and capped, and shall be fired against a hard-faced armor plate from 1 to 1½ calibres thick with the velocity given in the following table, with the requirement that two of the shell shall go through the plate unbroken and then be in condition for effective bursting:

Calibre of shell.	Thickness of plate.	Striking velocity.	
		Harvey.	Krupp.
	Inches.	Foot-secs.	Foot-secs.
3 inches (14-pounder)	3	2,025	....
	4	2,550	....
	4.5	2,800	....
4 inches	4	1,925	....
5 inches—50 pounds	5	2,075	....
	6	2,400	....
	7	2,700	....
5 inches—60 pounds	5	1,900	....
	6	2,200	....
	7	2,500	....
	7.5	2,625	....
6 inches	6	1,870	1,990
	7	2,100	....
	8	2,321	....
	9	2,533	....
7 inches	7	1,795	....
	8	1,995	....
	9	2,170	....
	10	2,360	....
8 inches	8	1,730	....
	9	1,890	....
	10	2,050	....
	11	2,200	....
	12	2,350	....
10 inches	10	1,625	....
	11	1,750	....
	12	1,875	....
	13	2,000	....
	14	2,125	....
	15	2,250	....
12 inches	12	1,600	1,880
	13	1,700	....
	14	1,800	....
	15	1,900	....
	16	2,000	....
	17	2,100	....
13 inches	13	1,550	....
	14	1,650	....
	15	1,750	....
	16	1,850	....
	17	1,950	....

For intermediate thicknesses the velocity shall be determined by interpolation.

See Plates I, II and III.

28. Specifications for Forged Steel Common Shell.—Designs of shell may be submitted for the Bureau's approval, or the Bureau's drawings may be used. If drawings are submitted, the exterior dimensions and tolerances must correspond with the Bureau's drawings in respect to diameter of body, of band, and position of band, and the over-all length shown on the Bureau's designs will not be exceeded. In case the Bureau's drawings are accepted, the shape of the interior cavity may be changed, if desired, subject to the Bureau's approval. (See Plates I, II and III.)

29. The shell must be of domestic manufacture and must be finished to the dimensions shown on the drawings approved by the Bureau within the limits of tolerance stated thereon. The cavities must be concentric with the exteriors. The ratio of the cubic capacity of cavity to total volume of shell including cavity shall not be less than a minimum to be fixed by the Bureau.

30. The right is reserved to alter the shape of shell not in course of manufacture should it develop at any time that such alteration is desirable. All such changes are to be made at the expense of the contractor.

31. The shell must be made of the best quality of steel, and must be sound and free from cracks, blowholes, and all other defects seriously affecting their resistance and value as projectiles; this condition to be determined by the Government inspectors.

32. At the specified distance from the base a groove or band score is to be turned for the rotation band with the necessary roughening to prevent the band from turning on the shell. The rotation bands must be of good quality of copper, must be properly pressed into the before-mentioned grooves, preferably by hydraulic pressure, and must then be finished to the dimensions shown on the approved drawings.

33. Shell will preferably be made with bases turned in. If fitted with base plugs, a forged steel base plug with external thread fitting closely in a corresponding thread cut in the base of the shell, and with an internal thread to take the fuse, is to be set home in each shell, the exterior threads of base plug and interior threads of the shell being first coated with red lead. This base

plug must fit gas tight, and must be so set home that it would require great force to start it out again. The Bureau reserves the right to have the shape or dimensions of the base plug changed at any time, which shall be done without extra charge.

34. Shell of 8-, 10-, 12-, and 13-inch calibres must have an annular groove turned in the face of the base, to be of the dimensions prescribed by the Bureau for fitting base covers.

35. Maximum and minimum gauges will be furnished for the fuse hole.

36. All shell must be thoroughly cleaned, the cavities carefully coated with a suitable lacquer.

37. Each shell shall be suitably tempered.

38. The shell shall be subject to Government inspection during all the process of manufacture, and the contractor shall furnish all necessary facilities to the Government inspector to enable him to properly perform his duties.

39. Except when specially provided to the contrary, all tests, measurements, etc., shall be made at the expense of the contractor, under the supervision of the Government inspector and with the contractor's gauges and instruments.

40. After final treatment and before submission to ballistic test, each shell shall be subjected to an internal hydraulic pressure of 500 pounds to the square inch, and any shell which develops unsoundness, holes, or cracks, or leaks around base plug will be rejected.

41. The shell shall be presented for acceptance completely finished, except banding and lacquering, in lots of 500 3-inch, 4-inch, 5-inch, and 6-inch, 250 7-inch, 250 8-inch, 200 10-inch, 200 12-inch, and 200 13-inch.

42. The ballistic test shall be as follows: Three shell shall be selected from each lot; shall be banded and lacquered, and submitted to test. One shell of the three submitted shall be brought to standard weight by filling with sand, and shall be fired with suitable velocity against a face-hardened nickel steel plate, unbacked, of thickness equal to one-half the diameter of the shell. This shell must pass through the plate unbroken and then be in a condition for effective bursting. Another shell shall be fired unloaded down the range at service velocity, and must not break

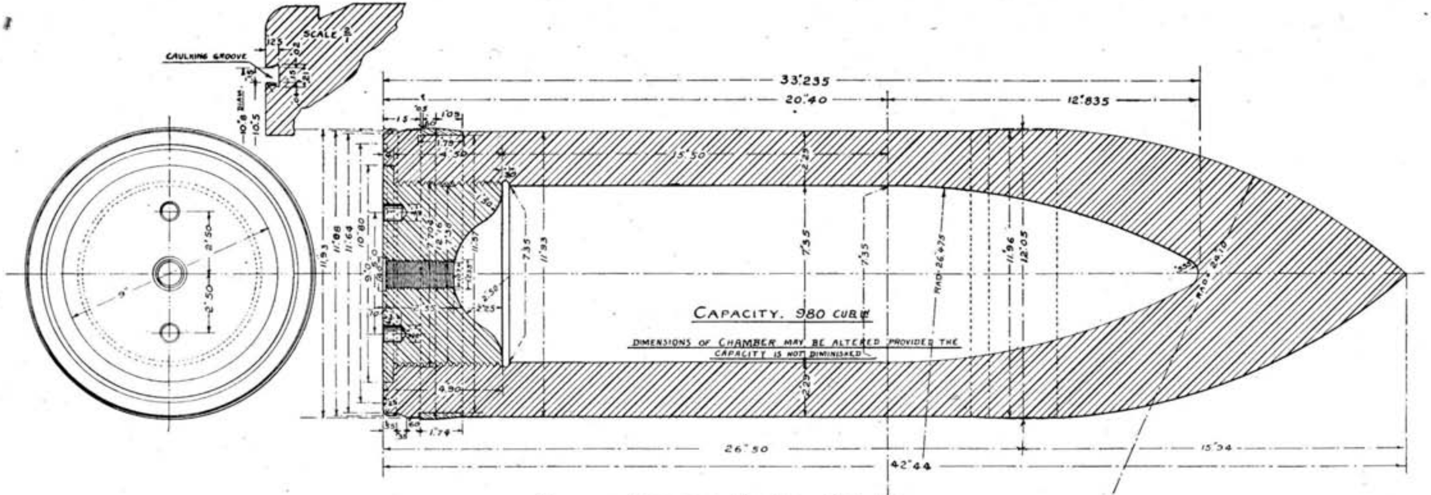


FIG. 1.—COMMON SHELL. Par. 71.

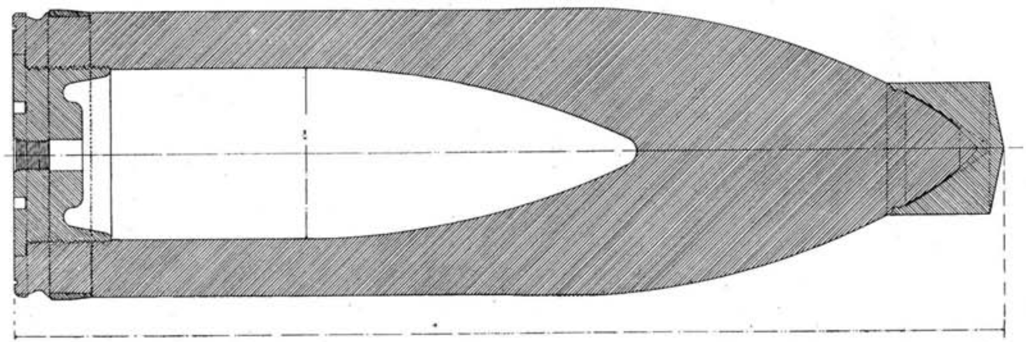


FIG. 2.—A. P. SHELL. Par. 70.

12-INCH PROJECTILES.

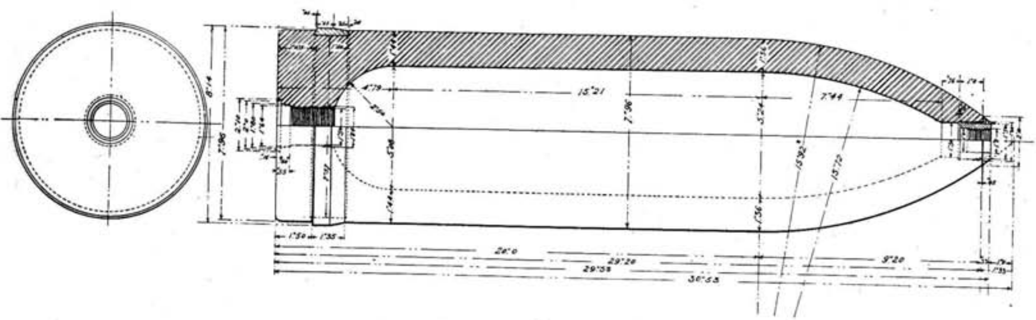


FIG. 1.—COMMON SHELL. Par. 71.

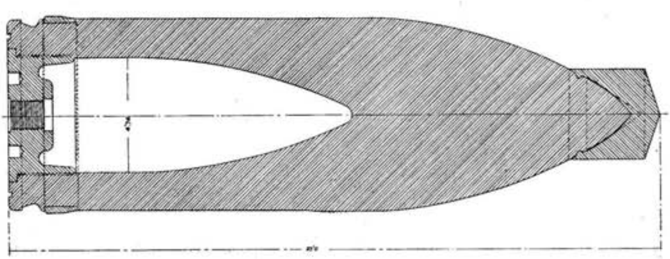


FIG. 2.—A. P. SHELL. Par. 70.

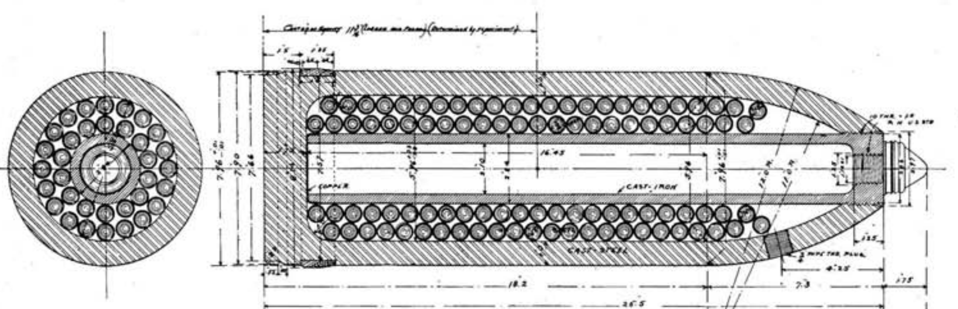


FIG. 3.—SHRAPNEL. Par. 75.

8-INCH PROJECTILES.

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Back of Plate II,
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Faces Plate III,
Chapter XXVI.

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