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NOTES ON AMMUNITION

BULLETINS 216-R2 AND 287

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DECLASSIFIED AFTER 12 YEARS.
DOD DIR 5200.10

COAST ARTILLERY SCHOOL
Fort Monroe, Va.

PRESS OF
BURKE & GREGORY, INC.
NORFOLK, VA.

COAST ARTILLERY SCHOOL

FORT MONROE, VIRGINIA

October 31, 1918.

The following "Notes on Ammunition," prepared under the immediate supervision of the Commandant, is published for use as a text book in the Coast Artillery School and in the universities giving preliminary military training, and supersedes all bulletins heretofore published on this subject.

By order of Colonel Welshimer,

C. L. Kilburn,

Lt. Colonel, C. A.

Secretary.

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NOTES ON AMMUNITION

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NOTES ON AMMUNITION

GENERAL DEFINITION AND CLASSIFICATION OF AMMUNITION.

Ammunition, in general, is the term applied to all elements, including the projectile itself, used to send a projectile from the bore of a gun.

Round of Ammunition—those elements used in firing a gun once. It is composed of:

Primer—a device used to ignite the propelling charge.

Propelling charge—the explosive placed behind the projectile in the bore of the gun and used to impart motion to the projectile.

Projectile—a missile thrown from a gun by the propelling charge to serve as a carrier for high explosive, gas, smoke, etc., which it is desired to carry to and explode or scatter at a definite point.

Bursting Charge—the explosive placed in the cavity of the projectile and designed to explode with sufficient violence to rupture the shell and hurl the fragments with destructive effect.

Fuze—a device attached to the projectile to cause the detonation of the shell at the time or under the circumstances desired.

Kinds of Ammunition—the relation of the above elements of a round of ammunition to each other determines the kind of ammunition. This division is as follows:

Fixed Ammunition—In which the primer, propelling charge, and projectile are in a single metal container, as in the Springfield rifle cartridge. This type of ammunition is used in 3″, 4.7″, and 75mm. guns.

Semi-Fixed Ammunition—in which the primer and propelling charge are in a single metal container, and the projectile is loaded separately. This type is used in the 4.7″ and 6″ howitzers, and 9.45″ trench mortar.

Separate Loading Ammunition—in which primer, propelling charge, and projectile are each loaded as a separate unit. This type is used in guns of 5″ caliber and up, 155mm. gun, and howitzers of 8″ caliber and up.

NOTES ON AMMUNITION

CHAPTER I

PRIMERS FOR SEACOAST AND MOBILE ARTILLERY

COAST ARTILLERY PRIMERS

Friction	Percussion
Electric	Drill
Combination Electric and Friction	Igniting

1914 Friction Primer

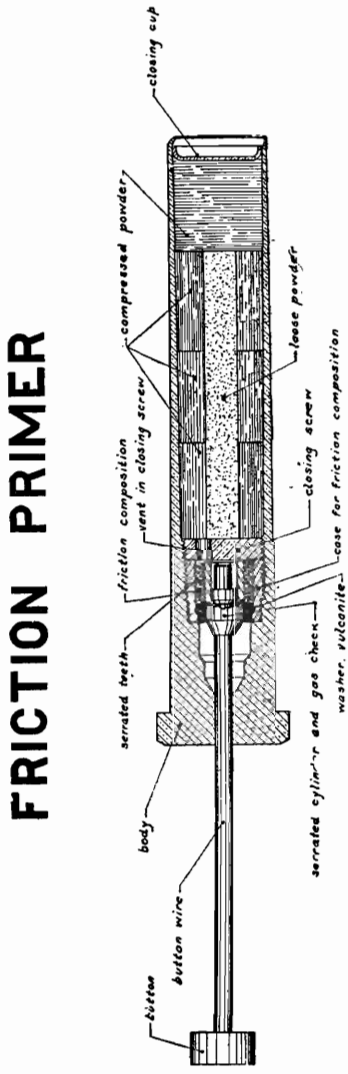
The chief parts of the friction primer are as follows:

Tobin Bronze Body	Gas Check
Button and Button Wire	Gas Check Seat
Serrated Cylinder	Closing Screw
Friction Composition	Black or Shrapnel Powder
	Closing Cup

This primer consists of a tobin bronze body resembling a small arms cartridge case, drilled through the base to receive a wire to which is assembled the gas check and a button to engage in the firing leaf. A threaded housing contains the friction composition and is covered by a closing screw drilled with three holes to permit the access of flame from the friction composition to the primer charge. In assembling, the housing containing the friction pellet is screwed home, the gas check is inserted and the wire passed thru it. The closing screw is then screwed in and the button screwed on the wire and riveted. The three tubular pellets of compressed powder are then inserted and the center hole filled with grains of loose powder. The end pellet is then inserted, the closing cup is pushed down on

top of it and the end of the primer crimped and shellaced.

In action, the button which engages in the firing leaf is pulled back. This pulls the wire back, forcing the serrated end of the wire through the friction pellet and seating the gas check to prevent the escape of gas to the rear around the wire. The tube of the primer expands under pressure, thus preventing the escape of gas around the exterior of the primer casing. The flame from the friction composition penetrates the holes in the closing screw, igniting the

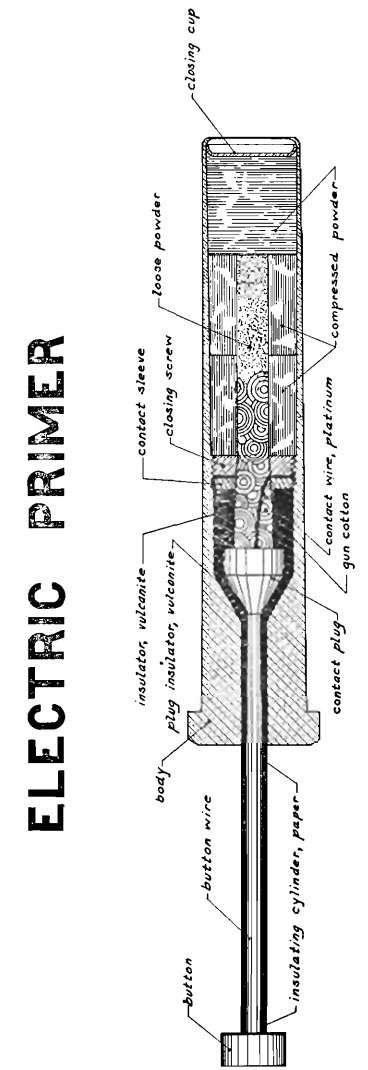


loose powder, which in turn ignites all the powder pellets, and forces out the closing cup allowing the flame to pass through the vent in the breech block and ignite the propelling charge.

Used in Coast and Mobile Artillery for service and action.

Friction composition:

Sulphur,	9%
Chlorate of potash,	52%
Sulphate of antimony,	27%
Glass,	12%



Electric Primer.

The action of this primer is as follows: One end of the contact wire is soldered to the contact plug, which is insulated from the body and attached to the button wire which is also insulated from the body. It forms electrical contact through the bottom with the external circuit by means of clips attached to the firing mechanism. The opposite end of the contact wire is soldered to the contact sleeve, which is in electrical contact with the body. An electric current of sufficient intensity to heat the contact wire is passed through the primer and ignites the gun cotton. This ignites the primer charge of loose powder and pellets. The closing cap is blown out and flame sent through the vent to the propelling charge.

Combination Electric-Friction.

As the manufacture of this type has been discontinued no detailed description will be given here. This primer is designed to function as an electric primer. If this fails a lanyard may be attached and the primer fired by friction. However, the above order cannot be reversed as the contact wire would be broken.

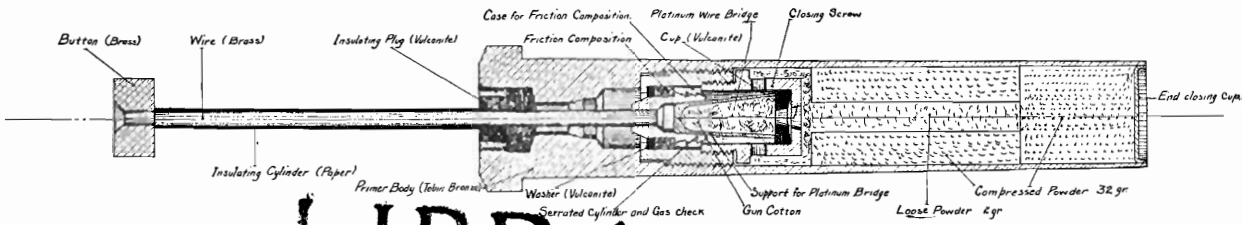
Percussion Primer.

There are two types of percussion primers in common use in Seacoast Ammunition, the 110 grain and the 20 grain. The only difference between these two primers is in the amount of black powder contained in the body of the primer. They are used in fixed and semi-fixed ammunition. The essential elements of a simple percussion primer are the *primer cup*, the *anvil*, and the *percussion composition*. All the metal parts are made of brass. A typical percussion composition standard for the 110-grain percussion primer is as follows:

Lead Sulph-cyanate	25%
Chlorate of Potash	53%
Sulphide of Antimony	17%
Trinitrotoluene	5%

COMBINATION - PRIMER

ELECTRIC — FRICTION

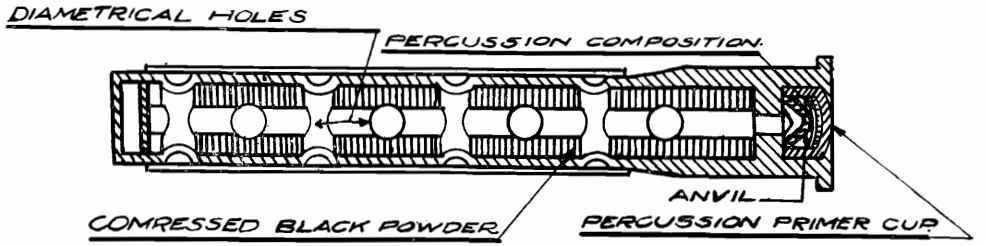


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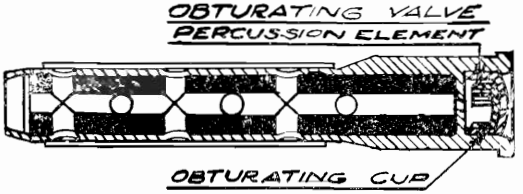
In the rear of the primer a recess or pocket is formed to contain the percussion primer proper. The cup, anvil, and percussion composition are assembled and inserted in this recess. A hole, drilled through the diaphragm, allows the flame to pass to the primer charge. The powder is pressed into the body of the primer around a central wire, which, when removed, leaves a longitudinal hole through the full length of the charge. Eight radial holes are drilled through the primer body and the compressed charge. The compression of the powder and the drilling of the holes through it increase the time of burning of the charge and cause it to burn with a torch-like effect, making ignition of the propelling charge more complete.

In action, the firing pin strikes the cup, indents it, and fires the percussion pellet by forcing it against the anvil. The flame passes through the hole in the diaphragm and sets off the primer charge. This blows out the closing cap and ignites the propelling charge.

They are used in fixed and semi-fixed ammunition only.



110 GRAIN PERCUSSION PRIMER.



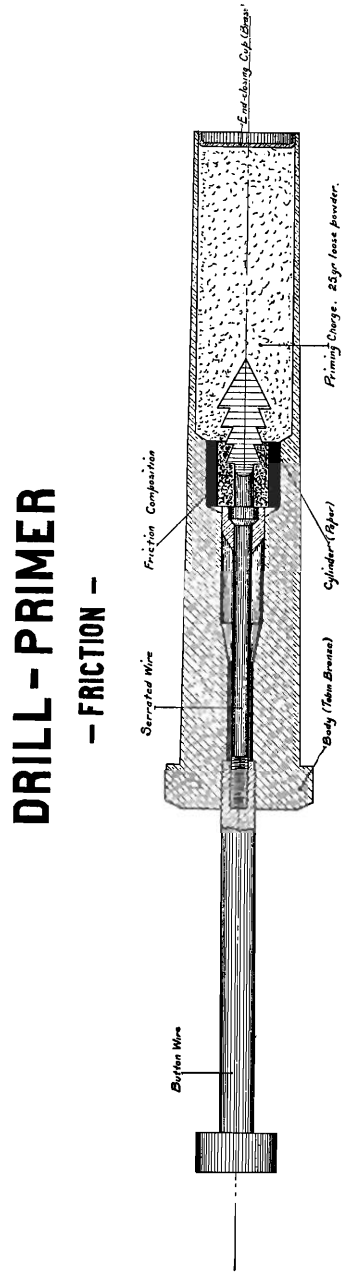
110 GRAIN IGNITING PRIMER.



20 GRAIN PERCUSSION PRIMER.

DRILL PRIMER.

This primer is designed to replace the relatively expensive 1914 Friction and Electric primers for drill purposes



and sub-caliber practice. It is a simplified friction primer and its action is similar to that described above under friction primers. Its advantages are that it is cheap and may be assembled at the post. To assemble the drill primer: Clean the case in lye or sal-soda water, dry, and reload with the aid of the assembling tool as follows: a serrated wire is placed in the primer body, a button wire screwed to its end, the friction composition inserted in its liner, a charge of black powder poured in, and the end of the primer sealed with a moistened closing cup.

IGNITING PRIMER.

These primers are used in the base of sub-caliber ammunition and require for their ignition a drill primer inserted in the breech block. This primer consists of a cup provided with a central vent to allow the passage of the flame from the regular primer, this vent being closed before firing by a thin layer of wax. This ignites the black powder in the body of the primer which forces a sliding valve back against the vent in the cup, preventing the escape of gas to the rear.

CARE AND STORAGE OF SEACOAST PRIMERS.

Primers are issued in hermetically sealed tins in suitable wooden containers. They should be stored in a dry, cool place apart from other kinds of ammunition and secure from entrance by unauthorized persons. These primers must not be opened until needed for use. They are inspected once a month by the responsible officer who sees that they are stored according to regulations and so reports to the fort commander.

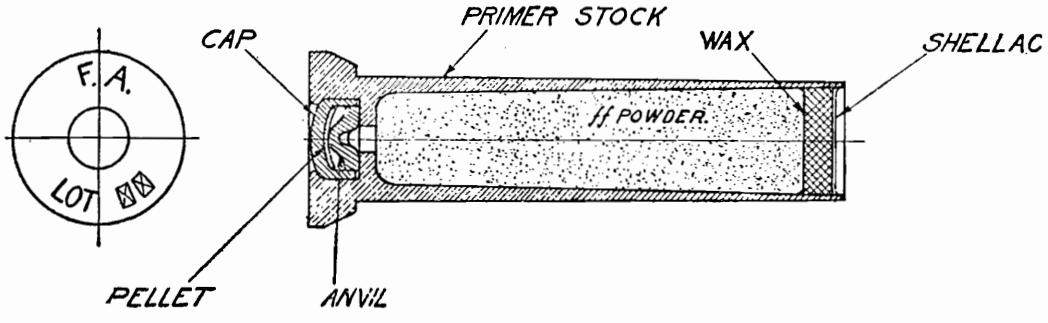
MOBILE ARTILLERY PRIMERS.

1914 FRICTION PRIMER.—

See Page 7 under Coast Artillery Primers for the detailed description and diagram of this primer.

21 GRAIN PERCUSSION PRIMER.—

This primer is so named because it contains 21 grains of black powder in the primer charge. Its essential parts are the primer cup, anvil, and percussion composition. It consists of a brass case resembling a small arms cartridge



21 GRAIN PERCUSSION PRIMER MARK II

36-23-107

case. The head or rear of this case is counter sunk forming a cup shaped recess, in which the percussion primer proper is inserted. The percussion composition contains the following ingredients: Fulminate of Mercury.....35%
Chlorate of Potash.....35%
Sulphide of Antimony.....30%

In action the blow of the firing pin explodes the percussion element by forcing the primer cup against the anvil. The flame passes through holes at the base of the anvil and ignites the primer charge. This blows out the closing cap and ignites the propelling charge.

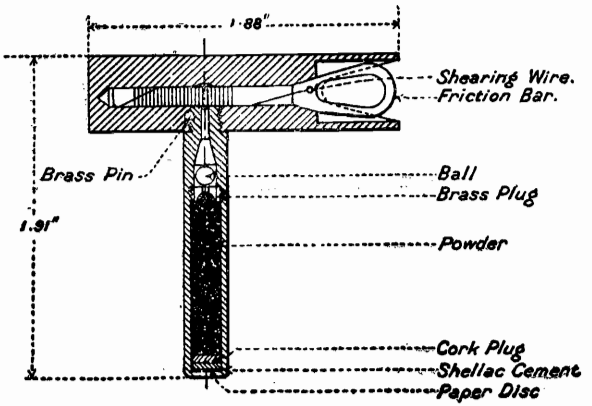
This percussion primer is used in fixed and semi-fixed mobile artillery ammunition, and in separate loading ammunition in certain instances such as the 155mm. Filloux gun, where the firing mechanism is so arranged that it contains a firing pin.

"T" Tube Friction Primer.—

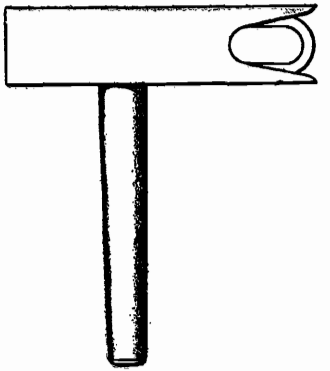
This primer is designed for use in British howitzers and is fired by the pull of a lanyard from the side of the piece instead of the rear as in the case of most friction primers. It consists of a head of gun metal brass, a body of solid drawn brass, a soft copper ball, and a friction bar of round copper wire. The latter is twisted into a round bar with a lanyard loop at one end, the body of the wire being roughened. A copper shearing wire holds the friction bar in place before firing. A hole in the side of the head over the friction bar is charged with 3 grains of friction composition laid over the roughened portion of the friction bar, the hole being closed by a brass screw. The body is charged with 8 grains of black powder and sealed with a shellaced cork and paper disc. The upper part of the body has a central tube which is enlarged at its lower part into a conical recess into which the copper ball fits and is held in place by a brass plug drilled with three holes to permit the access of the flame to the black powder charge.

TUBE, FRICTION, "T," MARK IV.

SCALE – 1/1



SECTION



ELEVATION

The action of the "T" Tube primer is as follows: When the lanyard is pulled the friction bar is drawn through the friction composition, igniting it. The flame passes around the copper ball, through the fire holes in the brass plug, and ignites the black powder in the body of the tube. The force of the explosion drives the copper ball tightly into its cupped recess, thus securing obturation. The walls of the primer body expand under pressure and prevent the escape of gas to the rear around the exterior of the primer casing. The force of the explosion of the primer charge forces out the closing cork and ignites the propelling charge in the powder chamber of the gun.

Storage and Care of Mobile Artillery Primers.

Primers are issued in tin boxes sealed by a metal strip soldered to both box and cover. This strip must not be removed until primers are required for use as dampness will cause misfires or hangfires. Primer boxes should be stored in dry dugouts, protected from weather and enemy shell fire, and should be kept apart from all other kinds of ammunition.

General Precautions for the Handling of Primers.

Primers, if used in a damaged or dirty condition, will not seal the vent effectively, causing possible erosion of the vent and, in consequence, difficulties in the extraction of subsequent primers. Care should be taken that the primer bodies are not dented, distorted or touched with a file, and that the primer bodies and vent are free from dirt when the primer is inserted in the vent.

Primers should be used in the order of their receipt at the battery to prevent their deterioration from long storage.

Any primer that has been fired and failed to function should have the button wire bent back through 180° to prevent further attempts at firing.

CHAPTER II

PROPELLING CHARGES.

Explosives in general—An explosive is a substance capable of being suddenly transformed into hot gases, which at the moment of their formation tend to occupy a far greater volume than the original substance from which they sprang, and in consequence exert great pressure on their immediate surroundings. The explosive reaction may be initiated by heat, friction, or percussion. In the case of high explosives a detonating system is normally used, which corresponds to a very violent and sharp blow, accompanied by heat and flame. The heat given out by an explosion is due to the chemical action between the atoms making up the substance, the atoms rearranging themselves and joining up with new partners to form more stable combinations. In a propellant such as smokeless powder the rate of explosion has to be controlled so as not to burst the gun, but in a high explosive such as T. N. T. it is given free rein.

Ignition—the setting on fire of a powder grain or charge.

Inflammation—the spread of the flame from grain to grain of the charge, or from point to point of the grain.

Explosion—rapid conversion of a substance into a large volume of hot gases and solids.

Progressive explosion—an explosion in which the conversion takes place comparatively slowly tending to produce a tearing or pushing effect.

Detonation—an explosion in which the conversion takes place with extreme rapidity, producing a crushing or shattering effect.

Propelling Charges.

Powders which are used for propelling charges are progressive explosives, which are comparatively slow burning, and must not be confused with the high explosives used for shell fillers. When these powders are ignited at one point, the reaction proceeds progressively over the surface of the grains, then at right angles into the grain until the whole mass is consumed. Explosions of this

nature are not different in principle from the burning of logs of wood in a stove. In both cases there is a progressive change from particle to particle throughout the whole mass. The rate of burning depends not only on the substance burned, but on the size of the pieces, that is, for the same substance, the rate of burning increases with the surface exposed. A log of wood which would burn for a long time if in one piece can be burned quickly if cut into small kindlings. The principle difference is that powder contains in itself all the elements necessary for its combustion, while wood will burn only if oxygen is supplied in sufficient quantity.

Requirements of a Propelling Charge.

Safe to manufacture, and free from injurious effects upon the operatives.

Incapable of being detonated.

Should produce a minimum amount of erosion of the bore and not overheat the gun.

Grains should not be brittle or porous.

Must be stable in storage.

Material should be available and cheap.

Must produce the required muzzle velocity within the limits of pressure allowed.

Powders Used and Discarded.

Black powder in small grains was the first powder used as a propelling charge. It is a mechanical mixture of 75% saltpeter, 15% charcoal, and 10% sulphur. The saltpeter furnishes the oxygen to burn the charcoal and sulphur. Black powder is extremely dangerous to manufacture and handle. It gives large volumes of smoke when fired, fouls the bore, and burns too rapidly to give proper distribution of pressure. For these reasons it is no longer used as a propelling charge, but is still used for saluting purposes, primers, igniters, time trains in fuzes, and bursting charges for shrapnel.

About 1860 General Rodman discovered that by compressing black powder into large grains a more progressive burning could be obtained.

After black powder *brown prismatic powder* was used in our service. This was similar to black powder, but the charcoal was replaced by undercharred rye straw.

This gave a slower burning powder with less smoke. It gave more uniform muzzle velocities than modern smokeless powder due mainly to uniformity in making up the powder charge.

Size and Shape of Powder Grain.

The most desirable form of powder grain is one that gives off gas slowly at first, starting the projectile before the high pressure is reached, then with increasing burning surfaces evolves gas more rapidly, maintaining the pressure behind the projectile as it moves down the bore, and being entirely consumed the instant that the projectile leaves the muzzle.

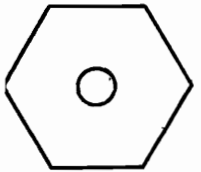
The form and size of the powder grain should be so regulated as to produce the required muzzle velocity with maximum pressure not exceeding that allowed for the gun.

The rate of emission of gas from a burning grain is dependent upon the rate of burning and the area of the burning surface. The rate of burning increases with the pressure and also with the temperature of the burning gases.

Carrying out this idea of a proper form of powder grain, the cannon powder in our service is formed into cylindrical grains with seven longitudinal perforations. (See diagram on page 23). This form of grain often leaves slivers of unburned powder after the projectiles have left the bore of the gun. To overcome this defect, a grain having six cylindrical ribs on its circumference, the centers of the ribs being the six outside holes of the former shaped grain. This grain is known as the corrugated multiperforated cylindrical grain, and is the form of grain now being manufactured in the U. S. The length and diameter of the grain vary for different guns, the size increases with the caliber and length of gun, and for the same gun, decreases with increased muzzle velocity. *Powder designed for one gun should never be used for any other gun, except in cases of absolute necessity, and then a powder grain of larger dimension than the one usually used should be employed, as the use of a smaller grain will develop pressures in excess of those for which the gun was designed, probably resulting in the destruction of the piece.*

Critical dimension of a grain of powder is that dimension which when burned through the entire grain is con-

FORMS OF POWDER GRAINS



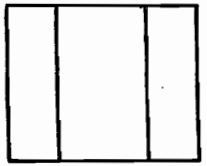
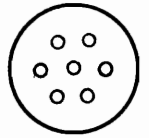


Fig. 1.

BROWN PRISMATIC



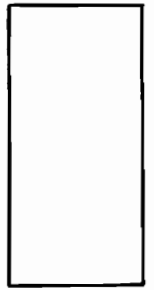
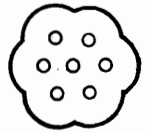


Fig. 2

PERFORATED CYLINDRICAL



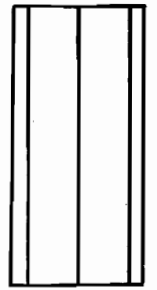


Fig. 3.

PERFORATED CYLINDRICAL (CORRUGATED)

sumed. It is the thickness of the web between any two holes or between an outside hole and the circumference.

In other services, cannon powders are made into grains of various shapes. Cubes, solid and tubular rods of circular cross sections, flat strips, and rolled sheets are among other practical forms.

Manufacture of Smokeless Powder.

Modern propelling charges are chemical compounds which burn pratically without smoke. In our army and in the French the powder used is nearly all pure nitrocellulose, but the British use a mixture of nitrocellulose and nitroglycerine. Experiments are being conducted in this country which indicate that a flashless powder has been developed, but no definite information is available. This powder is said to be satisfactory for howitzers but has not yet been developed to a point where it can be used in high velocity guns.

Nitrocellulose Powder.

Cotton linters, cheapest form of cotton, after bleaching and purifying, are run through a picker which opens up the fibers and breaks up the lumps. It is then thoroughly dried and prepared for nitration. The method of nitration most commonly employed is to put the cotton in a large vessel filled with a mixture of nitric and sulphuric acids. Sulphuric acid absorbs the water developed in the process of nitration, which would otherwise too greatly dilute the nitric acid. After immersion for a definite length of time the acid is drawn off and water run in, care being taken that the cotton is submerged during the change. Wet nitrated cotton is now removed from the nitrator and repeatedly washed and boiled to remove all traces of the free acid. As the keeping qualities of the nitrated cotton are dependent upon the thoroughness with which it is purified, specifications for powder in the United States Army and Navy require that the nitrated cotton be given at least five boilings at this stage of manufacture, with a change of water after each boiling, the total time being 40 hours. Following this preliminary purification, the cotton is run through a pulping machine. This is necessary because of the difficulty experienced in removing the free acid unless the fibers are cut up into short lengths. After

pulping, the cotton is given six more boilings, followed by ten more cold water washings. The resulting material is known as wet gun-cotton or pyrocellulose and is a high explosive, very dangerous to handle when dry.

Colloidization. This process comprises a changing of gun cotton, an explosive of the high order, to a low order explosive, by colloiding it in a mixture of two parts ether and one part alcohol by volume or 64% ether and 36% alcohol by weight. It is first partially freed from water by a centrifugal wringer and by pressing the pyrocellulose into solid blocks and forcing alcohol through the mass, which forces out the water. The blocks are transferred to a mixer and the proper amount of ether added. The mixture of ether and alcohol dissolves the pyrocellulose into a soft paste-like mass in which all trace of the cellular structure of cotton has disappeared. A stabilizing agent, diphenylamine, is added during the mixing process.

As soon as the process of colloidization is complete, the mass is pressed into blocks, forced through a macaroni press to mix it, and the strands again pressed into blocks. These are transferred to a finishing press, where the material is forced through dies and comes out in the form of perforated rods, which are cut up into short lengths. The grains are now thoroughly dried, and after drying the powder is blended, and finally packed in air-tight cans or boxes.

NITROGLYCERINE POWDER.

The British use a powder called "*Cordite*", the name being derived from the cord-like form it assumes in manufacture. This powder is a mixture of 60% gun-cotton, 35% nitroglycerine and 5% vaseline. This mixture produces an explosive of high order which is reduced to a powder of low order by a process similar to the process of colloidization in nitrocellulose powder except that this is accomplished in the case of nitroglycerine powders by "*Acetone*" in the place of ether and alcohol.

Nitroglycerine powders are more powerful than nitrocellulose powder, permitting the use of smaller powder chambers, and hence of lighter guns. Nitroglycerine powders also give more regular ballistics, do not become brittle in storage, are cheaper, and more non-hygroscopic than nitrocellulose powder. However, nitroglycerine powder

has the disadvantage of producing greater temperatures for a given pressure, thus causing greater erosion of the bore.

Ballistite is another nitroglycerine powder used in mobile artillery. It is used in trench mortars.

MAKE UP OF POWDER CHARGE.

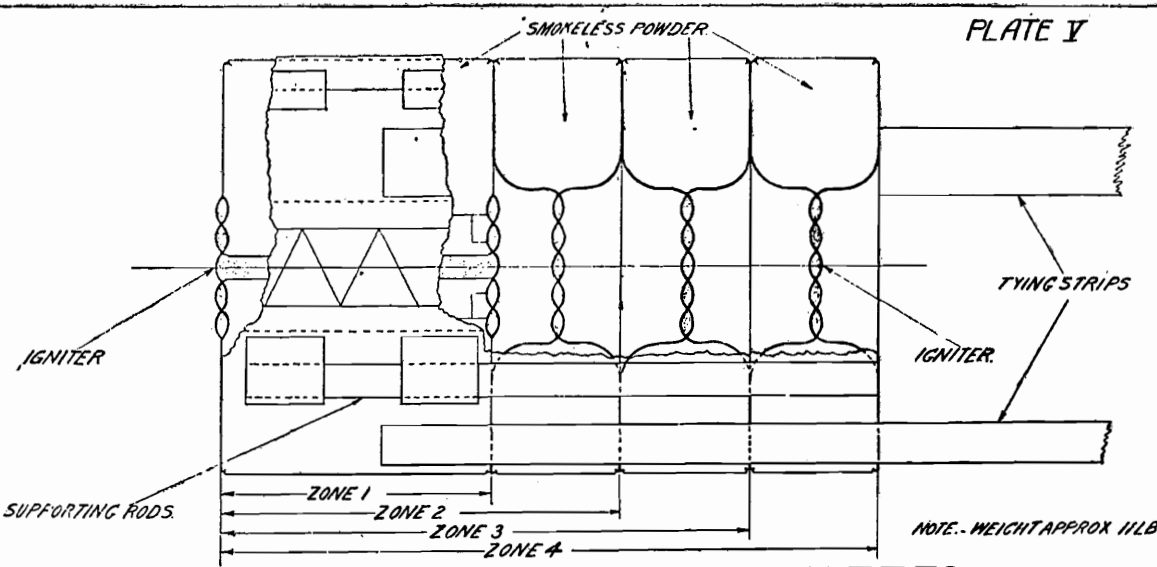
The material used for powder bags is raw silk, known as cartridge cloth, which burns without leaving any residue. Cotton cloth sometimes leaves burning fragments in the bore after firing. As the products of combustion of nitrocellulose powder are explosive when mixed with air, a spark left in the bore when the breech is opened, may result in an explosion, which is called "*flareback.*"

Powder charges for guns in Coast Artillery are made up of base charges, a different size charge being made up for each caliber gun. These base charges contain what is known as an "*igniter*" or igniting charge, to insure the complete ignition of the entire charge. An igniter may be either an end igniter, which is a small amount of black powder quilted into the ends of the charge, or a core igniter, which is a column of black powder running through the center of the charge. These end and core igniters are used so that the flame from the primer will instantly ignite the entire powder charge and thus insure uniform burning of the powder. In powder charges for Seacoast Mortars, where a system of zones is employed, requiring a different muzzle velocity for each zone, to obviate the necessity of issuing and handling individual charges for each muzzle velocity, *sectionalized charges* are used. This sectionalized charge consists of a base charge, with its end and core igniters, and one or more *increments*, which are small charges in separate bags secured to the base charge by tying strips of cartridge cloth. These increments do not contain igniters.

As all Mobile Artillery cannon now use two or more muzzle velocities, sectionalized charges are used in all mobile artillery powder charges. There is a difference, however, between the sectionalized charges of mobile artillery and those used for the mortars in Coast Artillery, in that the increments in mobile artillery charges contain core igniters running longitudinally, whereas those in seacoast mortars contain no igniters.

In order that the powder charges may be handled easily, it is necessary that they possess a certain degree of rigidity. To secure this in sectionalized charges several strips or rods of nitrocellulose powder are inserted longitudinally along the outer surface of the charge. The following diagram shows the construction of the powder charge for an 8″ Howitzer, Mark VI.

PLATE V



POWDER BAGS FOR 8 IN HOWITZER.

3C-23-159

Care and Storage of Powder.

In Coast Artillery—powder is issued in sealed metal containers, which must not be opened until powder is needed for use. It should be stored in dry magazines, where the temperature does not rise above 95° F., and separate from other kinds of ammunition.

In Mobile Artillery—powder issued same as above. It should be stored apart from other ammunition in shell proof dugouts if possible. If no dugouts are available it should be stored in dumps at least 20 yds. apart, and not more than fifteen containers in each dump, protected from the weather and enemy shell fire. It should be carefully camouflaged, and kept at as uniform a temperature as possible by protecting it from the direct rays of the sun.

Deterioration of Powder

The deterioration of powder may be detected by the characteristic odor of nitrous vapors upon opening a case of powder, by the fact that the powder bags are eaten away or have turned yellow, brown, or black, or by the fact that the powder grains themselves become pasty or contain yellowish spots.

Deterioration may also be detected by a special test, known as the methyl violet test. This consists in placing a number of grains in a bottle together with a piece of the methyl violet paper, upon which the date has been marked. This paper is left in the bottle for thirty days. If at the end of this time the paper has changed color, the powder has deteriorated, and should be returned to the base for further examination.

General Consideration of Powder.

The ballistic qualities of each lot of powder vary slightly. Therefore, it is important that powder charges be grouped by lot number. Also for a given shoot, in order to obtain as uniform a muzzle velocity as possible, it is essential to use powder of the same lot, using it in the order of receipt at the battery.

Powder Blending is for the purpose of obtaining charges which give uniform muzzle velocities; this is accomplished by distributing among all the sections to be formed

an equal amount from each of the original containers used. Powder is blended in the shade so that the temperature will not be unevenly effected by the rays of the sun; also in dry weather, as the presence of moisture in powder lowers the muzzle velocity. Powder is usually blended by the shovel or cycle method, in which a single pile of powder is shoveled from the bottom into five or more piles, and then back again. This operation, called a cycle, is performed five times, and an equal amount of powder by weight placed in each section. The mixing is done on paulins with wooden shovels to prevent possible sparks. Blending is always done before firing of powder in any one lot in Seacoast Artillery, never of powder of different lots without the permission of the Ordnance Department.

In the field blending is very obviously impracticable. For this reason all powder in Mobile Artillery is blended at the base, weighed out into the proper size charges, placed in bags, and sealed in metal containers. A battery of mobile artillery receives its powder ready for use.



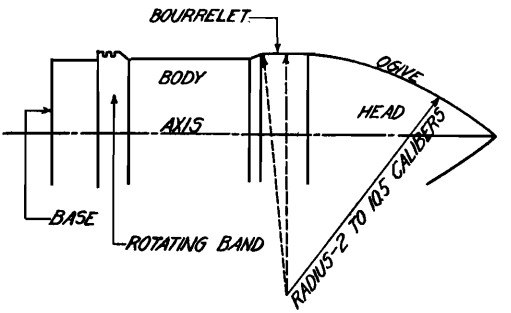
CHAPTER III

PROJECTILES.

General Considerations.

All modern projectiles have the same general shape, cylindrical with ogival head. The length is from $2\frac{1}{2}$ to 5 times the caliber of the gun. The longitudinal section of the ogive is usually the arc of a circle, the radius of which varies from 2 calibers to 10.5 calibers. The ogive may extend to the point, if a base fuze is used, or it may be truncated to form the fuze seat for a point fuze. In rear of the ogive is the maximum diameter of the shell itself, which is known as the bourrelet. The body of the shell extending from the rear of the bourrelet to the rotating band is of slightly smaller diameter than the bourrelet. The copper rotating band has a greater diameter than the bore of the gun until the force of the explosion makes it conform to the shape and size of the lands and grooves. In rear of the rotating band is the base, which is cylindrical or conical, the latter shape being called "boat-tailed."

Diagram showing the general shape of a projectile and its important parts:



Ogive—The head or ogive of a projectile is a circular curve struck from a center on a line perpendicular to the axis of the projectile and with a radius expressed in calibers. The radius was formerly about 2 calibers for all projectiles, but it has been found in recent years that a marked reduction in air resistance and consequent increase in range could be obtained by increasing the radius of ogive. This

radius now runs as high as 10.5 calibers. Projectiles with these sharp points, however, do not have the same capacity for piercing armor as projectiles with blunter heads, even though the former are provided with armor piercing caps.

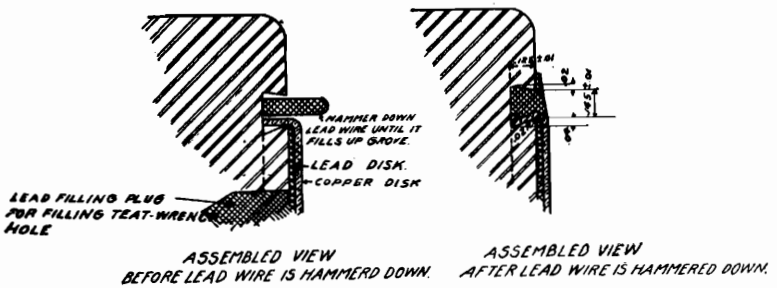
C. R. H.—This abbreviation means the "Caliber Radius of Head." (It is sometimes used in range tables, especially British.)

Bourrelet—The bourrelet has a carefully finished surface which is of but slightly less diameter than the diameter of the bore of the gun between lands. This difference in the diameter of bourrelet and that of the bore is known as clearance and is only a few hundredths of an inch. The purpose of the bourrelet is to provide a bearing surface which centers the forward end of the projectile in the bore, and so prevents any shock against the sides of the bore and consequent irregularity in departure from the muzzle. The body of the projectile is machined off to a smaller diameter than the bourrelet to prevent any contact with the lands and thus reduce the friction. This also reduces the cost of manufacture as the dimensions do not have to be so exact nor the finish so smooth.

Rotating Band—Between the body and the base an undercut groove is made for the rotating band. The bottom of the groove has waved ridges or knurling to prevent the turning of the band with respect to the projectile. A ring of copper, alloyed with $2\frac{1}{2}\%$ nickel, is heated and slipped over the base of the projectile, and pressed into the undercut groove while still hot. It is machined into shape after it has cooled. The width of the band is from $\frac{1}{8}$ to $\frac{1}{3}$ caliber, increasing with the caliber of the gun, and the outside is usually cone shaped to fit the centering slope. The diameter of the band is somewhat greater than the diameter of the bore between grooves, so that some of the copper must be scraped off as the projectile moves forward. To facilitate this, one or more grooves, called "cannelures", are cut around the band. The purposes of the rotating band are to seat the projectile when rammed, and prevent the escape of gas forward, to center the rear of the projectile and to impart rotation to the projectile.

Base Cover—In base fuzed projectiles there is danger of premature explosion in the bore of the gun due to leakage of the hot gases of the propelling charge through the base plug and fuze threads. In point fuzed projectiles this

same danger appears, though to a less degree, due to the pores in the metal of the base of the shell. Therefore to prevent this leakage of the gases into the interior of the shell, base covers are attached to all heavy artillery projectiles after they have been fuzed. A circular undercut groove is made in the base of the projectile outside the base plug. A lead disc is placed over the base of the projectile covering the space within the circular groove. Over this is placed a flanged copper disc, the flange entering the undercut groove, into which it is caulked with lead wire.



BASE COVERS

COAST ARTILLERY PROJECTILES.

Projectiles used in Coast Artillery may be classified as follows:

Armor Piercing (*A. P.*) *Shot*—used against the side of armored vessels at short range to obtain penetration.

A. P. Shell—used against the side of armored vessels at longer ranges to damage the armor without penetration.

Deck Piercing (*D. P.*) *Shell*—used in high angle fire to penetrate the deck of vessels and explode after penetration.

Common Steel Shell—used in light armament against unarmored ships.

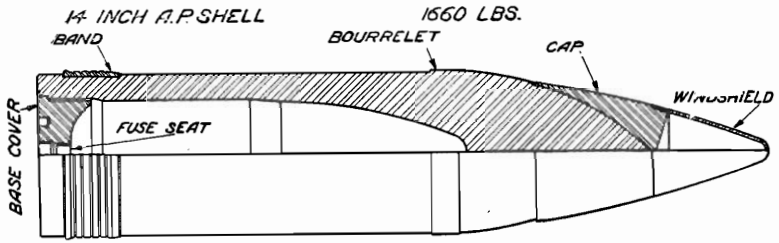
Sub-Caliber—used in target practice.

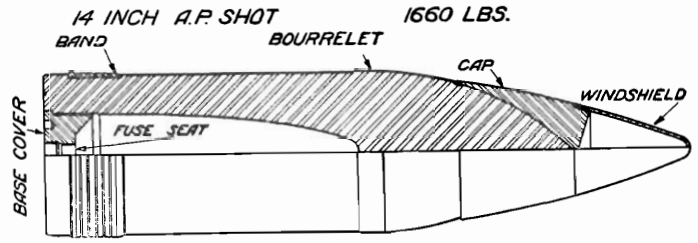
Target Practice—cast iron projectiles for use in target practice.

Comparison of Shot and Shell.

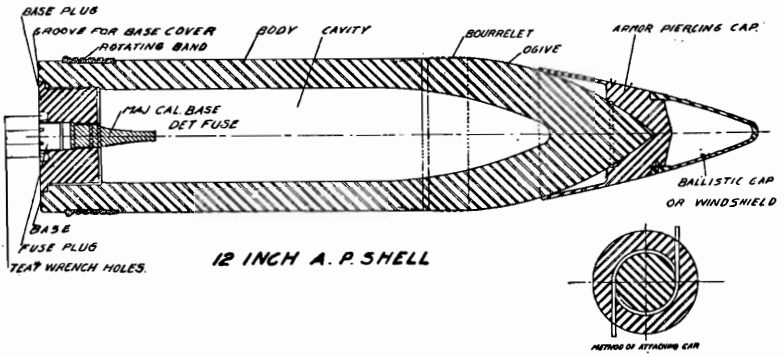
Shot and shell are of equal weight when used for the same gun. The shot, however, is shorter than the shell,

has thicker walls and carries less high explosive. Due to the thicker walls of the shot it has a greater penetrative power than the shell. The diagram below shows this comparison. In the shell the bursting charge is 5 to 6% of the total weight. In the shot it is 1.5 to 2% of the total weight of the projectile.





Armor-piercing Cap—All armor-piercing projectiles are now fitted with soft steel caps which, under ordinary circumstances, increase the penetration of the projectile when attacking hard-faced armor.

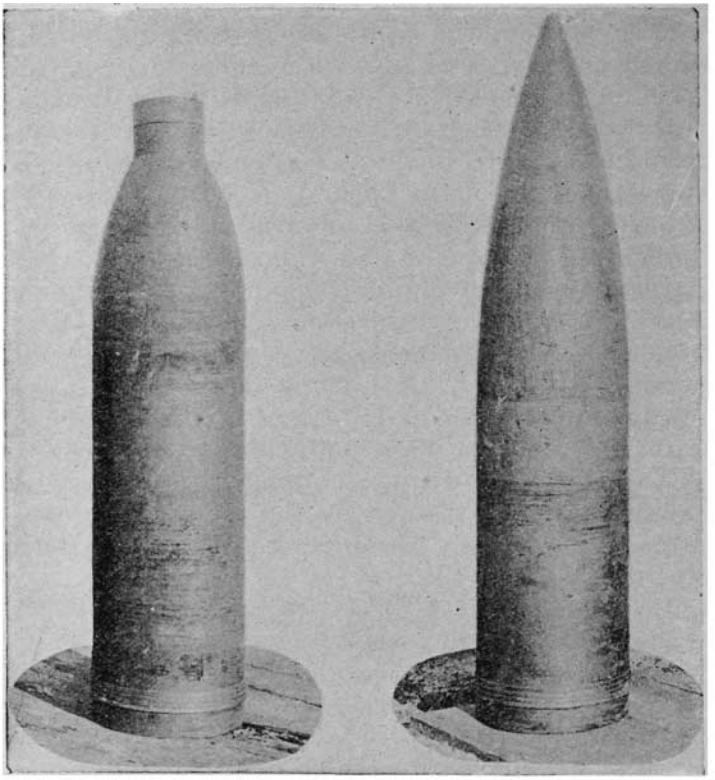


As shown in the above diagram the *A. P.* cap is

fastened to the body of the shell as follows: an annular groove of semi-circular cross section is ground into the head of the shell and a similar groove is cut in the cap. These grooves coincide when the cap is placed in position. Two pieces of wire are then driven into the grooves through tangential holes drilled in the side of the cap, thus fastening the cap to the head of the shell.

If no *A. P.* cap were used on armor piercing projectiles, upon impact of the point of the projectile with the specially hardened surface of modern armor the point would probably be broken or crushed and the head of the projectile flattened. The flattening of the head causes loss of penetration. However, when using the *A. P.* cap, the cap itself strains and bends the hard face of the armor plating. The cap is soft and the hard point of the projectile is able to pass through it, and upon coming in contact with the armor plate, already strained by the blow of the cap, it is able to pass more easily through it with no shattering of the point of the projectile.

Ballistic Cap (*Windshield*)—Until recently the cap in our service was cylindrical in form with a blunt nose. This form was considered the best for the attack of armor. However, a sharp-pointed cap is now being made because it was found that this form greatly improves the ballistic properties of the projectile. This new form of cap is being added to the projectiles on hand as soon as the shot hoists of the emplacements have been modified to accommodate the increased length of shells. The short caps—armor piercing caps—have been threaded so that the new ballistic caps may be added to the projectile by screwing them over the A. P. caps. The effect of these ballistic caps is a flatter trajectory, greater remaining volocity at a given range, increased range and greater perforating power.



12-Inch Shell with Old Cap

12-Inch Shell with New Model Long Pointed Cap

Special Features of Seacoast Projectiles.

Tracers—In order that the fire of the guns may be more accurately controlled through ease of identification of splashes and that the behavior of the projectile in its flight may be more effectively studied, a device known as a tracer has been developed. There are two types of tracers, a day tracer and a night tracer. The night tracer consists of a tracer and fuze, assembled in a short metal cylinder which may be secured in a seat prepared in the base of the projectile. There is a small air chamber at the mouth of the tracer, covered by a metal disc, in which is cut a gas port, the size of which depends upon the caliber of the gun in which the tracer is used. The cover is connected by a rod to the friction element. On explosion of the powder charge in the gun, the gas of the charge enters the air

chamber of the tracer through the gas port; and, while the projectile remains in the bore, the gas in the air chamber is under high pressure. After the projectile leaves the gun, the pressure on the tracer port being released, the cover of the tracer is forced to the rear and thus draws the central rod back and ignites the friction compound, which in turn, ignites the compressed, slow-burning composition. This burns with a bright white light for 15 to 20 seconds. During the day the tracing feature is accomplished by placing in the cavity of the projectile a mixture of lampblack and water.

On firing, the powder gases enter the shell through a small orifice at one side of of the base. After the projectile leaves the muzzle the internal pressure forces the tracer liquid into the air. Experiments indicate that shell provided with this day tracer can be observed for over 7,000 yards.

PAINTING AND MARKING OF SEACOAST PROJECTILES.

In general the painting of projectiles has two objects: to protect the metal from corrosion and to identify the types of projectiles and their contents.

The interior of all seacoast projectiles loaded with Explosive "D" are painted with a non-acid paint known as "rubberine" to prevent the forming of sensitive compounds between the explosive and the steel casing of the shell.

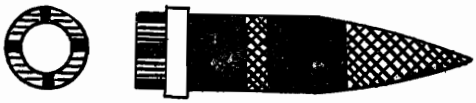
The threads of base plugs, fuze plugs and fuzes should not be painted with anything but cosmoline or vaseline. The use of any paint makes it impossible to remove the plugs when necessary.

The exterior of seacoast projectiles are painted various colors to indicate the material of which the projectile is made, the explosive with which it is loaded, and whether or not it is fuzed. All projectiles are first painted black all over except the rotating band, which is never painted. Immediately before firing, however, the bourrelet may be polished with emery cloth to reduce friction of the projectile and prevent paint from being deposited on the lands of the gun. To indicate the center of gravity, in order to facilitate handling with the shot tongs, and to indicate the material of which the projectile is made a band is painted around the center of gravity of the projectile. The following colors are used:

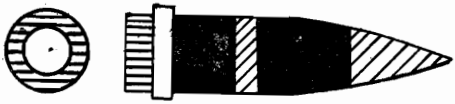
Forged steel.....blue gray.
Cast steel.....warm gray.
Cast iron.....olive green.

DISTINCTIVE COLORS FOR COAST ARTILLERY PROJECTILES

FORGED STEEL SHELL-UNFUZED



CAST STEEL SHEEL-FUZED



FORGED STEEL SHOT



CAST STEEL SHOT



TARGET PRACTICE PROJECTILES



BLUE GREY

WARM GREY

BLACK

YELLOW

OLIVE GREEN

The one exception to the general rule of using but one band upon the center of gravity is upon the target practice projectile. This projectile is painted black all over, the center of gravity band of olive green is added, and another band of the same color is painted between the center of gravity and the rotating band.

To indicate whether a projectile is a shot or shell the following paintings are used:

Shot—The entire ogive is painted the same color as the center of gravity band.

Shell—Two-thirds of the ogive is painted the same color as the center of gravity band, or the ballistic cap alone is painted that color, if it has one.

Loaded but not fuzed—Four black stripes, one in each quadrant, are painted on the base of the projectile from the rotating band to the base cover groove. When the projectile is fuzed these stripes are painted out with the color of the balance of the base. The base cover and the rotating band are never painted.

CARE AND STORAGE OF SEACOAST PROJECTILES.

Pile projectiles on their sides with base toward accessible side of pile. Place skids between them to protect the rotating band and pile each type of projectile separately, grouping them by lots.

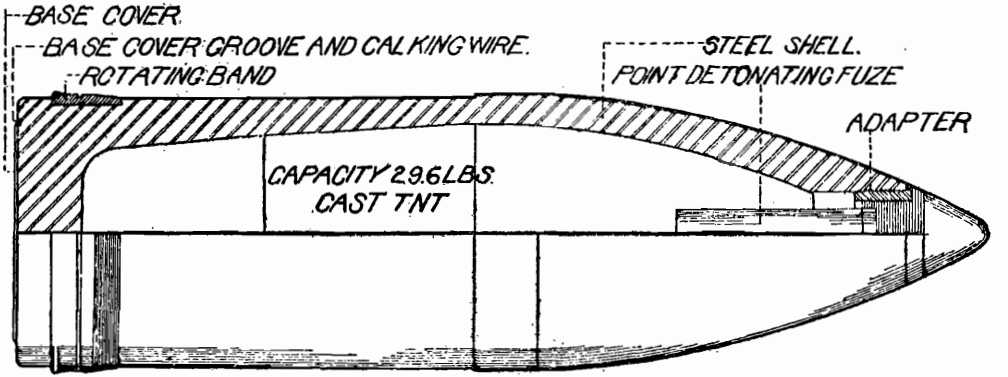
Projectiles should be painted before storing and slushed with oil if the magazines are damp.

Great care should be exercised to avoid any damage to the rotating band.

Before firing, the paint should be scraped from the bourrelet, the projectiles thoroughly cleaned and a fillister of heavy grease placed immediately in front of the rotating band.

Coast Artillery projectiles are usually shipped in crates; however, if no crates are available the rotating bands should be protected by rope grommets or other suitable material.

PLATE VI



8 INCH COMMON STEEL SHELL MARK-I.

36-23-105

MOBILE ARTILLERY PROJECTILES.

Mobile Artillery projectiles may be classified as to the material of which they are made, as to whether they are base or point fuzed, and as to the use for which they are designed. Projectiles are now made of *common steel*, which may be cast or forged steel, and of *semi-steel*, which is obtained by purifying cast iron in a special furnace. Semi-steel contains from 2.75% to 3.25% of carbon and is much more resistant than ordinary cast iron, although less so than steel. It is used extensively because of its lower cost and ease of manufacture.

Mobile Artillery projectiles of less than 10″ caliber have point fuzes. Projectiles of 10″ caliber and over usually have base fuzes, although point fuzes are now coming into more general use even on large caliber projectiles.

Mobile Artillery projectiles are classified as to their uses as follows:

High explosive shells, shrapnel, chemical shells, including toxic, smoke, and incendiary shells, illuminating shells, and anti-aircraft projectiles.

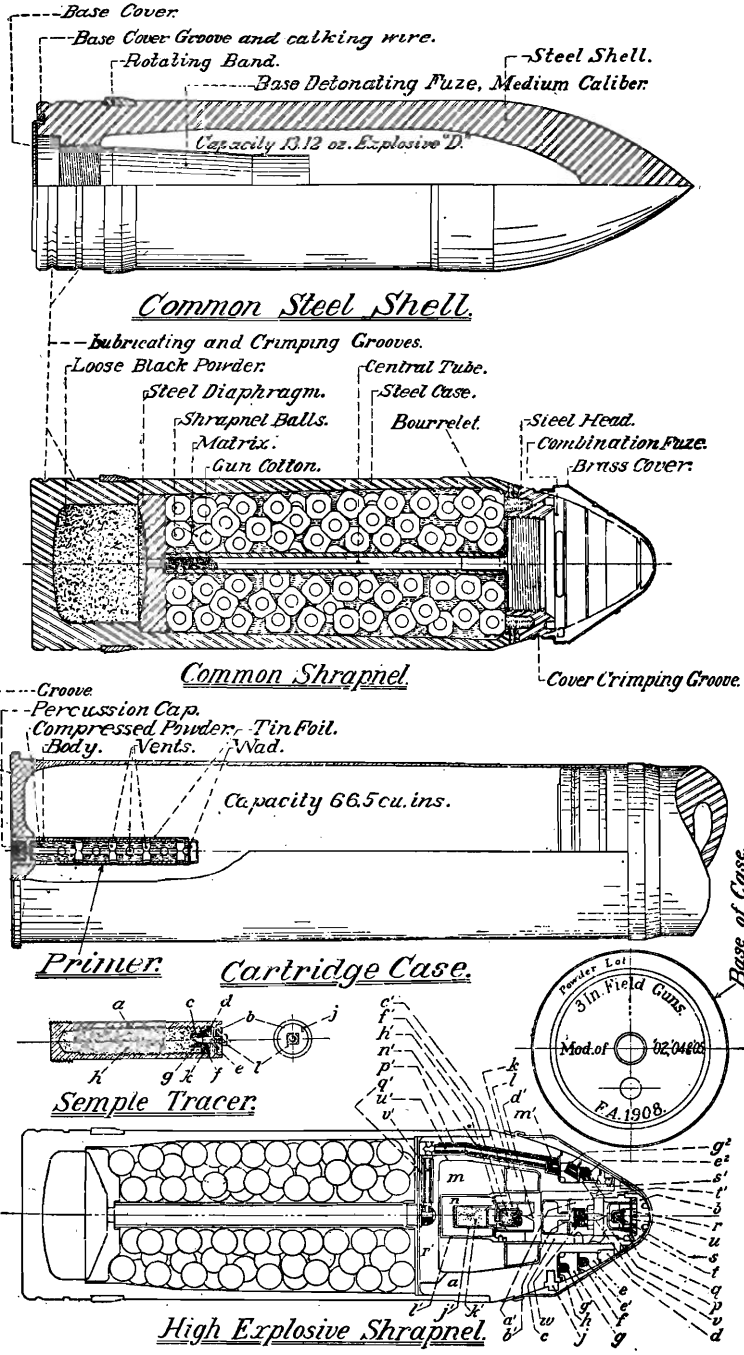
High Explosive Shell.

H. E. shells may be common steel or semi-steel. They consist, as the name implies, of a steel body filled with a high explosive called the bursting charge. They are used in cannon of all calibers against personnel and materiel.

The walls of the common steel mobile artillery shell are thinner than those of the armor piercing shell in Coast Artillery, and thinner than the semi-steel shell. The walls of a howitzer shell are thinner than those of a gun shell as a general rule for a given materiel. But the use of all of them is practically the same.

Shrapnel.

Shrapnel may be defined as a projectile capable of bursting in air under the action of a time fuze and throwing out a number of lead balls with a velocity, which added to the remaining velocity of the projectile can produce killing effects upon exposed troops. The case of a shrapnel when functioning as such should not burst. Shrapnel fuzes are also provided with a percussion element which causes a burst upon impact. Shrapnel is intended primarily for use against unprotected personnel.


Base Cover.
Base Cover Groove and caulking wire.
Rotating Band.
Steel Shell.
Base Detonating Fuze, Medium Caliber.
Capacity 13.12 oz. Explosive "D."
Common Steel Shell.
Lubricating and Crimping Grooves.
Loose Black Powder.
Central Tube.
Steel Diaphragm.
Steel Case.
Shrapnel Balls.
Bourrelet.
Steel Head.
Matrix.
Combination Fuze.
Gun Cotton.
Brass Cover.
Common Shrapnel.
Cover Crimping Groove.
Groove
Percussion Cap.
Compressed Powder.
Tin Foil.
Body.
Vents.
Wad.
Capacity 66.5 cu. ins.
Base of Case.
Primer.
Cartridge Case.
Powder Lot
3 In. Field Guns.
Mod. of
'02, '04 & '08.
F.A. 1908.
Semple Tracer.
High Explosive Shrapnel.

GAS SHELL.

Gas shell are very similar to those used with high explosives but are filled with non-explosive chemicals designed to kill or incapacitate troops by poisoning them internally or by direct action on the skin or eyes. While the use of the term gas shell is general, it is a fact that none of the chemicals used are gases. Most of them are liquids while a few are solids. The function of the shell is only to act as a container and carrier for the chemicals.

The principal difference between gas and high explosive shell is that the nose of the gas shell is modified to receive a different type of booster. (Boosters will be described later.) The booster used with high explosive shells would not be satisfactory in gas shell because in the latter type enough high explosive must be contained in the booster to rupture the shell walls and scatter the contents, whereas the function of the high explosive shell booster is merely to give an explosion of sufficient violence to detonate the main charge of the shell. Either steel or semi-steel can be used in the manufacture of gas shell. Because of the high strength of steel, the shell walls may be made thinner than in the case of semi-steel and consequently a steel shell of a given weight can carry a considerable larger quantity of gas than can be put in a semi-steel shell of equal weight; on the other hand on account of the large amount of explosive required in the booster charge to open the walls of the steel shell, there is a tendency for the chemical to be dissipated to too great an extent. The present tendency seems to be, therefore, towards the use of semi-steel for gas shell. Both steel and semi-steel shell are designated for use in our service.

Because of the fact that some of the chemicals used would be attacked and rendered inert by the steel of the shell and booster, if it came in contact with them, it is necessary that the shell to be used with these gases be provided with a lining of some material on which the chemicals do not act. A lead lining has been adopted in our shells for this purpose. Experiments are also being made on the use of enamel in the case of semi-steel shell. Enamelling of the steel shells is not feasible because the high temperatures employed in enamelling interfere with the heat treatment previously given the shell.

SMOKE SHELL.

Smoke shells are similar to high explosive and gas shells but filled with a chemical which is designed to produce a heavy smoke at the point of burst. Shells of this type are used for two distinct purposes: for spotting the point of burst of the shell and to produce a concentration of smoke in a given area (blinding observation posts, etc.). White phosphorous is used as a filler for smoke shells up to 4″.7 caliber.

INCENDIARY SHELLS.

Incendiary shells are used to ignite any combustible materiel in the vicinity of the burst. They are also used very effectively with time fuzes against balloons.

ILLUMINATING SHELLS.

Illuminating shells are used chiefly in curved angle fire and contain stars provided with silk parachutes similar to those used in fireworks. It has a time fuze and a small charge of black powder whose function it is to throw the base to the rear and ignite the stars. The latter fall slowly and cast a bright light on the surrounding objects lasting about 45 seconds. The best height of burst is about 300 meters.

ANTIAIRCRAFT PROJECTILES.

Formerly shrapnel were used in firing upon aircraft but it has been proved that high explosive shells with clockwork fuzes are more effective. The function of antiaircraft fire is to prevent observation by enemy observers by keeping them at such a height that observation is practically impossible.

PAINTING AND MARKING MOBILE ARTILLERY PROJECTILES.

Mobile Artillery projectiles are painted for protection of the metals and to serve as a means of identification.

The rotating band, base cover and fuze cover of all projectiles will not be painted.

The following colors are used to denote the various types of shells:

DISTINCTIVE COLORS FOR PAINTING MOBILE ARTILLERY PROJECTILES

COMMON STEEL HIGH EXPLOSIVE SHELL.

FIXED



UNFIXED



SEMI-STEEL HIGH EXPLOSIVE SHELL



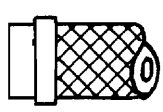


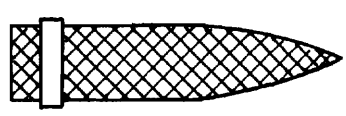
COMMON SHRAPNEL



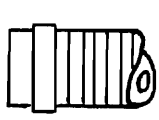


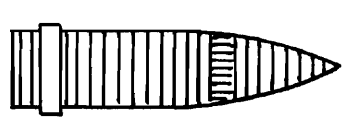
ANTI-AIRCRAFT TRACER SHELL



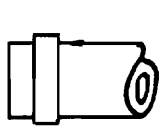


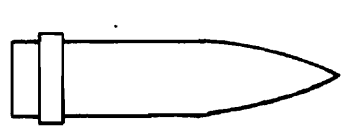
H.E. AMATOL SHELL WITH SMOKE MIXTURE



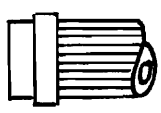


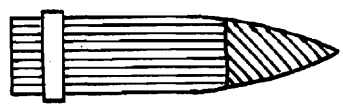
ILLUMINATING SHELL



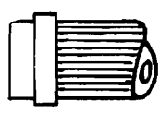


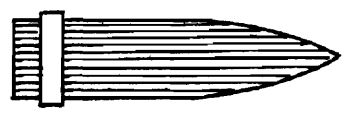
INCENDIARY SHELL





TOXIC (GAS) SHELL





TARGET PRACTICE SHELL





SMOKE SHELL





RED

GREEN

BLACK

YELLOW

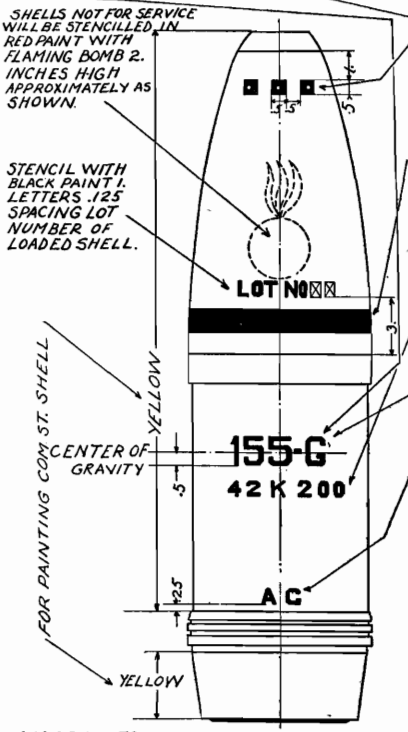
BLUE

WHITE

Common steel high explosive shell.yellow from point to base.
Semi-steel high explosive shell... yellow ogive, black body.
Common shrapnel.....red from point to base.
Antiaircraft tracer shell..... blue from point to base.
Illuminating shell..... white from point to base.
Gas shell..... green from point to base.
Incendiary shell.....red ogive, olive green body.
Smoke shell..... black from point to base with an olive. green band just above rotating band
Amatol shells containing a smoke mixture..olive green band just above the bourrelet.
Target practice shells.....Black from point to base.

Shells are stencilled indicating caliber and type of cannon, character of shell filler, weight, lot number, purchase number, date of purchase, initial of manufacturer. Stencilling is done in black on yellow and white background, and in white on other colors.

SHELL MARK	WEIGHT ZONES OVER	TO AND INCLUDING	NO. OF SQUARES & PUNCH MARKS	WEIGHT STENCILING (METRIC EQUIVALENT)	REMARKS
155-G OR 155-H	91 LBS - 3 OZ.	92 LBS - 5 OZ.	2	41 K 700	UNFUZED BUT INCLUDING MARK III BOOSTER 73-1-55 WITH SPECIAL ADAPTER 74-4-25
	92 LBS - 5 OZ.	93 LBS - 6 OZ.	3	42 K 200	
	93 LBS - 6 OZ.	94 LBS - 8 OZ.	4	42 K 700	
	94 LBS - 8 OZ.	95 LBS - 10 OZ.	5	43 K 200	
	95 LBS - 10 OZ.	96 LBS - 12 OZ.	6	43 K 700	



EXPLOSIVE	SYMBOL
T.N.T. CAST	A C
50-50 AMATOL	AM 50-50
80-20 AMATOL	AM 80-20

DIAGRAM FOR PAINTING AND MARKING FILLED SHELLS

* FOR PAINT SPECIFICATIONS SEE ORDNANCE PAMPHLET 1868A

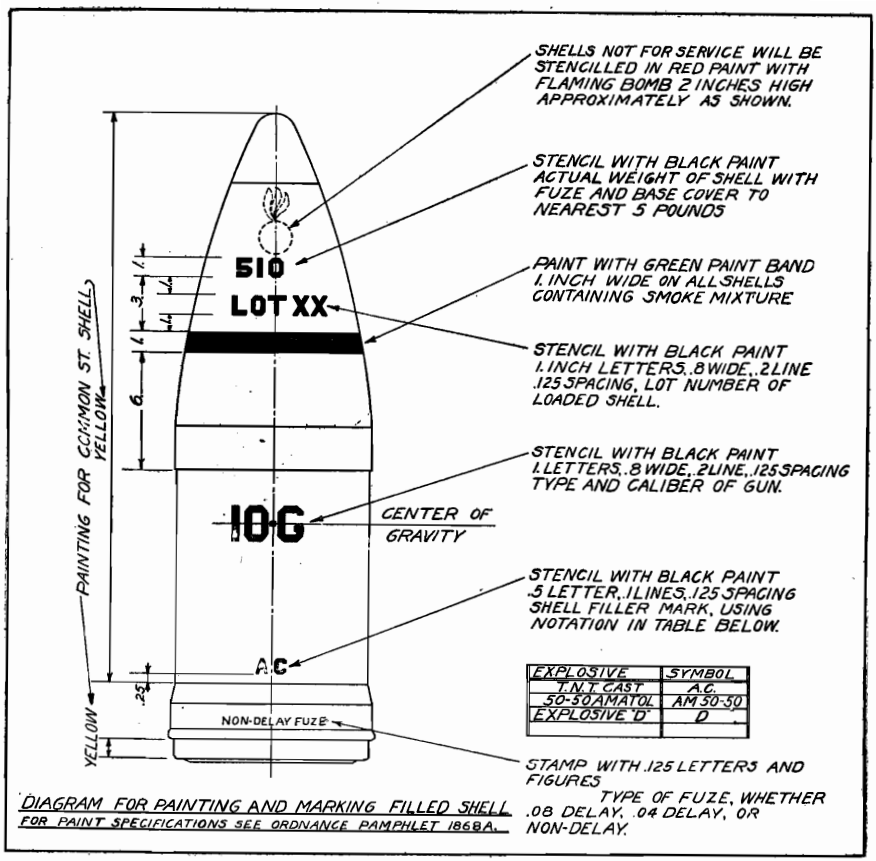


DIAGRAM FOR PAINTING AND MARKING FILLED SHELL
FOR PAINT SPECIFICATIONS SEE ORDNANCE PAMPHLET 1868A.

Stencilling indicating caliber and type of cannon is in figures and letters 1″ high on the body of the projectile, viz: 6 G-6″ Gun; 8 G-H—8″ gun or howitzer. 12 M—12″ Mortar; 3 AA—3″ antiaircraft. The character of the shell filler is indicated in $\frac{1}{2}$″ letters just above the rotating band, viz: AC—T. N. T.; Am 50-50—Amatol 50-50; Expl D—Explosive "D". The weight of the projectile is stencilled to the nearest five pounds on the ogive. Relative weights are indicated by punch marks above the bourrelet as follows: one—underweight; two—normal; three—above weight. The lot number, date of purchase, purchase number and manufacturers initials are in 1-8″ letters just above the rotating band opposite the shell filler stencil.

Transportation of Projectiles.

In the past it has been customary to pack projectiles in heavy wooden crates for shipment, thus insuring absolute protection to them en route. Owing to the enormous quantities of projectiles which are now being shipped and the extra weight and loss of cargo space which the old method would entail it has been decided to follow the example of our allies and ship projectiles uncrated relying upon rope grommets to protect the rotating band. This will of course mean that particular care must be exercised by those engaged in the transportation of shells that they are not subject to unduly rough handling and that the grommets are kept in their proper position. To facilitate the handling of the shells there will be provided screw eyes which will be screwed into the fuze seat of the projectile, thus not only protecting the fuze seat but affording a means of picking up the shell.

Care and Storage of Mobile Artillery Projectiles.

On account of the size and weight of heavy artillery projectiles it will be found impractical to store them in dugouts. They should be placed in dumps separate from other kinds of ammunition and not fuzed. Dumps should be 20 yards apart and not more than 15 shells to one dump, if practible. Dumps should always be camouflaged and made splinter and weather proof, if possible. Splinters may damage shells but only a direct hit will detonate them. Fuzed shells are more easily detonated than unfuzed shells and as fuzes generally deteriorate when exposed, not more than six shells for one gun will be kept fuzed at a time. Care must be taken that shells damaged by shell fire are not loaded into the gun particularly at night. The damage caused by splinters may be easily missed, but may be sufficient to cause a premature explosion or damage to the bore. Whenever possible stand the projectiles on end on planks separated from each other by strips of wood. If for lack of space they have to be stored in layers put boards or clean branches between them to protect the rotating band. Special care must be taken to keep the rotating bands in good condition as damaged bands produce unsteadiness of the projectile, irregular shooting, and erosion of the bore. Any burrs should be filed off before firing.

COPPER FOULING OF THE BORE.

Copper fouling of the bore due to the depositing of copper from the rotating band in the grooves increases the resistence in the bore and should be carefully guarded against. The following method of decoppering has been developed and is now used in the French service.

This process consists of introducing into the chamber of the gun an alloy consisting of 60% tin and 40% lead by weight which breaks up at the moment of firing into two components, the tin uniting with the copper in the bore of the gun to form a fusible brass alloy. The lead does not unite with the copper but acts principally as a lubricant for the succeeding rounds and tends to granulate the brass alloy and facilitate its removal.

Exhaustive tests made by the French have given rather surprising results. Not only is the process very effective in removing the copper, but it prolongs the life of the gun and increases its range almost equal to that of a new gun.

The alloy is used in two ways; in *decoppering rounds*, to remove the existing copper fouling and in *non-coppering rounds*, to prevent the accumulation of such copper from further firing. The alloy is issued in the form of thin bands folded flat and made up into 20 gram packages.

It is intended that future powder charges will contain sufficient alloy to prevent further copper fouling but until such a time as these non-coppering rounds can be issued continuously it will be necessary for batteries to make use of the decoppering rounds at various intervals to keep the guns in good condition. The cartridges and cartridge bags containing the alloy can be distinguished by the mark A-n, A referring to the alloy and n to the number of grams of alloy contained in the charge. Unless the charges are marked as containing the decoppering alloy it will be incumbent on the battery personnel to introduce the alloy into each charge before firing.

Directions for Introducing Decoppering Alloy in Charges.

Remove from packet the proper amount of alloy as designated above. (Tables showing amount to be used with all caliber guns will be issued as soon as prepared.)

Crumple the band of alloy without crushing it so as to form it in proper size for introduction into cartridge bag. Untie the bag and place the alloy on top of smokeless charge so that it will be close to the base of the shell and then retie the bag.

Before firing the round the gun to be decoppered should be heated by firing a dozen or so rounds without alloyed charges at a rather rapid rate. Continue firing at the same rate with the alloyed charges to prevent the gun from cooling.

From 20 to 40 rounds are generally necessary to decopper a gun of average wear and fouling.

When firing alloyed charges it is important that neither the bore, projectiles or rotating bands be lubricated.

When the operation has been completed the gun must be cleaned in the usual way. No notice need be taken of the yellowish or grayish color noticeable in the bore in some cases.

CHAPTER IV

BURSTING CHARGES.

The criterion for a high explosive is the production of a great volume of gas in so exceedingly short a period as to be practically instantaneous; the shorter this period is the "higher" the explosive. To secure this great rapidity of chemical change, substances are selected that have the atoms necessary to form the heated gases, arranged in the closest proximity to one another. *In a chemical* molecule, the atoms are so arranged (as distinct from mere mechanical mixtures), and therefore chemical compounds are selected for bursting charges, since all bursting charges are explosives of high order. Such molecules contain atoms capable of rearrangement. A molecule of T. N. T., for instance, contains atoms of carbon and oxygen not directly united but straining at one another and only requiring a sufficient shock to break their bonds and rush together to form a stable gas. The disruption of the molecule of T. N. T. also liberates other gases, chiefly nitrogen, together with large quantities of water vapor, and some carbon remains unburnt. The presence of another molecule, such as ammonium nitrate, capable of breaking up by shock into gases containing an excess of oxygen, aids the combustion of the products of detonation and forms more heated gases.

The velocity of detonation of T. N. T. is about 7,000 meters per second, whereas that of gun powder is only 200 to 300 meters per second. The pressure reached by some high explosives amounts to 300 tons per sq. inch as against about 50 tons for gun powder. This accounts for the great difference in the effects produced by explosives of the high order as compared with those produced by explosives of the low order. Many high explosives can only be ignited with difficulty, although large quantities when once inflamed, may eventually burn violently, but they are all readily caused to detonate by means of a sufficiently powerful initial impulse. The full power of a high explosive is only obtained when detonation is complete. High explosive shell sometimes only partially detonate or merely explode. (See chapter on Propelling Charges for the difference between detonate and explode).

Requirements of a Good Shell Filler.

Reasonably safe to manufacture and easy to load.

Stand shock of discharge and of impact.

Be detonated completely by a service fuze, and cause sufficient fragmentation of the projectile.

Be stable in storage and reasonably non-hygroscopic.

Not form sensitive compounds with ordinary metals, or if so, be able to be prevented by simple means.

Supply ample and quickly obtainable at reasonable cost.

Kinds of Explosives Used as Bursting Charges.

T. N. T.—Tri-nitro-toluol, commonly known as T. N. T., is known in other countries under such names as trotyl, tolite, etc. It was adopted in this country some time before the war as a filler for high explosive shells, mines, bombs, etc., and is used alone or mixed with ammonium nitrate. It is a cream colored crystalline substance when pure, darkening on exposure to the light. It melts at 80° C to a brown liquid. Its density when cast is about 1.55 to 1.60. The fact that T. N. T. melts at a temperature less than the boiling point of water gives it a great advantage over most other high explosives, since it facilitates its manipulation for shell filling. Other advantages of T. N. T. are that it does not tend to corrode and does not form sensitive compounds with metals. Alkalis, however, have a bad effect on its stability, and it does not give proper density of loading unless the shells are very carefully filled. T. N. T. may be used in shells of all caliber, but as a rule is used only in point fuzed projectiles, as it has been found more advantageous to use Explosive D in base fuzed projectiles, in which it is possible to load this explosive by means of tamping.

Amatol—a combination of ammonium nitrate and T. N. T. The ammonium nitrate by itself is not considered an explosive, but when mixed with T. N. T., forms a more powerful explosive than T. N. T. itself. Its great value is that it opens up an enormous supply of cheap, easily obtainable material. Ammonium nitrate is a white crystalline substance, which when ground up resembles common table salt in appearance. It melts at 170° C when quite pure and dry, but when mixed with other salts sometimes found in ammonium nitrate it may melt at temperatures as low as 110°. Its chief disadvantage is that it is very hygroscopic. Also due to the oxidizing power

of ammonium nitrate very little smoke is given out at burst and so observation is difficult. Amatol is made up in two ways: one is a mixture of 50% T. N. T. with 50% ammonium nitrate, and the other is a mixture of 80% ammonium nitrate with 20% of T. N. T. 50/50 amatol is filled into the shell in a similar manner to that of filling molten T. N. T. 80/20 amatol, which is not fusible, may be tamped in or loaded with an extruding machine.

Smoke Mixture—All amatol filled shells contain some form of smoke mixture to aid in spotting the burst. In the case of 50/50 amatol a mixture of 75% alumimum and 25% 80/20 amatol is used. In the case of 80/20 amatol a mixture of ammonium chloride, ammonium nitrate, and T. N. T. is used. This smoke mixture is compressed into 5 ounce cylinders and wrapped in waxed paper to protect it from moisture. One of these cylinders is dropped into the shell, a small amount of amatol is poured in and allowed to cool so as to fasten the smoke mixture in the bottom of the shell. Then the filling is proceeded with as usual.

Amatol is used in point fuzed projectiles of all calibers.

EXPLOSIVE "D."

Explosive D has for many years been used in this country as a high explosive shell filler, but is now used in only certain types of shells, T. N. T. and amatol being used to a far greater extent. The advantages of explosive D are its insensitiveness to shock, its stability in storage, and the availability of the materials used in its manufacture. However, its disadvantages are that it forms sensitive compounds with metals and is not fusible, thus requiring tamping. Explosive D is an orange colored salt melting at a temperature very slightly below the ignition point (about 302° C). The pure salt is very insensitive to shock and cannot be exploded by any of the ordinary shocks liable to be received during handling or loading.

Preparation of the empty shell—Shells to be filled with Explosive D should be thoroughly inspected to insure completeness of coating of the interior of the shell. Great care should be taken that the cavity be free from all dirt and chips of any kind, and that there be no metallic salts contained in the paint or in any of the compositions used to coat the interior of the shell, where it may come in con-

tact with the shell filler. The paints generally used for this interior painting are non-metallic, chemical-resistant paints. No paints except those authorized by the Ordnance Department should ever be used for this purpose. Another means of preventing any contact between the explosive and the metal is by use of a shell lining of T. N. T. This method is briefly as follows: the shell is cleaned and varnished as for cast T. N. T., then filled with molten T. N. T., allowed to stand for about a minute, and the T. N. T. poured off, leaving a thin coating upon the walls of the cavity. The shell is filled withExplosive D and a T.N.T. surround formed around the fuze. This surround unites with the cavity lining of T. N. T., and thus forms a total surround of T. N. T. between the explosive and the metal wall of the shell.

SHELL LOADING.

T. N. T. and 50/50 amatol are fusible and are loaded into the shell in a molten state in the following manner: The explosive is melted in steam kettles or on steam-heated pipes and poured into the shell at a temperature as near the crystallizing point as possible. When it is poured in hot, it crystallizes slowly, forming large crystals. The resulting charge is therefore less homogeneous and dense than in the case of explosive poured in at a temperature a little above its setting point. Hence the necessity of pouring at a low temperature. To produce a good solid filling it is advantageous to have the shell at above 30° C., otherwise the cold metal will rapidly solidify the explosive and the trapped air would be retained. If proper care is not taken in loading the shell, voids may be formed in the filler due to too rapid contraction of the explosive upon solidification. This forming of voids in the shell filler due to improper loading is known as *cavitation* and is a serious fault, for it is certain that this is one of the causes of failure of the shell to burst. Where cavitation exists the head of the bursting charge sets back at the moment of discharge leaving the detonating system. When this set back is appreciable the explosion of the detonating system is insufficient to leap the gap with the necessary force, and a mild explosion or a blind results.

To prevent cavitation the liquid should be probed with wooden rods when nearing the solidification point so as to remove all gases. This probing must be done

gently so as not to entangle air in the viscous mass, and must not be continued after the first signs of solidification. In shells containing more than 5 pounds of explosive the filling should be done in two or more stages, collected gases being removed at each stage.

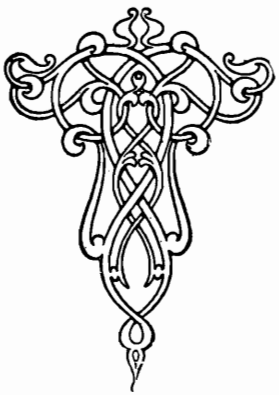
80/20 Amatol—This form of amatol may be tamped into the shell in a heated condition by means of a specially adapted stemming rod, or may be loaded by means of an extruding machine as follows: The amatol is carried from a steam jacketed hopper and forced into the shell by means of a worm or screw feed device, which revolves in a steel tube, the principle being similar to that of the familar meat grinder.

Explosive D—Since this explosive is not fusible, it is loaded through the base of the projectile in a powdered form and stemmed or tamped in with a suitable stemming rod. Small portions of the explosive are fed into the shell at a time, each portion being carefully tamped before the next is added to insure efficient density of loading. Since Explosive D is loaded in a powdered form it is impossible to form a fuze seat in it that will stand up under transportation. It is necessary, therefore, to place an aluminum fuze seat liner in the fuze seat formed in the explosive or to cast the fuze seat from T. N. T. In the case of Coast Artillery projectiles, which are usually loaded at the posts, the fuze seat is drilled with special tools and the fuze inserted directly.

Forming the Booster Cavity—The booster cavity is the cavity in the shell filler to admit the insertion of the booster and the fuze.

The method of forming the booster cavity in a shell is either by drilling or forming. To drill the cavity, the shell is filled completely and the cavity is drilled by means of a special drill. This method is dangerous, however, and the cavity is usually formed instead. When the cavity is to be formed, the shell is not completely filled, a hole larger than the booster being left. Into the end of the shell is fitted a form or mold. The upper end of this form is a cup in the bottom of which holes are drilled leading into the cavity of the shell. The lower end of the form

is a solid mold the size and shape of the booster. Molten T. N. T. is poured into the cup of the form until the cavity of the shell and the cup are full. After the T. N. T. has solidified, the form is twisted to break the T. N. T. in the holes of the cup, and the form is lifted out, leaving a cavity which exactly fits the booster and fuze.



CHAPTER V

FUZES.

Classification of Fuzes.

A fuze is a device, attached to the shell, used to ignite the bursting charge of the projectile at the time or under the circumstances desired.

Fuzes may be divided into three general classes according to their mode of action:

(1) Time fuzes, or those which are designed to produce the explosion of the shell at a predetermined time after the shell is fired.

(2) Percussion fuzes, or those designed to function when the shell meets some resisting object.

(3) Combination fuzes, or those containing both the time and percussion elements.

Time fuzes may be further classified as (a) powder train fuzes or those whose time of operation is regulated by the burning of a train of compressed powder, and (b) clockwork or mechanical fuzes depending upon the operation of a clockwork for their time of functioning.

Percussion fuzes are classified as to:

(1) Location in the shell: (a) Point; (b) Base.

(2) Time of functioning after impact: (a) Instantaneous; (b) Non-delay; (c) Short delay; (d) Long delay.

(3) Method of arming: (a) Inertia; (b) Centrifugal force; (c) Those combining both inertia and centrifugal force.

General Considerations.

The present high explosive bursting charge must be insensitive to shock of discharge and shock of impact. Explosives that meet these requirements need for their detonation a fuze with a powerful detonator, which must be sensitive. Where the explosive charge is large, the amount of detonator required would make the handling and firing of the fuze unsafe. For that reason there is introduced into the fuze an auxiliary or booster charge which is exploded by the detonator and in turn detonates the bursting charge

in the projectile. A detonating fuze consists of three elements: *primer*, *detonator* and *booster*. Either the primer or booster may be omitted. To secure the most effective results the booster charge should surround or be in intimate contact with the detonator. If delay action is required one or more delay pellets are inserted between the primer and the detonator.

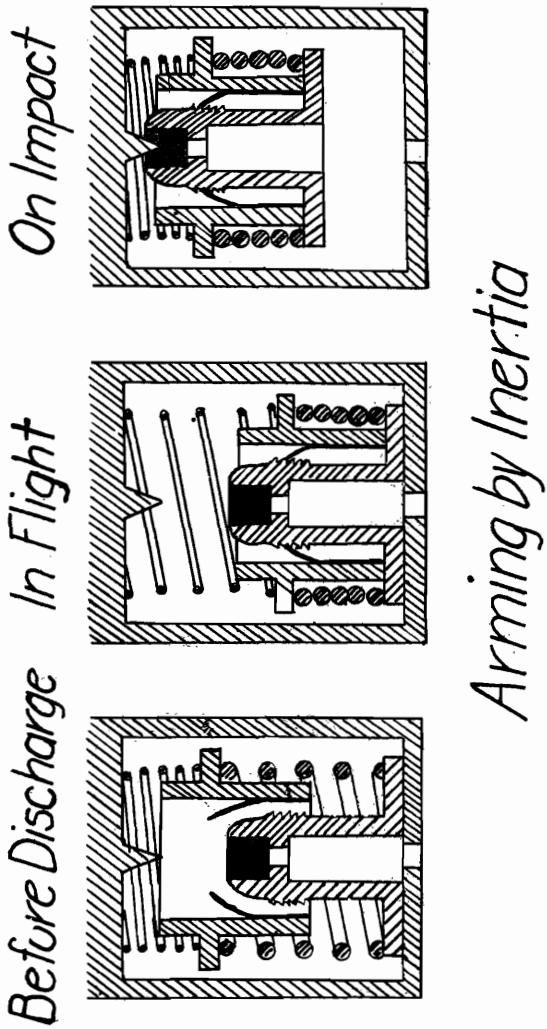
Fulminate of mercury is universally used for the priming and detonating elements. Its value as a detonator lies in the suddenness of action and the enormous pressures developed, the volume of gases evolved being 1340 times the volume of the solid fulminate at ordinary temperatures and pressures which is further increased by the heat resulting from the explosion. It may be developed by a blow, by the action of an electric spark, by friction, or by heat above 195° C. When exploded in its own volume, fulminate of mercury gives more than twice the pressure developed by nitroglycerine and nearly three times that of gun cotton. Repeated experiments with various compounds have proven that fulminate of mercury is the only one which will always insure detonation of the first order.

Tetryl is used either alone or in combination with T. N. T. for the booster charge.

A percussion detonating fuze is said to be armed when all the parts or particles of the fuze, which must move on impact in order to function, are free to do so. A fuze may arm by *inertia* or *set-back*, due to the abrupt forward motion of the projectile on discharge; by *centrifugal force* due to the rotation of the projectile; or by a *combination* of inertia and centrifugal force.

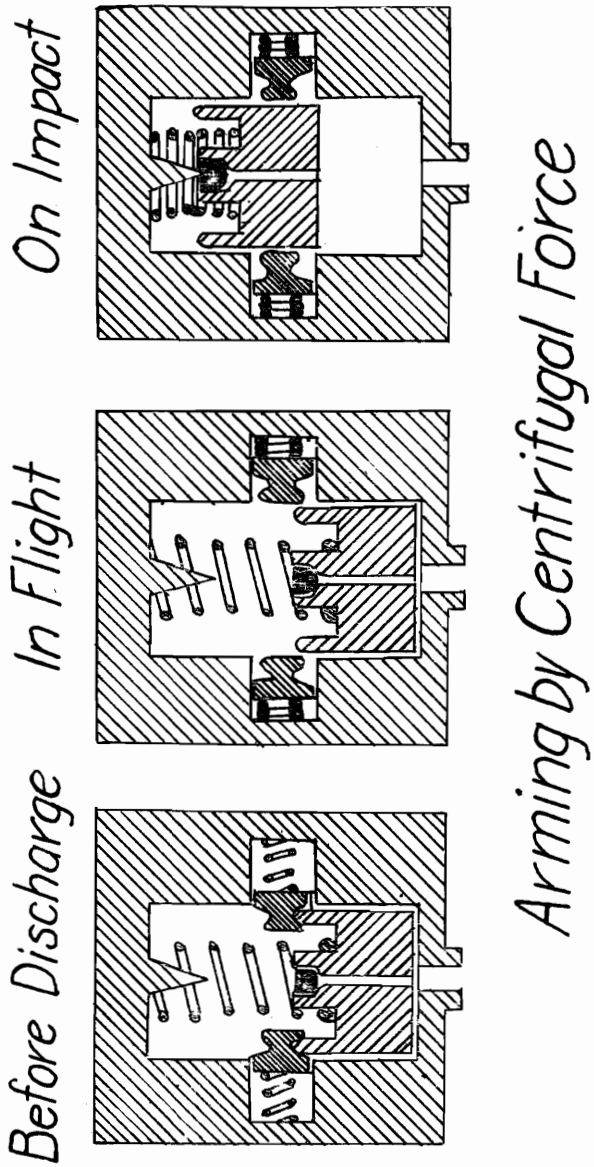
The action of the fuze arming by *inertia* is as follows: this type of fuze consists of a primer-plunger, anvil or firing pin, arming sleeve, arming spring and creep spring. The arming spring is fitted between the sleeve and the primer-plunger, and by keeping these two elements apart, prevents the primer from coming into contact with the firing pin. At the moment of departure the sleeve goes backward due to inertia, compressing the arming spring. Clasp-hooks, which are fitted inside the sleeve, are then able to engage the notches on the primer-plunger. The sleeve, plunger, and arming spring are thus linked together in one piece, which is held back only by the creep spring. The fuze is now armed, because the plunger is free to move

forward on impact, compressing the creep spring, and firing the primer against the firing pin. Fuzes arming by inertia may be classified by the smallest coefficient of acceleration which insures their working at the moment of discharge.



The action of the fuze arming by *centrifugal force* is as follows: fuzes of this type consist of the primer-plunger, firing pin, creep spring and locking bolts. The primer-plunger is fixed in position away from the firing pin during transportation and loading of the projectile by means of locking bolts, which are themselves held in place by small springs. These

locking bolts are thrown out by centrifugal force due to the rotation of the projectile, thus arming the fuze by



freeing the primer-plunger and allowing it to move forward on impact.

The fuze may arm when the shell is still in the bore of the gun or after it has left the muzzle. Even if arming

were to take place after the shell had left the bore of the gun, a premature functioning of the detonator while in the bore would result in detonation of the projectile, by exploding the booster which in turn would explode the shell. Therefore, a shell cannot be said to be "bore safe" unless the detonator and booster are kept separate as long as the projectile is in the bore of the gun, regardless of the time of arming. Much time has been expended in perfecting an absolutely bore safe fuze, one that cannot function until after the projectile has left the bore of the gun. Up to the present time all bore safe fuzes embody one of two designs. One of these is made with two relative positions of the detonator and booster, and the other with a barrier between these elements. In the first design, the detonator is mounted within a saftey chamber, usually in the rear of the fuze stock. If the detonator is exploded prematurely, the resulting gases will expand into this chamber and will not detonate the booster. Either during flight or upon impact the detonator slides into the booster and is then in the firing position. In the second design, the passage from the detonator to the booster is filled with compressed tetryl so that it virtually forms a combination with the former element. A barrier is placed in this passage which prevents the detonating wave from firing the booster. To arm the fuze completely this barrier must be removed.

CARE AND HANDLING OF FUZES.

The sensitiveness of fulminate of mercury and the amount of high explosive used in the booster charge render the handling of fuzes, especially recovered detonators such as may be found on the battle field, very dangerous.

ALL DETONATING FUZES MUST BE HANDLED WITH CARE.

They should only be disassembled by or under the direction of a commissioned officer who thoroughly understands their construction and operation. The following regulations *must* be enforced in the field:

1. IT IS ABSOLUTELY FORBIDDEN TO DISMANTLE ANY FUZE.

2. ANY FUZE WHICH, IN SPITE OF THIS PROHIBITION, HAS BEEN DISMANTLED, MUST BE DESTROYED. FIRING IT RISKS BURSTING THE GUN. HANDLING IT INVITES SERIOUS ACCIDENTS.

3. ANY FUZE THAT HAS BEEN FIRED AND FAILED TO FUNCTION IS DANGEROUS, BECAUSE IT IS ARMED AND LIABLE TO DETONATE AT THE SLIGHTEST JAR. IT IS ABSOLUTELY FORBIDDEN TO TOUCH IT WHETHER IT IS SEPARATE OR ATTACHED TO THE SHELL.

4. TO DESTROY A SHELL OR A FUZE PLACE A CHARGE OF HIGH EXPLOSIVE IN CONTACT WITH IT, COVER OVER WITH EARTH AND SET OFF THE EXPLOSIVE WITH AN ELECTRIC PRIMER.

DETAILED DESCRIPTION OF FUZES.

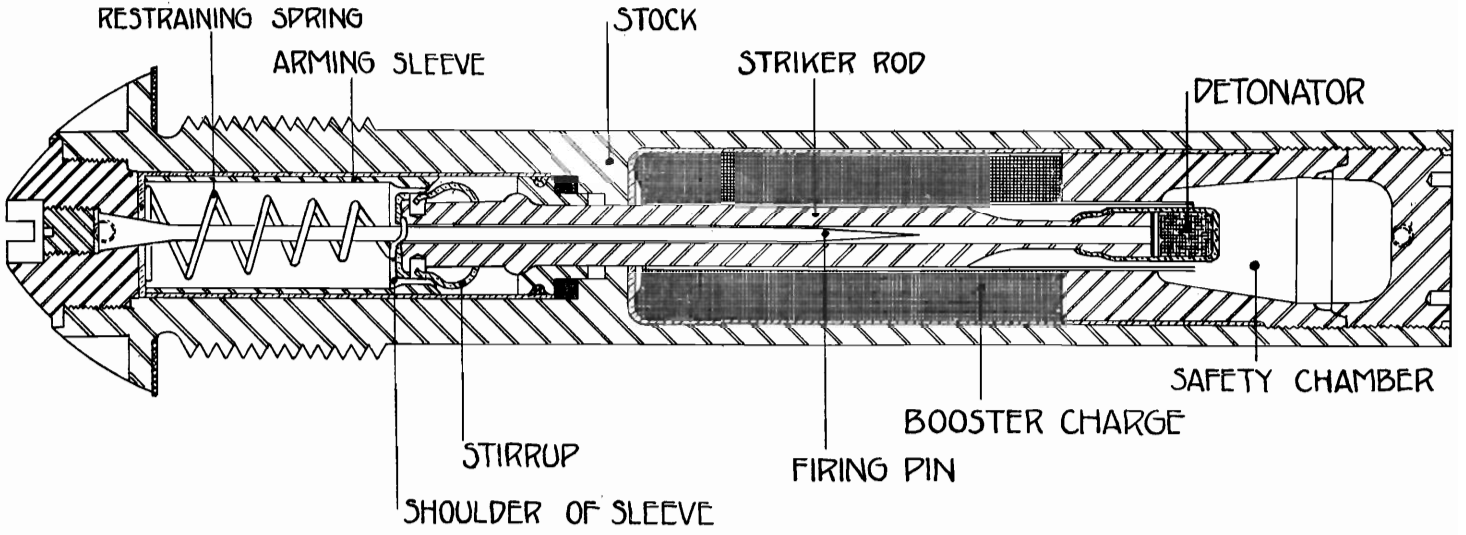
MARK I—CLASSIFICATION.

Country of Design—Russia
Method of Arming—Inertia
Location in Projectile—Point
Time of Action—Non-delay

Safety Devices—
safety chamber
arming sleeve
creep spring
Booster—self-contained

This is a modified Russian fuze and is used in steel shells for 3″ field guns.

POINT DETONATING FUZE, MARK I - RUSSIAN TYPE



DESCRIPTION.

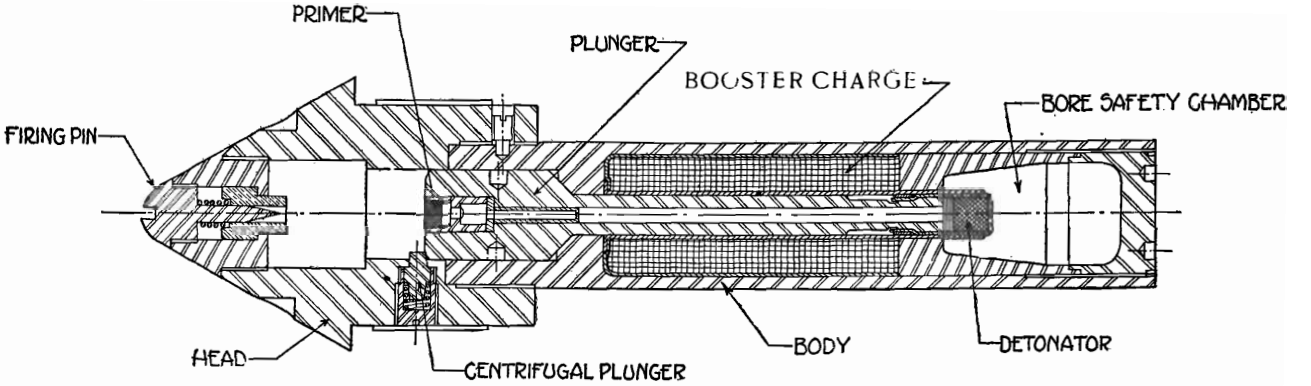
This fuze has what is known as the *detonator safety feature.* Before arming, the detonator is surrounded by an air chamber in such a manner that if the detonator should become ignited prematurely, either in storage or in the bore of the gun, the gases can expand into the safety chamber and not cause the booster charge to explode and ignite the bursting charge of the shell.

In action, the detonator is located in the safety chamber until the striker rod moves forward on impact of the projectile carrying the detonator opposite the booster charge and impinging it on the firing pin. The striker rod is held in the rearward position during transportation and storage by means of the arming sleeve and stirrups. When the projectile is accelerated in the bore of the gun the sleeve sets back over the stirrups, bringing them in front of the shoulder on the sleeve. The striker rod is now held to the rear only by the restraining spring which is compressed as the striker rod goes forward on impact.

This fuze differs from the types previously used in that the firing pin explodes the detonator by direct impact with it, rather than by means of a separate primer.

MARK II—CLASSIFICATION.

Country of Design—Russia
Method of Arming—Centrifugal Force
Location in Projectile—Point
Time of Action—Delay or Non-delay
Safety Devices—3 centrifugal plungers, safety chamber, and firing pin bushing and restraining spring.
Booster—self-contained.



POINT DETONATING FUZE MARK II

DESCRIPTION.

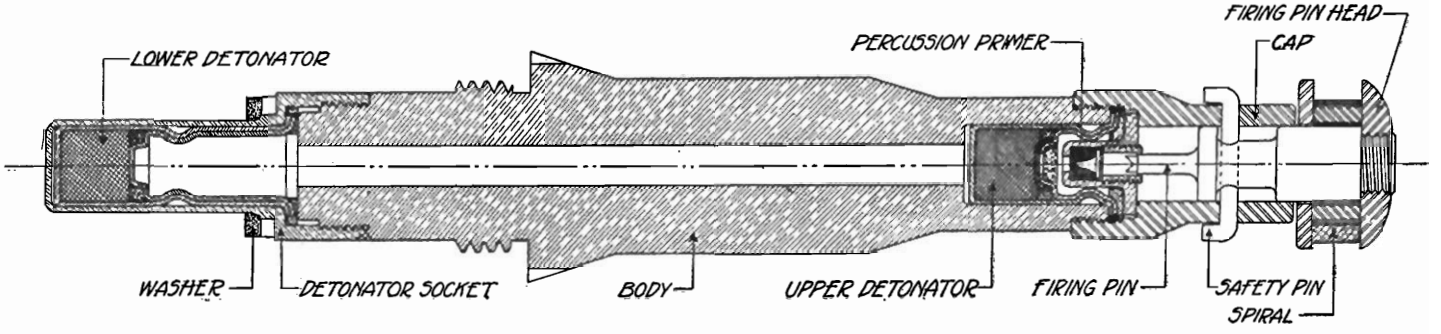
The Mark II fuze also embodies the *detonator safety feature* as described for the Mark I fuze.

In action, the detonator charge proper is located in the safety chamber until the piece is fired. The rotation of the projectile then causes the centrifugal plungers to move outward against their springs leaving the plunger free to move forward into the armed position where it is locked by the expansion of the split ring against a shoulder in the fuze head. On impact, the firing pin is driven into the percussion primer, which ignites the relay detonating charge. The resulting flame ignites the detonator proper, exploding the booster charge, which ignites the bursting charge of the shell.

MARK III—CLASSIFICATION.

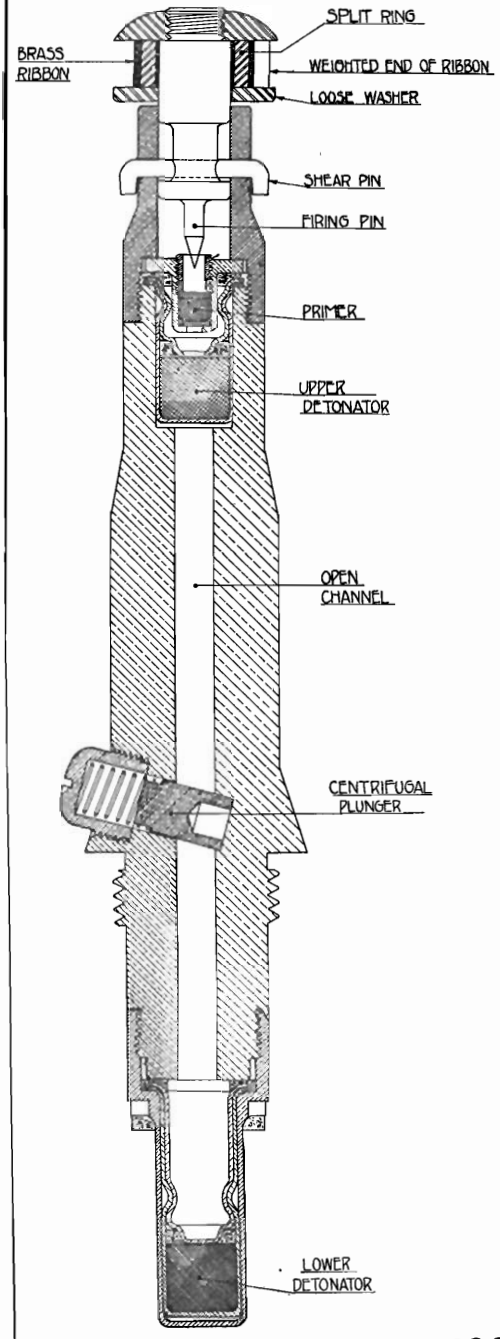
Country of Design—France
Method of Arming—Centrifugal Force
Time of Action—Instantaneous
Location—Point
Safety Devices—Spiral ribbon, safety spring (centrifugal plunger)
Booster—Separate

There has been added to the original Mark III fuze an additional safety feature known as the centrifugal plunger, which breaks the passage between the upper and lower detonators until after the projectile has left the bore of the gun. Centrifugal force causes it to move outward against its spring thus allowing lower detonator to be exploded.



DETONATING FUZE - MARK - III.

MK.III FUZE WITH ADDED SAFETY DEVICE



DESCRIPTION.

The action of the fuze is as follows: The rotation of the projectile causes the spiral to unwind, due to centrifugal force acting on the weighted end. When the spiral flies off the half rings accompany it. This arms the fuze by permitting the backward thrust of the pin on impact to fall directly on the safety pin. When the safety pin is bent the firing pin impinges on the percussion primer. The explosion of the primer in turn explodes the upper detonator. The explosive wave from the upper detonator reaches the lower detonator through the central channel, exploding it and detonating the booster charge in the booster casing. These explosions follow in such rapid succession as to make the bursting of the shell practically simultaneous with the first impact of the firing pin head.

Regulations governing the transportation and handling of the Mark III, instantaneous point detonating fuze.

This fuze is protected during transportation by having a tarred tape wound around the neck of the fuze and a tinfoil cap fitted over the tape. This prevents injury to the brass ribbon and thus insures proper functioning of the fuze. The following regulations must be enforced:

1. Do not remove the tarred tape and tinfoil cap until after the fuze has been screwed into the projectile, when a pull on the loose end of the tape will quickly remove them.

2. Never screw a fuze of this type into a projectile if the tarred tape and tinfoil cap are not in their proper places.

3. After the fuze is screwed into the projectile and the tape removed from the neck of the fuze, examine the brass ribbon and safety pin to see that they are properly adjusted. If the ribbon is broken, the fuze cannot function, for centrifugal force cannot act upon it unless the weighted end of the ribbon is in place. If the safety pin is not in place there is danger of a premature explosion of the projectile.

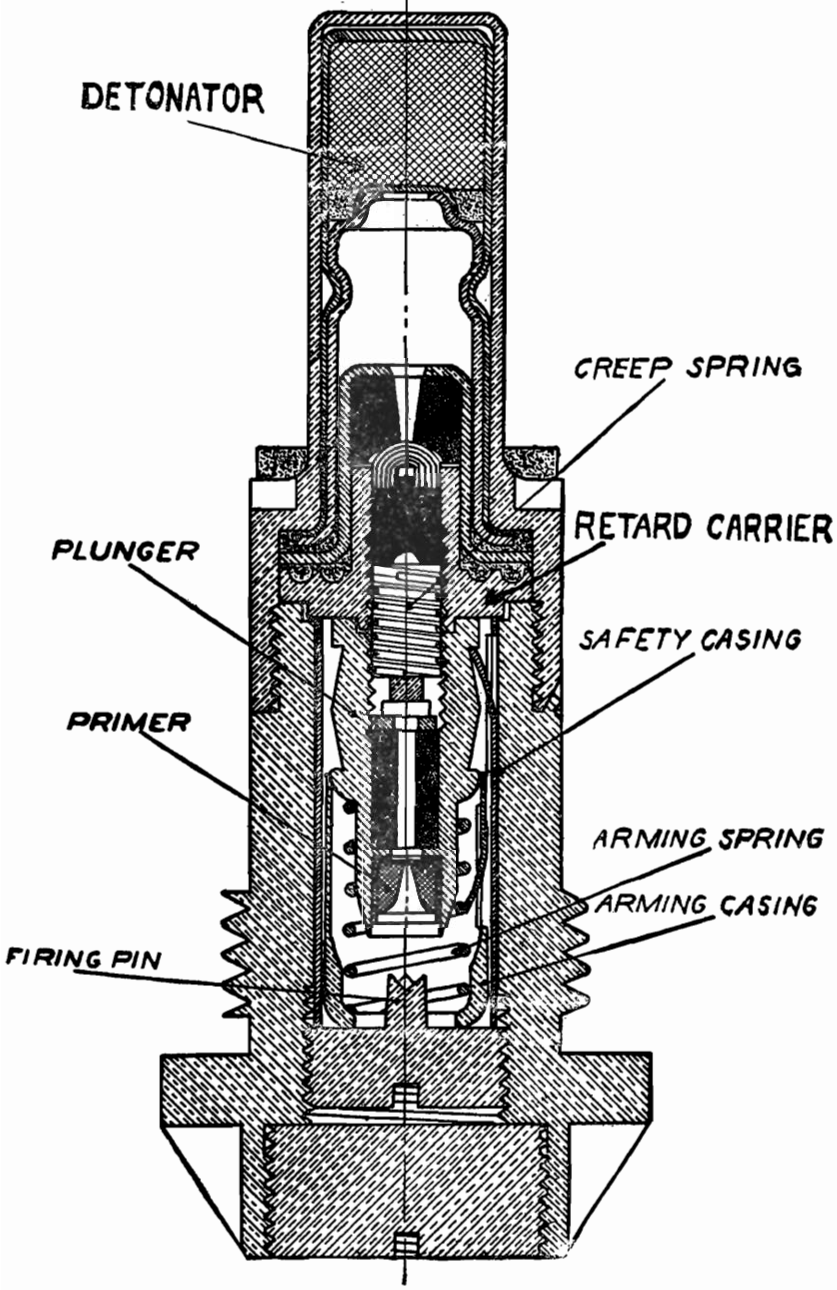
MARK IV. CLASSIFICATION.

Country of Design—France
Method of Arming—Inertia
Location—Point
Time of Action—Delay or Non-delay
Safety Devices—safety casing, creep spring
Booster—separate

DESCRIPTION.

The firing pin is on a plug screwed in the head of the fuze. The percussion primer is carried on a plunger which rests on the retard carrier against which it is held by the three prongs of the safety casing. An arming casing is placed inside of the safety casing and is pushed forward by the arming spring, which rests on a shoulder of the plunger. On firing, the arming casing, by its inertia, compresses the arming spring, the lower edge pushing the prongs of the safety casing off the plunger, and is itself caught by three prongs which engage under another shoulder on the plunger, holding the arming spring compressed and making a rigid unit of the arming casing, arming spring and plunger. The plunger is prevented from drifting forward by a small spiral spring which fits in female threads in both the plunger and the retard carrier. This spring is not strong enough to prevent the plunger from going forward on impact. On impact the plunger drives forward in the safety casing and the primer strikes the firing pin and detonates. The flame from the primer either ignites the delay pellet or sets off the detonator direct which detonates the booster charge.

DETONATING FUZE, MARK IV, FR. TYPE 24/31
MODEL 1899-1915



MARK V. CLASSIFICATION.

Country of Design—France
Method of Arming—Inertia
Location—Point
Time of Action—Delay or Non-delay
Safety Devices-Safety
  casing
  creep spring
  safety head
  safety support
Booster—Separate

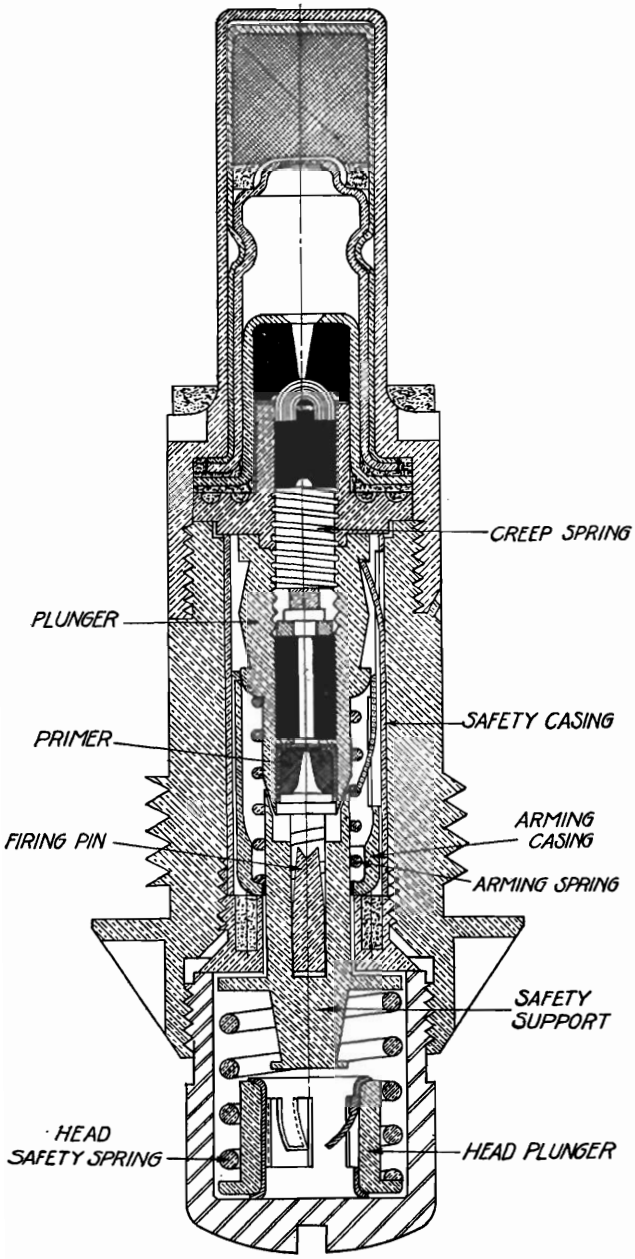
The Mark V fuze is designed and functions exactly as the Mark IV, except for the addition of a head safety. The Mark IV fuze was designed for use in howitzers and mortars which have relatively low muzzle velocities. It was found, however, that this fuze, armed as it was by inertia, was too sensitive and armed too easily for use in guns of high muzzle velocity. The Mark V fuze was therefore developed with an added safety feature which makes it much harder to arm and renders it safe for use in high power guns.

DESCRIPTION.

The action of the arming of the head safety is as follows: The safety support projects beyond the firing pin and prevents the firing pin from striking the primer even if the interior arming device should function prematurely. This safety support is held in place by a strong head safety spring, one end of which rests on the shoulder of the safety support and the other on a shoulder of the head plunger. When the gun is fired, the head plunger, due to inertia, compresses this spring and is caught and held to the head of the safety support. This leaves the safety support free to drift forward, thus uncovering the firing pin.

However, it has been found that the Mark V sometimes fails to function in high powered guns due to the crushing in of the forward cap on impact, and the consequent blocking of the movement of the safety support away from the firing pin. Therefore, a Mark IV fuze, known as the Mark IV* (star), with a specially strong retard spring, is used in 155 mm. Filloux and other high velocity guns.

DETONATING FUZE, MARK V, FR. TYPE 24/31
MODEL 1899-1908



Mark VII and VII–E.

Classification.

Country of Design—U. S. A. and France.
Method of Arming—Inertia
Location—Point
Time of Function—Delay or Non-delay
Safety Devices—Safety screw or safety pin.
Creep spring.
Booster—separate

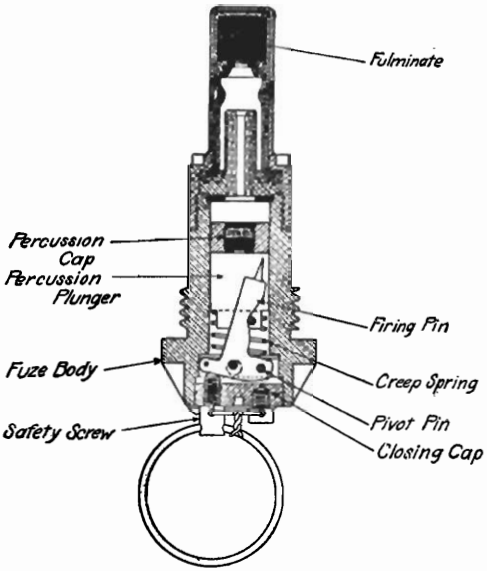
Description.

Since trench mortars have no rifling and thus no rotation of the projectile, fuzes used in them must arm by inertia. But the low muzzle velocities developed in trench mortars will not arm the Mark IV or Mark V fuzes, and therefore the Mark VII and VII–E were designed for use in this type of armament alone. The only difference between these two fuzes is that in the Mark VII there is a safety screw that has to be removed before firing, while in the VII–E there is a safety pin.

The safety ring must be removed before the arming device in the fuze can function. This should only be done immediately before the fuze is screwed into the projectile. Upon discharge, the set back, due to the abrupt forward movement of the shell, causes the percussion plunger to slide back into the bottom of the recess in the fuze body. As it does so, the rider pin slides along the cam-like side of the firing pin and forces the point of the firing pin to a central position over the primer. The shear pin, now bent, tends to hold the firing pin in this position. Upon impact, inertia drives the percussion plunger forward, overcoming the restraining action of the creep spring, and the point of the firing pin strikes the primer. The primer is thus fired and the flame is rapidly carried through the perforated relay pellet and explodes the detonator which in turn detonates the booster. In the delay type the delay pellet delays the action of the fuze for 1/5 of a second.

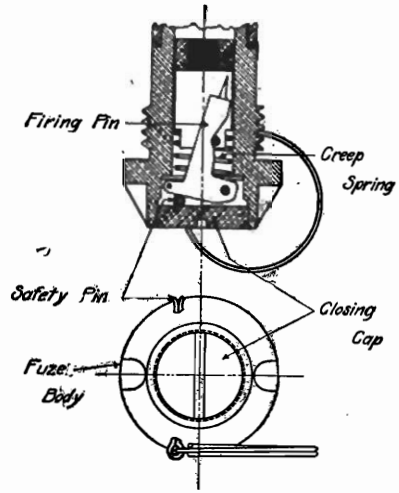
These fuzes are used in 6-inch trench mortar bombs; the delay type is also used in 240 mm. trench mortar bombs.

Mark VII



Trench Mortar Fuze, Mark VII, Nondelay.

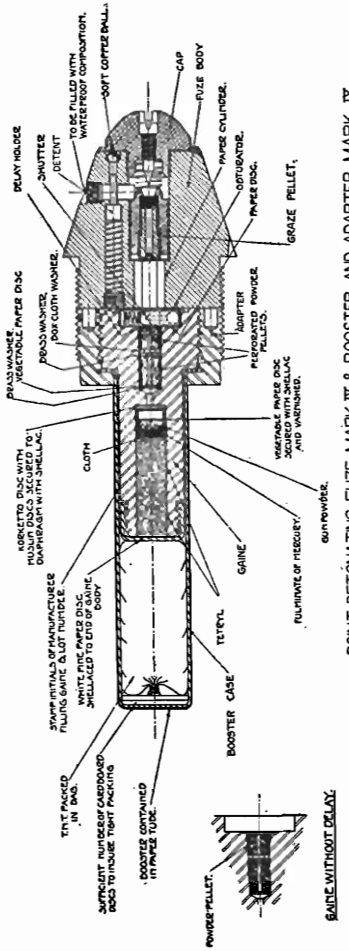
Mark VII—E



Firing Mechanism of Trench Mortar Fuze. Mark VII-E.

Mark IX—Classification.

Country of Design—Great Britain
Method of Arming—Combination of inertia and centrifugal force
Location—Point
Time of Functioning-Delay or Non-delay
Safety Devices—safety shutter
detent
creep spring
Booster—Self-contained.



POINT DETONATING FUZE MARK IX & BOOSTER AND ADAPTER MARK IX.

Description.

This fuze consists of a solid steel body, drilled to receive a percussion plunger, a detent and spring, and a

centrifugal bolt. The percussion plunger is retained by a steel cap containing the firing pin and is held from creeping by a creep spring. The detent and spring and centrifugal bolt are retained by screw plugs. The percussion plunger is brass and is threaded inside to take the plug which retains the percussion primer. The detent is brass and consists of a plunger and rod united by a ball and socket joint. The centrifugal bolt is brass and is held in place by the detent before the fuze arms.

In action the detent rod is withdrawn by set-back from behind the centrifugal bolt. Because of the ball and socket joint the rod is thrown to the side of its recess by centrifugal force and catches under the shoulder of the recess, while the detent spring is overcoming set back. The centrifugal bolt being free to move towards the circumference of the fuze, after the detent is withdrawn, frees the percussion plunger. At the same time, due to centrifugal force, the shutter is forced out against its spring, and the shutter rod drops down and catches on the corner of the shutter, holding the shutter open. In this way the passage between the primer and the detonator is opened, allowing the primer to fire the detonator. On impact the percussion plunger moves forward impinging the percussion primer on the firing pin. The flame from the primer passes through the percussion plunger plug and ignites the relay pellet which in turn explodes the detonator which detonates the booster charge.

Mark XII Fuze.

Classification.

Country of Design—France.
Method of Arming—Inertia.
Location—Point.
Time of Function—Instantaneous.
Safety devices—Safety piece, sleeve, and creep spring.
Booster—Separate.

This fuze is under production in France, but as yet only experimental lots have been produced in this country. It is similar to the Mark III, instantaneous, fuze in its uses. This fuze has been designed to be absolutely safe during transportation and handling as well as very sensitive at the moment of discharge and at the moment of impact. Furthermore its shape is very satisfactory from a ballistic point of view.

DESCRIPTION.

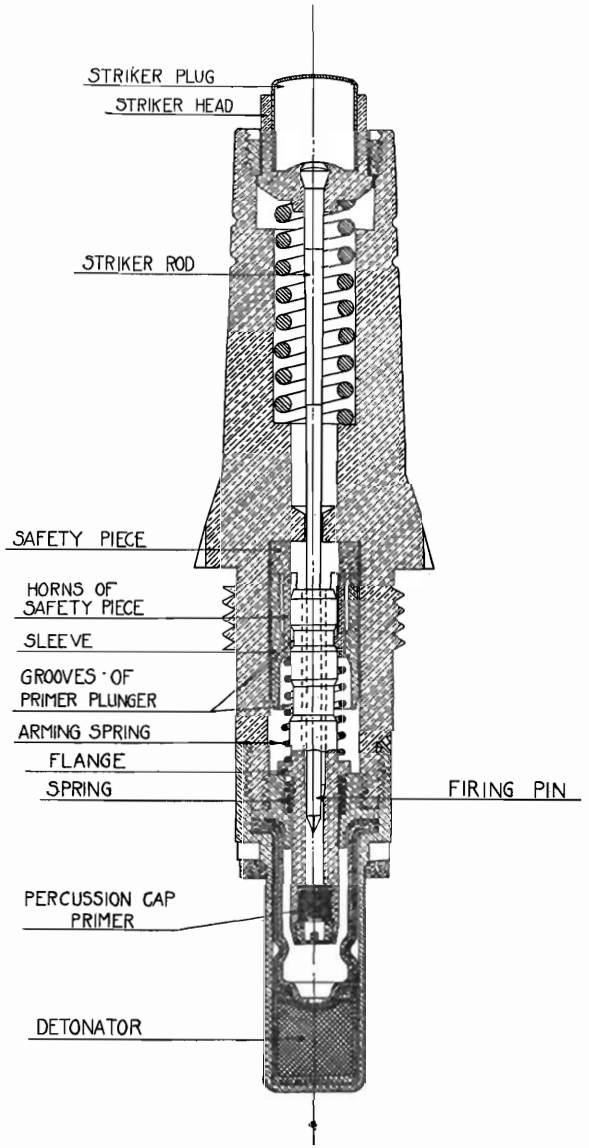
At the moment of discharge, the striker moves backward due to inertia pressing the long spring, but its point cannot reach the primer because the distance is too great. At the same time the sleeve sets back compressing the arming spring so that the clasp hooks of the safety piece are no longer held in upper groove of the plunger. The safety piece is therefore free to move backward due to inertia and the clasp hooks fit themselves into the lower groove of the plunger. The striker then moves forward due to the action of its spring. The sleeve goes forward also and the hooks of the safety piece are held in position by the sleeve in the lower groove of the plunger. Plunger, arming spring, sleeves and safety piece are thus held together and slide forward due to the action of the small spring behind. The primer is then about 1.5 mm from the firing pin. Upon impact, the striker is suddenly stopped, while the other parts of the fuze continue forward. As a result the primer is forced against the striker, causing the fuze to function. The action of this fuze is instantaneous.

ADAPTERS AND BOOSTERS.

Due to the fact that the opening in point fuzed projectiles must be large enough to permit the loading of the shell with high explosive, there must be some way to reduce this opening to hold the fuze. This is accomplished by means of an *adapter*, which is a metal washer or bushing used to reduce the opening in the point of a shell to the size of the fuze or another adapter.

A Booster, technically speaking, is a cylinder so inserted in the shell as to enclose the fuze detonator, leaving a space between the detonator and the outside casing sufficient to contain the *Booster Charge*. In ordinary usage the term booster refers to the booster charge itself. The necessity of the booster in fuzes as an aid to the fuze detonator has been explained at the beginning of the chapter. However, there is a distinction between the booster of a H. E. shell and that of a gas shell which must be clearly understood. The function of a booster in a H. E. shell is to act as an auxiliary detonator and insure complete detonation of the bursting charge of the projectile. The booster of a gas shell must be strong enough to completely rupture

MK.XII FUZE



F-8-10

the shell, as gas shells contain no bursting charge. It must also be borne in mind that the liquids used in gas shells are rendered inert by action with ordinary metals, and that therefore, the booster casings must be coated on the outside with a lead coating when used in chemical shells.

MARK III, SEMPLE TYPE, BASE DETONATING FUZE.

CLASSIFICATION.

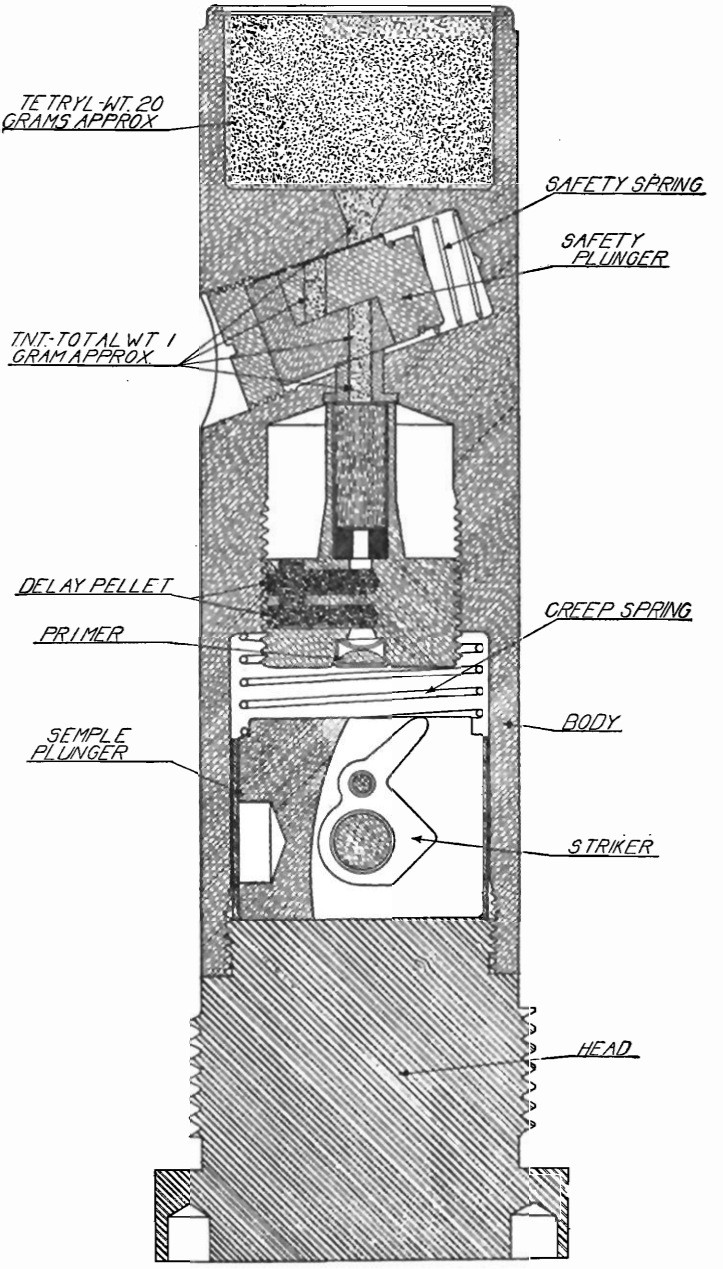
Country of Design—U. S. A.	Safety Devices—Radial pins and Safety Plunger Creep Spring
Method of Arming—Centrifugal Force	
Location in Projectile—Base	
Time of Action—Delay or Non-delay	Booster—Self Contained

DESCRIPTION.

Before firing the plunger is held against the head of the fuze and away from the primer by means of the creep spring, also the Semple striker is held in such a position that it is not opposite the primer. It is locked in this position by centrifugal locking bolts. The detonator is connected to the booster by means of a passage filled with T. N. T. A section of this passage lies in the safety plunger. Before firing the passage is interrupted by the safety plunger being held by a safety spring in an offset position. This insures the fuze being "bore safe" as there is no connection between the detonator and the booster charge until after the shell has left the bore of the gun.

Upon firing, the locking bolts fly out under centrifugal force due to the rotation of the projectile; this frees the Semple striker which also due to centrifugal force rotates around its pivot pin, thus bringing the striker opposite the primer. The plunger is held from drifting forward by means of the creep spring. At the same time the safety plunger, due to centrifugal force, moves outward against the action of the safety spring until the passage through it lies in line with the passage fron the detonator to the booster, thus making a continuous train of T. N. T. between these two. On impact the inertia of the striking plunger causes it to move forward, overcoming the resistance of the creep spring, causing the striker to detonate the

BASE DETONATING FUSE MARK III SEMPLE TYPE



primer, which in turn either ignites the delay pellet or explodes the detonator, which in turn through the T. N. T. train detonates the booster charge.

Fuzes marked "H" will be used in Howitzers and will arm at 1500 R. P. M.

Fuzes marked "G" will be used in Guns and will arm at 2000 R. P. M.

Fuzes marked "M" will be used in Mortars and will arm at 1300 R. P. M.

TIME FUZES.

Powder Train Time Fuzes.

Frankford Arsenal time fuzes have a train of compressed black powder embedded in grooves (in the form of about $\frac{3}{4}$ of a circle) in two metal rings. The lower ring, which is graduated on the outside in seconds of time, is movable and a change in position changes the length of the powder train which must be burned through before the fuze acts. Moving the lower ring changes the relative position of the vent which connects the two trains. The time train is ignited at the moment of firing by the action of a ring resistance plunger striking a percussion cap. A safety point is provided where the vent is opposite the solid portion of one of the rings, so that the entire upper train can burn through without igniting the lower train. All these fuzes have a percussion element as well as the time element.

At the time the United States entered the war we had satisfactory powder train combination fuzes for times of burning adjustable up to 21 and 31 seconds, respectively, in the two designs. These fuzes are standard and are now being used in service. As it was desirable to have time fuzes available for longer periods a modification of the 31 seconds fuze has been developed by the use of slower burning powder. , This gives a maximum time of operation of 45 seconds.

The 31-second Frankford Arsenal fuze is to be completely superseded by the 45-second fuze, which is identical except in the speed of burning of the time train and the graduations of the time-train ring. As there are a considerable number of 31-second fuzes used in the service, only the description of that fuze will be given here, the 45-second fuze being too similar to require separate explanation.

The principal parts of the time element of the 31-second combination fuze are: the time or concussion plunger, the concussion resistance ring, the firing pin, the vent leading to the upper time train, the compressed powder pellet, the upper time train, the vent, the lower time train, and the compressed powder pellet in the vent leading to the powder magazine.

The plunger is cylindrical and contains the primer composition in a recess in its base. The concussion-resistance ring prevents contact of the primer and firing pin by supporting the weight of the plunger, which rests on it. The acceleration of the projectile at the moment of discharge causes the plunger, due to inertia, to spread the ring and bring the primer into contact with the firing pin. Thus begun, the functions of the important parts are best explained by the following description of the time action: Assuming first the "zero" setting as shown in the plate, the concussion plunger arms and fires its primer at the discharge of the gun. The flame passes out through the vent, which is drilled in the walls of the plunger chamber and is exactly opposite the hole in the inner surface of the upper time train at its farthest end. At the zero setting the vents are registered, the flame passing directly down vent to the lower end of the time train, then through the vent to the magazine, from which the flame is transmitted to the bursting charge of the shell. Assuming any other setting, the rotation of the graduated ring so that zero is the required number of divisions from the datum mark, separates the vents, thus stopping the direct access to the train and forcing the flame to travel counter-clockwise until it reaches the new position of the vent, then pass down to the lower train and back clockwise until it reaches the new position of the lower vent, where it

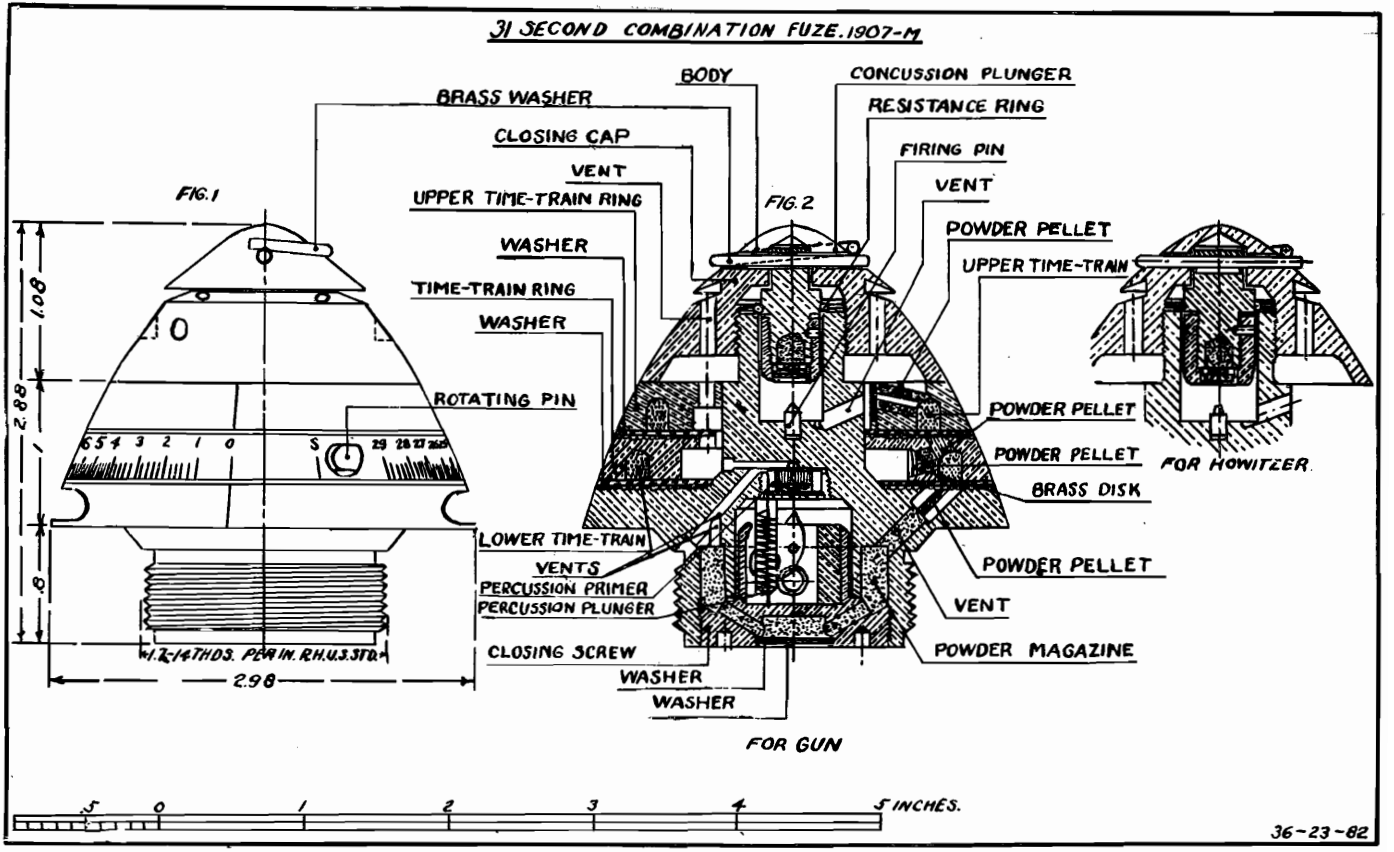
ignites the powder pellet and explodes the powder magazine. The lower powder train ring is graduated in a clockwise direction on its outer edge from 1 to 31.6 seconds. For the 31.6 setting the vent leading to the beginning of the lower time train is opposite the end of the upper time train, and the end of the lower time train is opposite the vent leading to the magazine. It will then be seen that the entire length of both powder trains must be burned through before the flame can reach the powder magazine and burst the shell.

The safety setting is obtained by utilizing the solid surfaces of the upper and lower time train rings left between the ends of the annular grooves. This point is marked by a line on the outer edge of the movable time train and surmounted by an *S* and is located about halfway between the zero mark and the 31.6 mark. When this point is brought opposite the datum mark, the vent is rotated to beneath the solid metal, separating the ends of the upper time train in the upper ring; while the vent leading to the powder magazine is covered by the solid metal separating the ends of the lower time train in the lower ring. With the fuze set at safety, the upper time train may burn entirely out, if the plunger should be accidentally fired, without the flame reaching the magazine. The solid metal of the lower ring covering the vent gives additional safety in case of gas or flame leakage.

Washers are glued to the upper surface of the graduated time train ring and to the upper face of the flange of the fuze stock. Both surfaces are scored to make the washers adhere firmly. The washers act as a gas check and prevent premature action of the fuze.

The compressed pellet in the vent leading from the outside to the beginning of the lower time train is to release the pressure of the gases of the burning train. The escape of the gases from both time trains is through the annular spaces and out the vents in the closing cap.

The percussion element of the fuze consists of a centrifugal plunger and ordinary percussion plunger. The centrifugal plunger is provided with a slot to receive the firing pin, which is mounted on a fulcrum and kept in the unarmed position by two pins which fit in recesses on opposite sides of the plunger by the tension of the springs. These springs are designed to suit the velocity of rotation


31 SECOND COMBINATION FUZE. 1907-M
FIG. 1
FIG. 2
BRASS WASHER
CLOSING CAP
VENT
UPPER TIME-TRAIN RING
WASHER
TIME-TRAIN RING
WASHER
ROTATING PIN
BODY
CONCUSSION PLUNGER
RESISTANCE RING
FIRING PIN
VENT
POWDER PELLET
UPPER TIME-TRAIN
POWDER PELLET
POWDER PELLET
BRASS DISK
POWDER PELLET
VENT
POWDER MAGAZINE
LOWER TIME-TRAIN
VENTS
PERCUSSION PRIMER
PERCUSSION PLUNGER
CLOSING SCREW
WASHER
WASHER
FOR GUN
FOR HOWITZER
1.08
2.88
.8
2.98
1.2-14THDS. PER IN. R.H.U.S.STD.
5 INCHES.
36-23-82

of the particular projectile in which the fuze is used. Centrifugal force due to the rotation of the projectile forces the pins outward against the tension of the springs, releasing the firing pin, which is also rotated into its armed position by centrifugal force. Two spring housings hold the entire plunger and its housing away from the primer during handling, transportation and flight. The system of vents through the walls of the fuze conducts the flame from the percussion primer to the magazine.

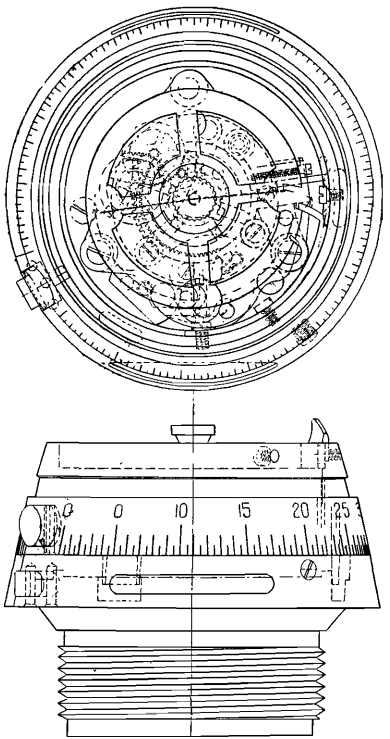
The bottom closing screw closes the percussion plunger recess and keeps the powder in the magazine. An hermetically sealed water proof hood of thin brass is provided for the fuze. The hood should be stripped off before attempting to set the fuze. Remove the safety wire before setting the fuze, and replace the wire if the round is not fired. If the safety wire cannot be replaced the round should not be carried in the ammunition chest or roughly handled, and should be fired at the next firing.

Clockwork Time Fuzes.

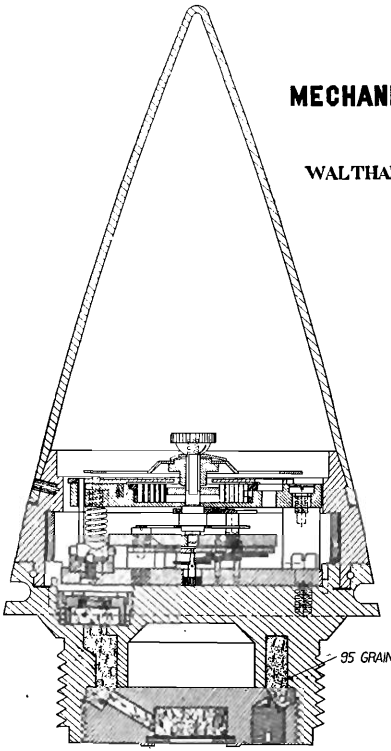
For certain classes of work, particularly in high angle fire as against aeroplanes and balloons, any powder train time fuze is not entirely satisfactory because the rate of burning depends on the atmospheric pressure which becomes less at the higher altitudes. A clockwork fuze has been developed which functions on elapsed time independent of atmospheric conditions.

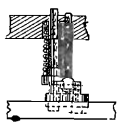
The Waltham Mechanical Time Fuze may be set for any desired time of burst, and is similar in construction to a watch. The shock of discharge starts the mechanism which operates to release a trigger and firing pin after a certain number of seconds have elapsed, for which the fuze is set and which is indicated by markings on a graduated rim.

The fuze consists of 65 parts and is driven by a steel watch spring, which is wound by a special key through a recess in the top plate cover. This spring is connected by friction to a flat steel set plate on top of the fuze mechanism, by a flat steel spring washer, which is held against the plate by a knurled nut. To set the fuze the cap, which is attached to a graduated ring, is turned until the desired setting of time in seconds on the scale is opposite the indicator marked on the body of the fuze. When this cap is turned, a steel hook, on the inside of the cap and attached to it, engages



MECHANICAL TIME FUZE
MARK I
WALTHAM(OHLSON) TYPE





73-7-/a .

in a small recess in the steel set plate, rotating this plate to the proper setting.

This set plate makes one revolution in approximately 75 seconds in the case of the 75 second fuze, and therefore is turned through an arc proportional to the desired time of burst as indicated on the graduated ring. A steel pin which is engaged in a forked arm attached to the main shaft of the mechanism, serves to lock it. This pin has a small shoulder on it, which rests against a spring steel cup slotted in several places to make it more elastic. When the gun is discharged the pin sets down into the cup, thereby releasing the forked arm, thus allowing the mechanism to start. The plate then is revolved by the spring until a notch in its periphery rotates to a position opposite a projection on the trigger releasing device, which then drops into place, releasing the trigger and the firing pin. The trigger releasing device is held in restraint by the hook projection on one end, which is held at the periphery of the set plate until the notch rotates to a position opposite the hook. The firing pin is forced into the primer by a spring which is held in compression by the trigger. The upper perpendicular arm is held in a safe position by the trigger releasing arm, unless the fuze is rotating at a rate of over 1700 r. p. m. The firing pin cannot come in contact with the primer, if it should be accidentally released, before the action of a centrifugal safety device consisting of a small steel piece held between the firing pin and the primer by a spring, but moving out under centrifugal force.

A governor similar in construction to the escapement in a watch controls the spring and the train of gears. This escapement is placed on the center of rotation of the fuze so that its function will not be appreciably affected by the centrifugal force. This fuze has no percussion mechanism.

STORAGE AND CARE OF FUZES.

Fuzes are packed in tin boxes sealed by means of a strip soldered to box and cover. These boxes should be stored in dry dug-outs or magazines, protected from weather and splinters, and if possible, shell proof. They should be kept apart from other kinds of ammunition. They should be used in the order of their receipt at the battery to prevent deterioration. As a general rule not more than six pro-

jectiles per gun should be kept fuzed at a time. If it is found necessary to transport shells into which the fuzes have already been fitted, the fuzes should be removed.

PAINTING AND MARKING OF FUZES.

To indicate the time of functioning after impact, point detonating fuzes are painted in the following manner:

Instantaneous—the neck of the fuze is blue and the head unpainted.
Non-delay—the head is painted white.
Short delay—the head is painted black.
Long delay—the head is painted violet.

All parts of base detonating fuzes that come in contact with the bursting charge are painted with a non-acid paint.

ADDITIONAL NOTES ON FUZES.

The notation "24/31" on French fuzes refers to certain dimensions: 24 being the diameter of the gaine or stock in millimeters and 31 the maximum diameter of the head. This indicates the size shell or adapter into which the fuze can be fitted.

All 24/31 fuzes fit U. S. boosters and adapters Marks I to VII inclusive for both H. E. and gas shell.

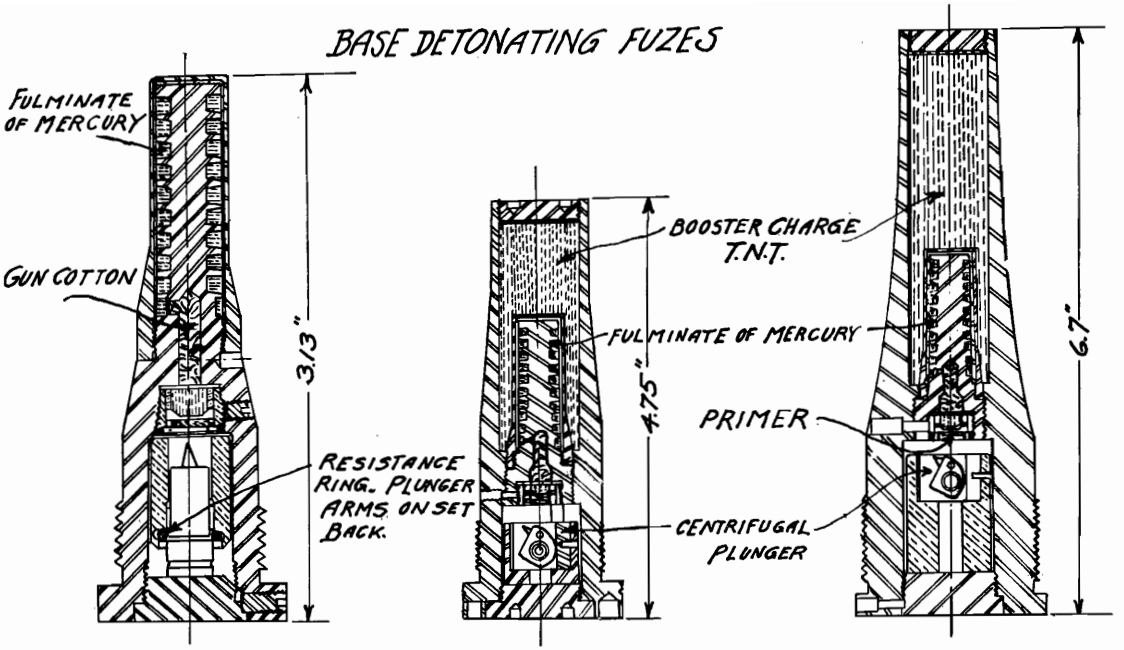
All semi-steel shell take the super-quick fuzes (P. D. F. Marks III, XII and XV—XII and XV are experimental).

Base Detonating Fuzes. The base detonating fuze Mark III, Semple type, will replace *all* other types of medium and major caliber base detonating fuzes.

The medium and major caliber base detonating fuzes, model of 1906, arm by inertia and have self-contained boosters. Both are made up with Non-delay, .04 second delay and .08 delay primers, the type of primer being indicated by suitable markings on the base. The lot number is also stamped on the base.

The minor caliber base detonating fuze is a ring resistance fuze armed by the set back of the plunger. It has no booster. It is not bore safe.

BASE DETONATING FUZES



MINOR CALIBER. (HAS NO BOOSTER)

MEDIUM CALIBER. (MODEL 1906)

MAJOR CALIBER. (MODEL 1906)

THE TWO FUZES SHOWN ABOVE ARE PRACTICALLY IDENTICAL IN DESIGN. BOTH ARE MADE UP WITH NON-DELAY, .04 DELAY AND .08 DELAY PRIMERS.

Other Types of Fuzes.

The following fuzes exist but are not described in this text:

Type	*Remarks*
Mark VI	3-inch Stokes trench mortar.
Mark VIII	Field artillery, experimental type.
Mark X	8-inch and above (experimental).
Mark XI	Trench artillery (experimental).
Marks XIII & XIV	Trench artillery.
Mark XV	8 and 9.2 inch howitzers (modified British fuze No.106), supersensitive.
Mark XVI	6-inch trench mortar.
Minor-caliber point percussion fuze, standard type, (Ring-resistance fuze.)	1-pdr. point-fuzed shell of future manufacture.

Centrifugal Fuzes.

Base percussion fuze, medium and major caliber, "link-lift" type.	Powder-charged shell from 2.95 to 12 in. inclusive, obsolete.
12-M fuze, "link-lift" design.	Torpedo detonating (T. D.) Pierce fuze stocks for 12-in. torpedo shell tapped for this fuze to about 2,200.

Combination Fuzes.

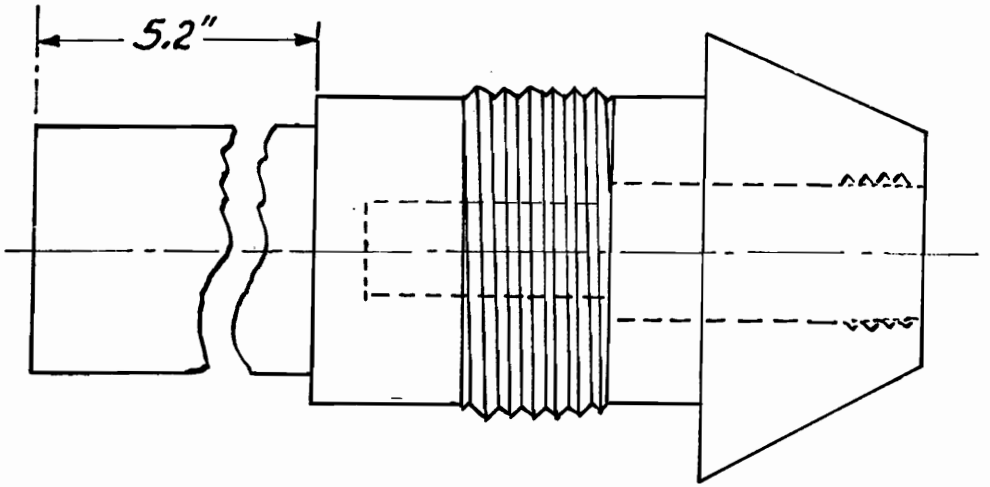
Frankford Arsenal 21-second combination fuze, model of 1907M.	Shrapnel for 2.95 in. mountain gun and 3-in. field gun. Centrifugal plunger.
Frankford arsenal 30-second combination fuze, model of 1911.	Shrapnel for 3-in. mountain howitzer and all 4.72 Armstrong 5-in. seacoast and 6-in. Armstrong shrapnel on hand or ordered prior to Jan. 1, 1914. Centrifugal plunger.
Ehrhardt 20.4-second combination fuze for 3-in. H. E. shrapnel.	Ehrhardt 3-in. H. E. shrapnel, 10,000 on hand and 10,000 additional ordered. Bore safety pellet.

Frankford Arsenal 21-second combination fuze for 3-in. H. E. shrapnel, model of 1912.	Frankford Arsenal 3-in. H. E. shrapnel. Bore safety pellet.
Krupp combination fuze.	3-in. field shrapnel. About 10,000 of these fuzes were purchased from the Krupp Company; obsolete. Supply exhausted.

Detonating fuzes for use in steel projectiles containing a bursting charge of high explosives.

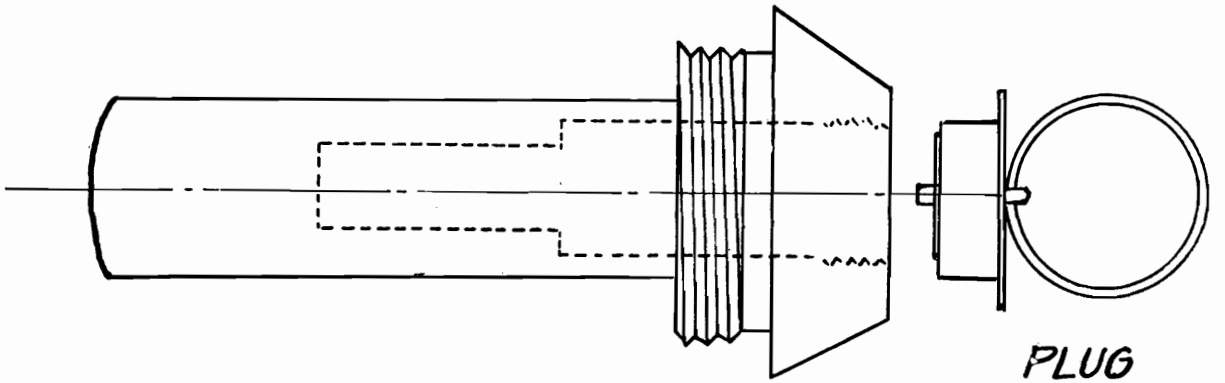
Minor-caliber base detonating fuze.	For use in 6-pdr. and 2.38-in. steel shell containing a bursting charge of trinitrotoluol.
Point detonating fuze for mobile artillery.	For use in steel shell for 3-in. field gun tapped in the point for this fuze. 8,000 have been manufactured for that number of steel shell now on hand. No more of these fuzes will be manufactured.
Medium caliber base detonating fuze.	For use in all steel projectiles from 2.95 to 7-in. in calibers inclusive. Superseding other fuzes for use in these projectiles when the present stock has been exhausted and when specially ordered.
Siege base detonating fuze. (Modified Pierce stock).	For use in steel projectiles of from 5-in. to 7-in. caliber adapted to this fuze until the stock of fuzes on hand (about 9,500) has been exhausted. No more of these fuzes will be manufactured.

Armor-piercing base detonating fuze (modified Pierce stock).	For use in 8, 10, and 12-in. gun shell and in 12-in. mortar shell adapted to this fuze until the stock of fuzes on hand (about 10,000) has been exhausted. No more of these fuzes will be manufactured.
Torpedo base detonating fuze (modified Pierce stock).	For use in 12-in. mortar steel shell on hand until the stock on hand (about 2,200) has been exhausted. No more will be manufactured.



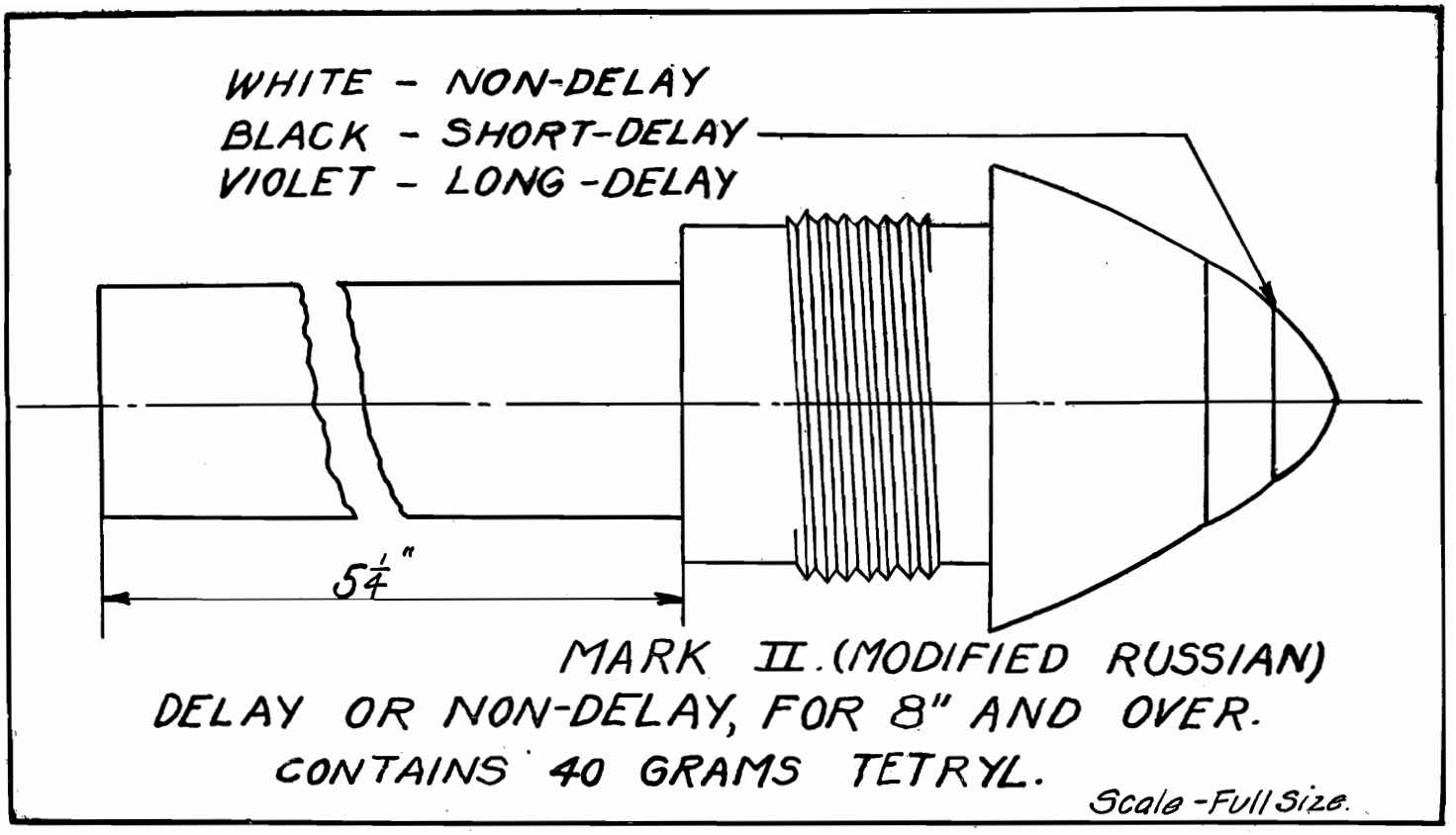
MARK II. BOOSTER AND ADAPTER.

Scale-Full Size.



MARK III. BOOSTER AND ADAPTER
FOR SMALL CALIBERS

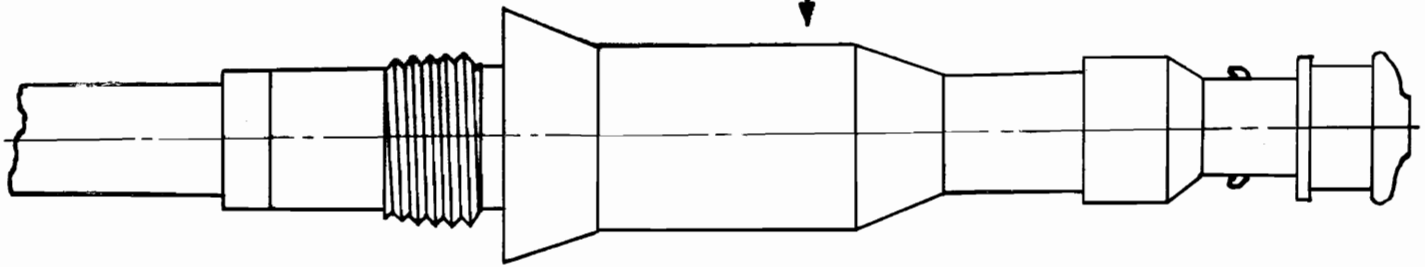
Scale-Full Size.



MARK II. (MODIFIED RUSSIAN)
DELAY OR NON-DELAY, FOR 8" AND OVER.
CONTAINS 40 GRAMS TETRYL.

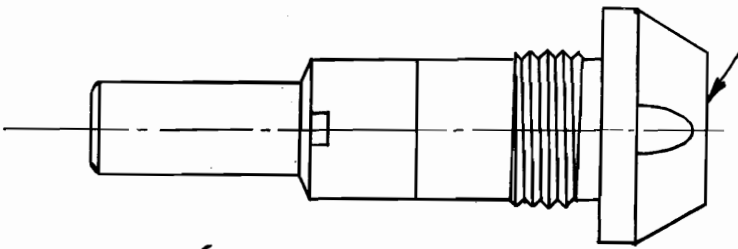
Scale - Full Size.

BLUE NECK, UNCOLORED HEAD
INSTANTANEOUS.



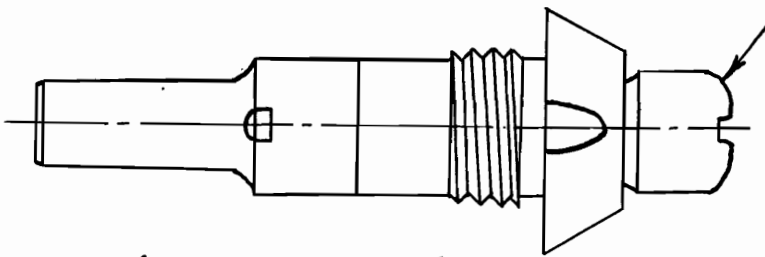
MARK III (LONG FRENCH)
INSTANTANEOUS, FOR ALL CALIBERS

Scale-Full Size.



WHITE – NON DELAY
BLACK – SHORT DELAY
VIOLET – LONG DELAY
GREEN MARKINGS ON THE HEAD INDICATE REINFORCED SPRINGS FOR USE IN 155 mm. GUN.

MARK IV. (SHORT FRENCH, EASILY ARMED)
DELAY OR NON-DELAY, FOR HOWITZERS

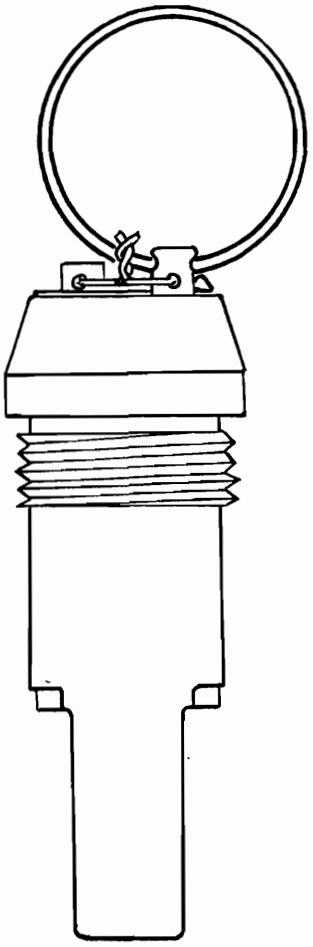


WHITE – NON-DELAY
BLACK – SHORT DELAY
VIOLET – LONG DELAY

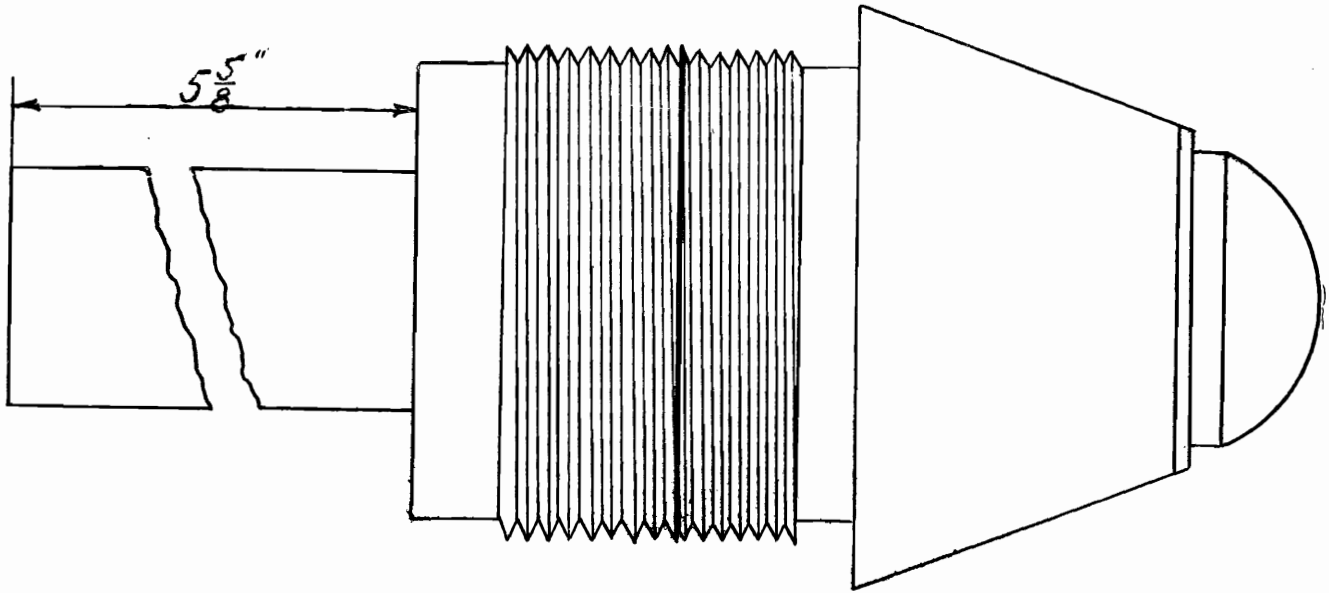
MARK V (SHORT FRENCH)
DELAY OR NON-DELAY FOR ALL CALIBERS

Scale – Full Size.

TRENCH MORTAR FUZE MARK VII
MARK VII E THE SAME EXCEPT RING



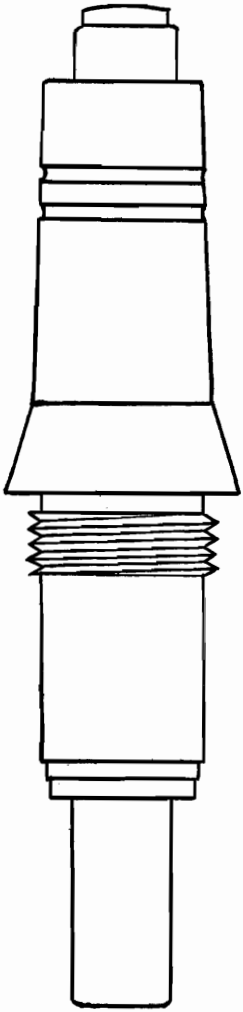
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POINT DETONATING FUZE MARK IX &

BOOSTER & ADAPTER MARK IX.

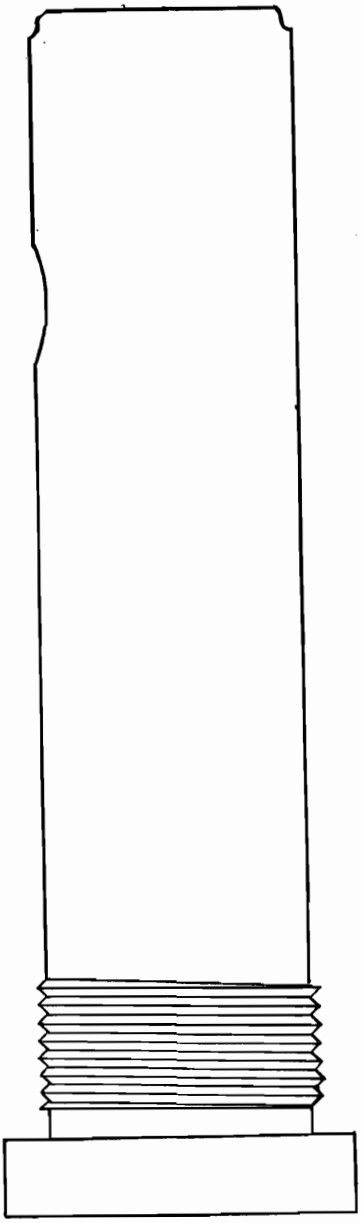
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POINT DETONATING FUZE MARK XII
FR. TYPE 24/31 R.Y.M. 1917.
LENGTH 5.15"

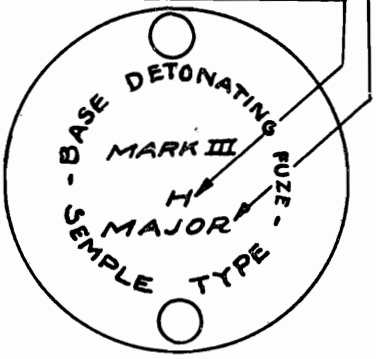
Scale-Full Size

Scale - Full Size.



NOTE-
STAMP MEDIUM
OR MAJOR

STAMP H, G or M



MARKINGS FOR BASE

MAJOR CALIBER BASE DETONATING FUZE.
MARK III SEMPLE TYPE.
LENGTH 6.28" ± .015"
MEDIUM CALIBER SAME DESIGN
LENGTH - 5.48" ± .015"

CHAPTER VI

EFFECT OF FIRE.

General Considerations.

In order to choose the proper cannon and ammunition to be used in a given case, taking into account the purpose of the fire, one must know the action of the different types of ammunition, which in turn requires a knowledge of the factors affecting the penetration of the projectile. These factors are the striking velocity, the shape and weight of the projectile, the type and position of the fuze, the angle of impact, and the nature of the object struck.

The importance of the value of the striking velocity in determining the penetration is self-evident. This velocity together with the mass $(\frac{w}{g})$ fixes the momentum which must be overcome by the resisting force, that in turn, being determined by the shape of the projectile and by the nature of the object struck.

The type of fuze (different time of functioning) determines the maximum possible penetration by limiting the time interval between impact and explosion, while the position at the point or in the base, determines the shape and strength.

The angle of impact (i.e., the angle between the tangent to the trajectory at the point of impact and the plane tangent to the surface struck at that point) is one of the most vital factors in determining the penetration. Upon it depends, in the first place, the question as to whether any penetration will be obtained, or whether ricochet will result. It is influenced chiefly by the angle of fall, a function of the range and of the powder charge used, and by the slope of the ground. It will be somewhat influenced by the use of "nose disks", which decrease the ballistic coefficient, increase the angle of fall, and also tend to decrease the penetration; as well as by the "presentation," i.e., the angle between the tangent to the trajectory and the larger axis of the projectile.

A hard even surface will tend to deflect a projectile at considerably greater angles of impact than will a soft or uneven surface. Therefore, ricochet under conditions of

wet, muddy ground will be limited to much smaller angles than will be the case in dry weather or on hard ground. The slope of the ground at the exact point of impact is the factor which, with the angle of fall, will determine the angle of impact, so that a slight gully or mound may completely change the result to be expected from the general slope of the area.

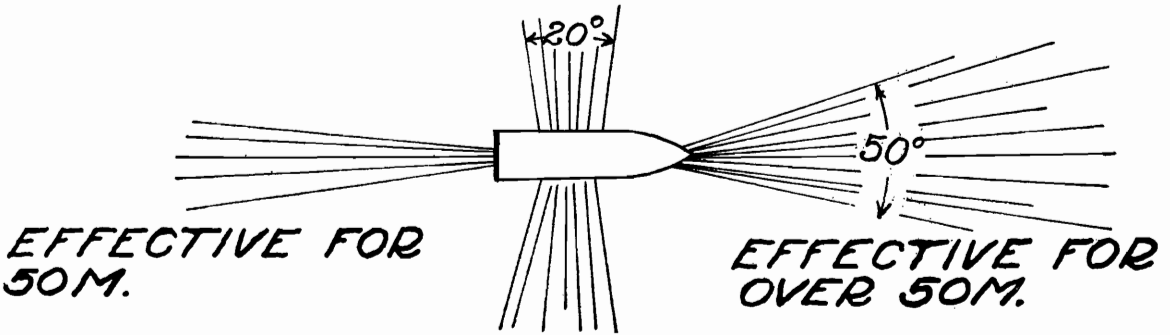
It is impossible to alter many of the above factors entering into the Ballistics of Penetration, and equally impossible to predetermine some of them. You will therefore realize that there will be considerable uncertainty as to the action of a projectile fired under any given conditions, and the best that can be done is to give tables, diagrams, etc., which show what may be considered as typical cases. As such our judgment may be guided by them, but they are not to be taken in any sense as hard and fast rules.

ACTION OF HIGH-EXPLOSIVE SHELL.

H. E. shell is used with a time fuze to give burst in air, or with fuzes of different degrees of delay to give a burst at different penetrations, or when ricochet is possible, to give with a delay fuze (about .05 sec.) a burst similar to that obtained with the time fuze.

The diagram, page 105, shows the shape of the sheaves formed with an air burst, the dimensions given applying to a 75 mm. shell. Shells of larger caliber will have the same general distribution but will cover a somewhat larger area.

Note that the main sheaf is perpendicular to the plane of fire; that the danger zone of a single shell is strictly limited in extent, though large fragments may be dangerous at much greater distances than those given; and that the danger zones for larger calibers increase in dimensions but not proportionally to the change in size.



LATERAL SHEAF EFFECTIVE FOR 20M.

Fig. 1.

PENETRATION OF PROJECTILES AT THE POINT OF FALL.

H. E. Shell.

When H. E. shell is used with other than a time fuze, the effects produced depend primarily upon the course it follows after contact with the ground and upon the point at which the burst takes place on this course. The course followed varies with several factors—the angle of impact, the residual velocity, the shape and weight of the shell, the presentation, and the nature of the terrain. But of all these factors the angle of impact is the most important. In accordance with the value of this angle the diagrams indicated below are obtained as the most probable course of the projectile.

Angle of impact: $\theta > 0°$ but $< 15°$. (Fig. 2, page 107.) The shell ricochets after merely grazing the ground.

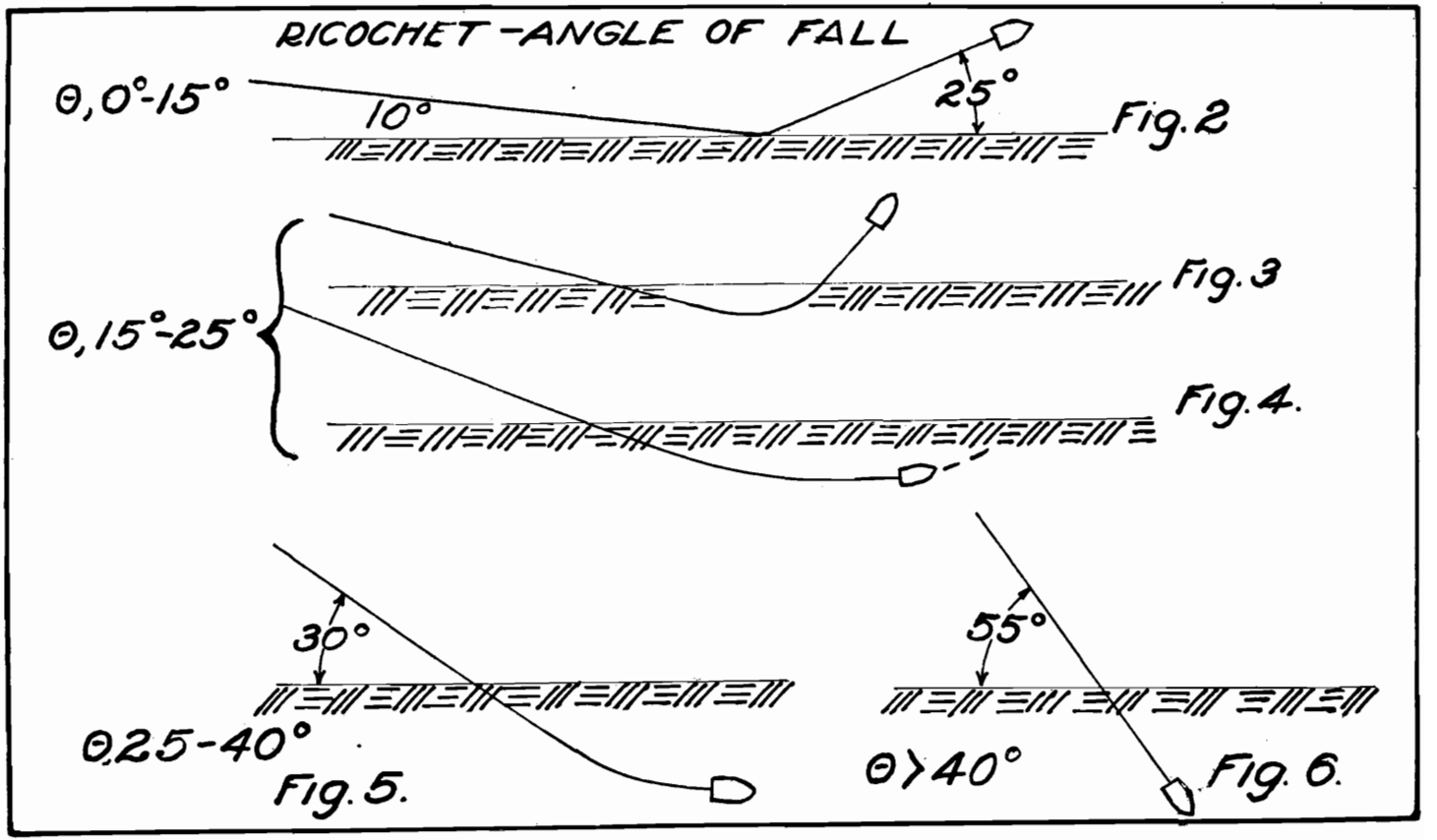
$\theta > 15°$ but $< 25°$. (Figs. 3 and 4). The shell, in accordance with the terminal velocity and its more or less tapering form, ricochets after making a certain subterranean course, or else remains in the ground a short distance below the surface.

$\theta > 25°$ but $< 40°$. (Fig. 5). The shell often assumes a winding course, usually with a tendency to return to the surface.

$\theta > 40°$. (Fig. 6). The shell generally assumes a rectilinear course and is buried to a depth which depends upon the terminal velocity, its weight, its shape, and the nature of the ground.

From the preceding observations it is clear that deep penetrations can be obtained only with the aid of projectiles of large caliber fired at very great angles.

The point of the burst and the form of crater produced depends upon the fuze used. For bursts close to the ground use instantaneous or non-delay fuzes. Instantaneous fuzes (Mark III, French I. A. L.) when they strike at an angle greater than 15° burst slightly above the ground and form a very slight sphere of compression of a depth of only 10 to


RICOCHET - ANGLE OF FALL
θ, 0°-15°
10°
25°
Fig. 2
θ, 15°-25°
Fig. 3
Fig. 4.
30°
0.25-40°
Fig. 5.
55°
θ > 40°
Fig. 6.

15 centimeters in the ground, whose crater indents the surface only to a slight degree. (Fig. 7, page 109). With angles less than 15° it should not be used, for there is danger of the fuze failing to function.

The effect is similar to that of the burst in air, but somewhat reduced. A vertical sheaf of fragments is formed at the point of fall approximately perpendicular to the plane of fire. This type gives a rather open smoke ball which does not rise to a great height.

A burst with slight penetration of the ground will be given with an angle of impact of 15° to 25° using a non-delay fuze. At a depth of one or two lengths of the projectile, the shell excavates the terrain in the form of a hemispherical shell crater, hurling fragments of earth and metal to a great distance. (Fig. 8). The effect depends upon the nature of the explosion, and for the same explosive, is proportional to the bursting charge. The smoke ball with this fuze is narrower and higher than with the instantaneous fuze since the force of the explosion in a sidewise direction is limited by the surrounding earth.

A burst at a depth three or four times the length of the projectile will be given with an angle of impact from 25° to 40° and a delay fuze. The volume of the earth excavated increases, but a part of it falls back, forming a conical shell crater. (Fig. 9).

A burst at a great depth will be obtained with an angle of impact greater than 45° and delay fuze. The explosive no longer has enough force to eject the earth above it. The sphere of compression forms an apparent dome at the surface, sometimes surrounded by a circular excavation. This results in a camouflet or a mine producing no exterior crater. (Fig. 10.)

The tables below indicate the approximate dimensions of the excavations in a soil of average consistency, and are based upon French shells.



Fig.-7

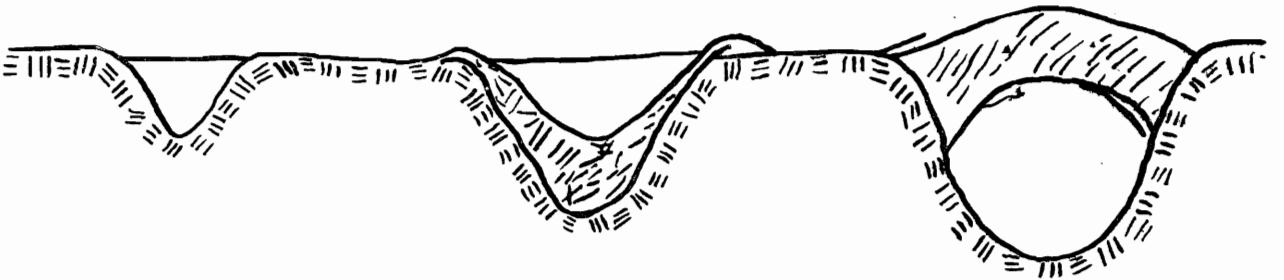


Fig.-8

Fig.- 9

Fig.-10

TABLE I.

CLEAN-CUT CRATERS.

Elongated shell	Diameter	Depth	Volume
Millimeters	Meters	Meters	Cubic Meters
120	2.5	0.9	2.6
155	3.5	1.1	6.0
220	4.5	1.4	13.3
370	6.0	2.2	36.0

Table I refers to clean-cut shell craters. It shows that even for average calibers up to 220 mm inclusive, the shell need not penetrate more than about 1 meter in order to throw out all excavated earth.

TABLE II.

Earth Moved—Delayed Fuze, Angle of Impact from 25° to 45°.

Craters partially filled with loose earth		
Elongated shell	External Diameter	Depth
Millimeters	Meters	Meters
155	3.5	1.5
220	5.5	2.3
270	6.0	3.0
370	10.0	6.0

TABLE III.

Maximum depth.

Maximum depth	
High-cap shell	Depth attained
Millimeters	Meters
155	3.0
220	4.5
270	6.0
370	10.0

If the depth of the burst increases, we obtain the figures of Table II, corresponding to a larger volume of earth removed, but with a shell crater partially filled up, the volume of earth ejected being less than in the case indicated in Table I.

If the depth of the burst increases still more, we get a camouflet (mine producing no exterior crater), where all the force of the explosion is expended under the form of violent pressure upon the neighboring soil. This pressure is disseminated in the underlying layers and enables us to attain depths greater than 1 to 1.50 meters in the final penetration of the projectile. Table III indicates the maximum depth which is thus obtained. The dullness of the detonation varies directly with the depth of ground at the point of burst.

SHRAPNEL.

The effect of shrapnel fire is dependent upon the remaining velocity at the point of burst and the additional velocity given by its explosive charge, which give the initial velocity to the balls; the presentation and the rotational velocity at the moment of burst which determine the direction; upon the ballistic coefficient of the balls which with the other factors determines their range. It is therefore evident that larger sizes of shrapnel will give a larger effective pattern. It is not used, however, in calibers over 6″. The following information applies to the use of 155 mm. case bursting shrapnel. The normal height of burst is 4 mils, but on account of the weight of the balls (25 gr.) and fragments, it is effective at higher bursts though the length of the effective pattern is thereby reduced. This shrapnel is effective on a percussion burst at ranges up to 2,000 meters.

Figure 11, page 112, shows the cone of burst of 155 mm. case-bursting shrapnel at 4000 m., 155 mm. L. gun, full charge. Height of burst 4 mils.

SPECIAL SHELLS.

Under special shells we shall include tracers, illuminating or star shells, smoke shells, gas shells, anti-balloon and anti-aircraft ammunition.

Tracers are used to visualize the trajectory in order to more readily effect an adjustment upon a balloon. They are also valuable for their incendiary effect.

Star shells are used to give illumination over certain areas which are to be watched or against which it is desired to fire. They have an incendiary effect but little use can be made of this property.

CONE OF BURST OF 155 MM. CASE-BURSTING SHRAPNEL AT 4000 M.
155 MM. L. GUN FULL CHARGE. HEIGHT OF BURST 4 MILS

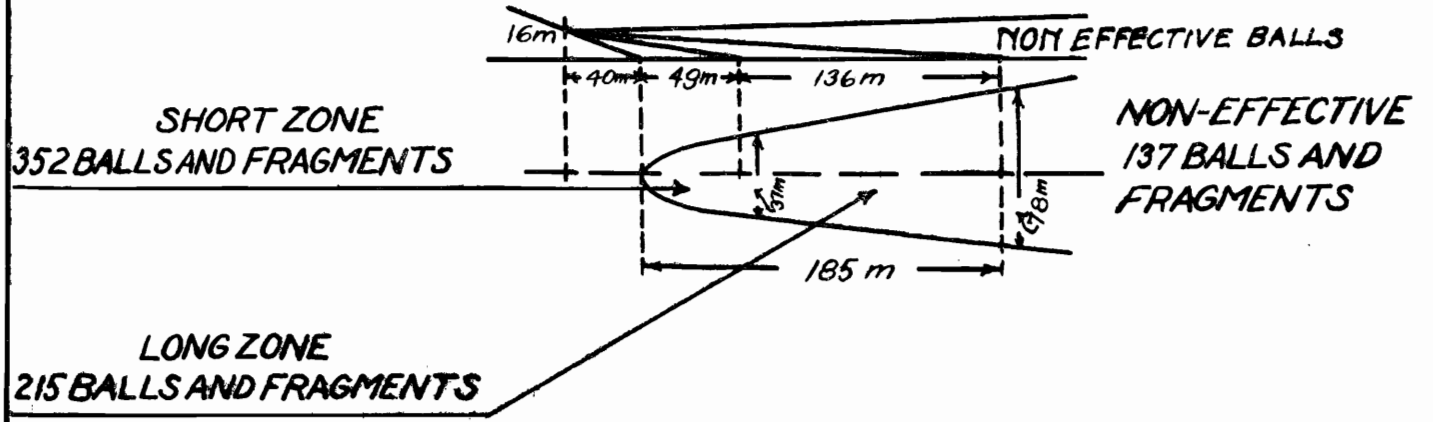


Fig.- 11

Chemical shells are of two types: *smoke* and *gas*. With the first named a white and opaque column of smoke is liberated from each shell. These columns merge with each other and form a dense screen, though with a high barometer and a low wind the smoke tends to rise rather rapidly. The most favorable conditions for the employment of these shell appear to be with a cross-wind of about 6m. per second and a low barometer. In such cases the shell should be concentrated on a point well to windward of the locality which it is desired to screen, so that the smoke will be blown across it in a thick curtain perhaps 60m. high. The phosphorus with which these smoke shells are filled is highly inflammable and has been found to have considerable incendiary effect.

Gas shells are filled with different chemical liquids which are scattered over the ground as soon as the shells burst and then slowly vaporize. The vapor of the lacrymatory shell produces intense irritation of the eyes and respiratory organs. It is not poisonous, but those handling the shell, if there is a suspicion of leakage, should be provided with protective goggles, and should at all cost avoid rubbing the eyes with the hands.

Of the so called lethal gases, chlorine, phosgene, and a mixture of the two are the most common. These are extremely dangerous, very small amounts producing fatal results.

The vapor of all these gases is heavier than air, and will therefore remain close to the ground, filling trenches, dugouts, cellars, covered gun emplacements, woods and hollows. The radius of action of this type of shell depends almost entirely on atmospheric conditions, especially upon the wind. The effect never reaches more than 10 to 20 km. behind the lines. The most favorable circumstances are a clear day, when the vapors are nearly colorless, a total absence of wind, or only a light breeze, (not over 3.5m. per sec.) blowing toward the enemy, and high humidity of the atmosphere. The effect is particularly marked in valleys, or small woods, and in forests the shells may be employed even when a strong wind is blowing outside. In the open, on a damp and muggy day with little wind, the effect may last for six hours or more, whereas on a dry, clear day, with a breeze, it will probably not persist for more than thirty

minutes. In woods, buildings, or covered emplacements, the effect may be felt for as long as 24 hours.

Gas shells may be employed against a position which it is desired to deny to the enemy for a certain length of time, or to create a barrage through which the enemy's troops cannot pass.

Their chief value is, however, for counter-battery work. The gas sinks into the dugouts, it affects the whole of the personnel; and most of all it requires the wearing of protective masks which is certain to interfere with the service of the battery. Moreover, by taking advantage of the wind, effect may be obtained, even if the position of the guns has not been located with the accuracy that is required for obtaining direct hits on gun emplacements. The effect will be most marked when the guns are concealed in woods, houses, etc., where they are least vulnerable to ordinary attack.

The quantity of vapor necessary to obtain an effective cloud can only be obtained by firing a large number of shell; with the 4.5 inch shell, at least one round for every two yards of front. The fire should be rapid until the necessary cloud has been produced, after which a slow rate will be sufficient to maintain it. Adjustment should be carried out with the ordinary shell, so as to give the enemy no warning of what is coming.

It is customary to fire 3 gas shells to one H. E. shell. Far from reducing the effect of the gas, shells bursting among it may be expected to increase it by forming eddies which will allow the gas to sink into the trenches, dugouts, etc. Shrapnel fire may also be expected to be effective in combination with smoke and gas, as these will probably cause the enemy to man his parapets, and in some cases to come out into the open.

Fire Against Balloons and Aeroplanes.

Owing to the height and distance behind the lines at which a balloon is stationed it requires a long range gun to reach it. Since the damage done by simply puncturing the envelope is only temporary and easily repaired it is desirable to use a type of projectile which will completely destroy it by a burst against it, or by an explosion of the balloon itself from ignition of the hydrogen.

The ordinary shrapnel is not available since the time

of burning of its fuze is too short for the long range (perhaps 10,000 m.) which must be used, and its rate of burning is irregular, being affected by the humidity and density of the atmosphere. A clock fuze has recently been developed which eliminates both of these sources of trouble, and which is used with a shell with incendiary properties for balloon attack.

Against aeroplanes, on account of their great speed and maneuvering ability and the long time of flight the probability of hitting is very low. Shrapnel being limited in its effect to one direction and also requiring a direct hit on the gasoline tank or the pilot, it is not very effective. H. E. shell with its greater all-around danger zone and with the very irregular fragments is more effective either by direct hit with a super-sensitive fuze or by exploding under the action of a clock fuze or an improved powder-train time fuze, both of which have been developed for this use. Two methods of attack are used. The first is by means of "zone fire", i. e., changing the range by definite steps in order to sweep a larger area, or by firing rapidly at a determined point and then waiting until the plane has again settled down and its new course determined, when the procedure is repeated.

ROLE OF ARTILLERY

The role of artillery fire may be classified as follows:

1. Against unsheltered personnel or materiel. This is principally the function of the machine guns and the 75 mm guns and will not be emphasized here. The use of heavily armed tanks may require the attention of the heavier artillery in the near future.

2. Barrage fire. Creeping barrage behind which troops have to move forward. Standing barrage on some portion of the enemy area to which it may or may not be necessary for infantry to approach. Flank barrage established to prevent troop movements to the flank. Most of this barrage work will be the task of the smaller guns but some so-called barrages on communications toward the rear, and the reinforcement of the smaller calibers during an emergency, will be included in the role of the heavy artillery.

3. Wire cutting. This is a task of the heavy artillery only under exceptional circumstances.

4. Destruction fire. Executed by heavy artillery on trenches' strong points, cantonments, ammunition dumps, railway junctions, etc., which owing to their protection or range cannot be reached effectively by the light artillery.

5. Counter battery work. Counter battery work is carried on against two types of batteries; those well protected and dug-in, and those trusting merely to camouflage to conceal their positions. In counter-battery work, accurate, well adjusted fire is necessary. There are two types of counter battery work: demolition fire, for the complete destruction of the battery; and neutralization fire to deny the enemy effective use of their battery. The attempt to secure "neutralization" may be by the use of gas shells, or by means of very rapid, less accurate fire rather than fire from exceedingly heavy guns.

6. Harassing fire. Mostly directed on important crossings and on points of traffic shown on photographs. It is executed at irregular intervals and should be intense only at probable hours of supply or if considerable enemy movement has been reported.

7. Balloon attacks to destroy or prevent the use of observation balloons.

8. Anti-aircraft fire for protection against hostile planes back of the front lines. Effective in keeping planes at such an altitude that accurate reconnaissance and photographic work are difficult.

Factors Entering Into Choice of Gun and Ammunition.

There are certain general considerations influencing the choice of the proper combination of armament and ammunition which should be kept in mind. The type of protection which the different targets have determines whether direct fire or curved fire is to be used. If heavy overhead cover is provided gun fire with a comparatively flat trajectory will not be effective, while howitzer or mortar

fire with a steep angle of fall will enable one to get penetration depending in amount on the weight of the projectile used. With a target of some height the direct fire of a gun with a high remaining velocity and large danger space will give better results than the howitzer.

Different powder charges may be used with both guns, howitzers and mortars. Whenever the proper choice is not determined by the required angle of fall and striking velocity the lower charge should be used as it is more economical in cost and wear of the gun, unless this advantage is counterbalanced by the increased dispersion.

Targets protected by defilade which can be overcome by no other means may be reached by the use of "nose disks" which increase the angle of fall. They are undesirable because they increase the dispersion. There use is confined to the light artillery.

The direction of the plane of fire with respect to the dimensions of the target is important in determining the type and amount of ammunition necessary. Since the longitudinal dispersion is much greater than the lateral, enfilade fire upon a long narrow target, such as a trench, will be much more economical of ammunition. Under such circumstances, however, one must consider whether the effective zone of burst of the projectile used is normal or parallel to the plane of fire.

If troops are to approach or follow an artillery barrage the safety zone required by the different shells must be considered. Table V gives approximate values for different types and sizes of ammunition.

	Longitudinal	Lateral
Shrapnel	½ zone of dispersion including fuze dispersion	
75 mm shell	½ " " " " " " 50 m	
4.5" " "	450—550 m.	250 m.
6" "	550—650 m.	300 m.
8" and 9".2 shell	700—900 m.	400 m.

TABLES FOR EFFECT OF FIRE.

Since one cannot determine with accuracy all of the causes entering into the results in artillery fire it must be borne in mind that the tables and figures given here are only average values and in any instance may be deviated from considerably.

When a mission can be accomplished in the time allowed with small caliber guns or howitzers do not use the heavy artillery.

If the artillery and ammunition given below as best suited for different targets is not available it will be necessary to use a combination approaching the desired one as closely as possible. With these limitations understood the following tables may be used as a guide.

ATTACK ON PERSONNEL.

	Gun	Projectile	Fuze	Remarks
Unsheltered	75—155 mm	Shrapnel	Time	
"	"	H. E. Shell	Delay (.05s)	angle of fall $<15°$
"	"	H. E. Shell	Instantaneous	angle of fall $>15°$
In trenches	75—155 mm	Shrapnel	Time	with enfilade fire
	"	H. E. Shell	Time	angle of fall $<15°$
	"	H. E. Shell	(Non-delay or instantaneous)	angle of fall $>15°$
	"	Gas shell		

	Gun	Projectile	Fuse	Remarks
Barrage	75—155 mm	Shrapnel	Time	With enfilade fire, best.
Frontal	"	H. E. shell	Delay (.05)	With frontal fire, $\omega < 15°$
		H. E. shell	Instantaneous	With frontal fire, $\omega > 15°$
		Smoke		For better screening
Flank	"	Shrapnel	Time	With frontal fire
		H. E. shell	Delay (.05s) or Instantaneous	Large safety zone required

If troops are not following, H. E. and Shrapnel may be used indiscriminately.

Attack on Artillery	Gun	Projectile	Fuze	Remarks
Neutralization protected or unprotected.	All guns 6″ and up	H. E. shell Gas shell	Fuze to depend on degree of protection. Instantaneous or non-delay.	
Destruction	Guns all calibers	H. E. shell	Instantaneous	$\omega > 15°$
Unprotected	"	"	Non-delay	$\omega < 15°$
Protected	"	"	Non-delay	$\omega > 15°$
			Time or delay (.05)	$\omega < 15°$
	Howitzers	"	Non-delay or slight delay	Against overhead cover
Destructive Fire on:				
Wire entanglements	Trench Mortars	H. E. Shell		
	Guns 75-155 mm	"	Non-delay	$\omega < 15°$
	"	"	Instantaneous	$\omega > 15°$
	"	"	Delay	For chevaux de Frise.
	Howitzers 8″	"	Instantaneous	For defiladed slope.
Trenches,	All light and medium caliber	"	Non-delay	$\omega < 15°$
Mach. gun emplacements	guns, howitzers	"	Delay slight	$\omega > 15°$
Observation stations	and trench mortars	"	" (medium)	$\omega > 25°$
Ammunition dumps, buildings, cantonments, etc.,	All calibers guns and howitzers	"	Non-delay Delay	For cellars, or if some protection
Railroads	Above 105mm	Incendiary H. E. Shell	Non-delay Delay	Use mixture of the two.
Concrete & steel protection vertical	Guns above 6″	H. E. Shell "	Base Delay Non-delay	For penetration if point fuze used
Horizontal protection	Howitzers	H. E. Shell	Non-Delay Long delay	To scatter materiel For penetration.

EXPENDITURE OF AMMUNITION FOR DIFFERENT MISSIONS

Table I.—WIRE ENTANGLEMENT. Estimated expenditure of ammunition for a 25m breach in wire.

Range	Calibers mm	Ground conditions at target.	Ammunition		No. shells estimated requirements for a wire entanglement 30 meters deep
			Projectile	Fuzes	
From 2500 to 4000 meters	75.....	Glacis or very slight counter-slope; hard ground or muddy clay	H. E. Shell	Instantaneous or Non-delay	600 at 2500 m; 700 at 3000m; 800 at 4000 m.
From 5000 to 7000 meters	75.....	Glacis or horizontal dry ground	"	Instantaneous	1000 at 5000 m; 1200 at 7000 m.
From 2000 to 4000 meters	155 Howitzer	Steep counter-slope	"	"	200 at 2000 m; 270 at 3000 m; 330 at 4000 m.
From 5000 to 7000 meters	155 gun or 155 Schneider Howitzer	Counter-slope	"	"	330 at 5000 m; 400 at 6000 m;480 at 7000 m.

Table II.—CRUSHING FIRE AGAINST SHELTERS.

From 2000 to 4000 meters	155 Howitzer	Medium [1]	H. E. Shell	Delay	80
	220 or 270	Strong [2]	"	"	"
More than 4000 meters	155 gun	Medium	"	"	150

1. Roof formed of alternate layers of logs and earth.
2. Roof of concrete or of rails and concrete.

Table III.—DESTRUCTION OF TRENCHES.

Range	Calibers mm	Ammunition		Estimated requirement No. of rounds
		Projectile	Fuze	
From 3000 to 7000 meters (1)	75.....	H. E. Shell	Delay	10 per linear meter
"	"	"	"	100 per important point, viz: 4 rounds per linear meter (frontal fire); 1.5 rounds per linear meter (enfilading fire)
From 2000 to 5000 meters	200 (2)....	"	"	70-100 rounds per important point
From 5000 to 7000 meters	155 gun or 155 Schneider Howitzer (3)	"	"	5-6 per linear meter, according to the range (frontal fire).

(1). Fire as far as possible exactly in enfilade.

(2). To reinforce the action of the 155 howitzer on the important points.

(3). SAFETY ZONE:—Give the infantry a prohibited zone of 200 meters during fire with the 155 howitzer. The troops must also be made to take shelter from the fragments, which may be projected several hundred meters to the rear.

TABLE IV.—DESTRUCTION OF A FORT.

Targets	Calibers mm.	Good Range in Kilometers	Ammunition.		No. rounds.
			Shells	Fuzes	
Rampart Shelters	293 howitzer 320 gun 370 mortar 370 howitzer 400 howitzer	8 15 7 12 12	Semiarmor piercing	Long delay base fuze	100 for targets at ranges less than 9 km. 150 for longer ranges.
Barracks, intermediate large shelters, German types	293 howitzer 320 gun 370 mortar 370 howitzer 400 howitzer	8 15 7 12 12	"	"	150—200 according as the range is less or more than 9 km.
Armored turrets French type	320 gun 370 howitzer 400 howitzer	15 12 12	"	"	150 per target
Armored batteries German type	320 gun 370 howitzer 400 howitzer	15 12 12	"	"	400—500 per target
Cement corridors	.(1)	(1)	"	"	100-150 per (2) corridor.
Pits	155 gun 240 gun 320 gun	8 10 16	H. E. Shell	Delay	150 per pit (2)

(1). All the above calibers and their corresponding ranges.

(2). Enfilade fire.

TABLE V. —DESTRUCTION OF TOWNS.

Kind of destruction	Calibers mm.	Shells	Fuzes	Estimated Rounds per 100 sq. m. block of houses.
Destruction of houses	155 howitzer; 155 gun; 220; 270	H. E. Shell or incendiary	Delay action, combination fuze.	4 of which 1 will be incendiary.
Crushing cellars	270, 280, 370 mortars, 293, 370, 400, howitzers.	Semiarmor piercing or H. E. Shell	Delayed action base fuze.	4

TABLE VI.—DESTRUCTION OF RAILWAYS.

Targets	Calibers mm.	Good ranges in kilometers	Shells	Fuzes	Estimated requirement, No. of rounds
Bridge or viaduct	270, 280 mortars	6	Semiarmor-piercing	Delay action base fuzes	100 - 200. rounds depending on the caliber
	293 howitzers	8	"		
	320 gun	15	"	"	
		7	"	"	
	370, 400 howitzers	12	"	"	
Fill	155 gun	8	H. E. Shell	Delay	*500
	240	13	"	"	*400
Switches	155 gun	8	"	"	400 rounds
	240	13	"	"	200 rounds
	100 rapid fire	12	Semiarmor-piercing	"	200 rounds
	140	13	or H. E. shell	"	

*These estimated expenditures apply to enfilade fire. For frontal fire, they should be quadrupled.

APPENDIX I

SEACOAST ARTILLERY AMMUNITION

CANNON	PROJECTILE			PROPELLING CHARGE	MUZZLE VELOCITY
	TYPE	WEIGHT	BURSTING CHG.		
		lbs.	% total wt.	lbs.	
3″ Gun	C. S. Shell	15	3	5	2600 f.s.
4″ Gun	A. P. Shell	33	3	7.5	2300 f.s.
4.7″ Gun	A. P. Shell	45	4	11	2570 f.s.
5″ Gun	A. P. Shot A. P. Shell	58 58	2 5	16.5 (M–'97) 22.2 (M–1900)	2600 f.s. 2600 f.s.
6″ Gun	A. P. Shot A. P. Shell	106–108x	2 4	29.7 (M–'97) 32 (M-'00'-05)	2600 f.s. 2600 f.s.
8″ Gun	A. P. Shot A. P. Shell	316–323x	2 5	83.5	2200 f.s.
10″ Gun	A. P. Shot	604-617x	2	182 (M–1900) 162 (others)	2250 f.s. 2250 f.s.
12″ Gun	A. P. Shot A. P. Shell	1046–1070x	2 6	334 (M–1900) 279 (others)	2250 f.s. 2250 f.s.
12″ Mortar M 1890, '90M1 and M 1908	D. P. Shell	700 824 1046	3	65 57 47	1500 f.s. (maximum) 1300 f.s. (maximum) 1050 f.s. (maximum)

12″ Mortar Model 1912	D. P. Shell	1046 700	3	78 lbs 89 lbs.	1200 f.s. 1800 f.s.
14″ Gun	A. P. Shot A. P. Shell	1660x 1660x	2 5	349 (M-'07, '07M1 430 (M-'10, '10M1)	2150 f.s. 2350 f.s.
16″ Gun	A. P. Shot A. P. Shell	2400x 2400x	2 5	666.5	2250 f.s.

The 3″, 4″ and 4.7″ Gun use 110 grain percussion primer, all others use the 1914 Friction, Electric, or Combination Electric-Friction primer.

The 3″ and 4″ ammunition is loaded fixed, the 4.7″ semi-fixed; all others separate.

Reference x indicates shell with ballistic cap.

All seacoast projectiles from 3-in. to 6-in. inclusive have medium caliber base detonating fuze.

All seacoast projectiles from 8-in. to 16-in. inclusive have major caliber base detonating fuze.

Both medium and major caliber base detonating fuzes are to be replaced by base detonating fuze, mark III, Semple type.

The bursting charge for all seacoast projectiles is Explosive D.

HEAVY MOBILE ARTILLERY

CANNON	PROJECTILE			PROPELLING CHARGE	MUZZLE VELOCITY	PRIMER	FUZE
	TYPE	WEIGHT	BURSTING CHG.				
4.7″ Howitzer	C. S. (Shell) Mk. I.	lbs. 60	%total wt. 6% 7%	10.5 oz.	454 f.s.	10 gr. Perc.	P. D. F., Mks. II, III, IV & V.
Pedestal and Railroad mt.	Mod. 1905. Shrapnel	45	1% (711 balls)	17.5 oz. 28.9 oz. 3.5 lbs.	620 f.s. 900 f.s. 1300 f.s.	" "	Med. Cal. B. D. 31″ & 45″ combination.
5″ Siege Gun, Mod. 1890 & 1898	C. S. Shell Mk. II	45	4%	5.5 lbs.	1830 f.s.	Obturating	Med. Cal. Base Det.
	Shrapnel	45	2%(280balls)			Friction	31″ & 45″ combination
5″ S. C. Gun, Wheel mount	C. S. Shell Mk. II.	52	15%	16.5 lbs.	1950 f.s. 2600 f.s.	1914 Fric.	P.D.F. Mks. III & V
6″ S. C. Gun, Wheel mount	C. S. Shell Mk. II.	90.5	15%	28 lbs.	1950 f.s. 2600 f.s.	1914 Fric.	P. D. F. Mks. III & V
155mm Model 1918 (Filloux)	C. S. Shell Mk. III	95	17%	25 lbs. 28 lbs.	596 m.s. 735 m.s.	21 gr. Perc.	P. D. F. Mks. III & IV & IV*
	Shrapnel Mk. I.	95	1.5% (849 balls)	25 lbs. 28 lbs.	596 m.s. 735 m.s.	"	31″ and 45″ combination.
7″ Seige How. Mod. 1890 & 1898.	Shell	105	7%	5 lbs.	1100 f.s.	Obturating	Med. Cal. Base Det.
	Shrapnel	105	2% (390 balls)			Friction	31″ and 45″ combination.
7″ Navy Gun R. R. Mount	Navy Shell	165		57.7	2700 f.s.	Combination Electric Percussion (Navy type)	Tracer B. D. F. (Navy type)

8″ How. Mod. 1917 & 1918. (Vickers, Mks. VI & VII.)	C. S. Shell, Mk. I.	200	15%	10.75 lbs. (Mk. VII) 17.5 lbs. (Mk. VII)	1300 f.s. 1500 f.s. (Mk. VII)	21 gr. Perc. or T-tube fric.	P. D. F. Marks II, III, IV & IX
8″ S. C. Gun R. R. Mount	C. S. Shell Mk. I.	200	15%	68 lbs. 56 lbs.	2600 f.s. 1950 f.s.	1914 fric.	P. D. F. Mks. II; III, V & IX
9.2″ How., Mk. I. 9.2″ How., Mk. II.	C. S. Shell Mk. IX. "	290 "	12% "	14 lbs. 24 lbs.	1200 f.s. 1500 f.s.	21 gr. Perc. or T-tube fric.	P. D. F. Mks. II, III, IV & IX
240 mm. How. Model 1918. (Schneider)	C. S. Shell Mk. I	356	14%	35 lbs.	545 m.s. (1700 f.s.)	21 gr. Perc.	P. D. F. Mks. II, III, IV & IX
10″ S. C. Gun, R. R. Mount	C. S. Shell Mk. II.	510	11%	160 lbs.	2400 f.s.	1914 Friction	P. D. F. Mks. III, IV*, V, 75″ Mech Time, M. C. B. D., Mk. III, Semple Type.
12″ S. C. Mortar R. R. Mount	H. E. Shell Mk. VIII	700 700	12% 12%	25–65 lbs. 25–65 lbs.	1500 f.s.	1914 Friction	Mk. III, IV. M. C. B. D. Mk. III, Semple Type.
12″ S. C. Gun, R. R. Mount C. S. Shell	C. S. Shell Mk. X Mk. VI	700 700	14%	250 lbs.	2250 f.s.	1941 Friction	Mks. III, IV*, V, 75″ Mech. Time, M. C. B. D. Mk III, Semple Type
12″ Gun, M 1 T8 (Bethlehem R. R. Mount)	C. S. Shell Mk. VI.	700	13%	240 lbs 337 lbs	2400 f.s. 3200 f.s.	1914 Friction	M. C. B. D. Mk. III, Semple Type
14″ S. C. Gun, R. R. Mount	C. S. Shell Mk. II.	1200 lbs	13%	450 lbs.	2900 f.s.	1914 Frict.	P. D. F. Mk. III, IV*, 75″ Mech. Time, M. C. B. D. Mk. III, Semple Type.

CANNON	PROJECTILE			PROPELLING CHARGE	MUZZLE VELOCITY	PRIMER	FUZE
	TYPE	WEIGHT	BURSTING				
14″ Navy Gun, R. R. Mount	Shell	1400 lbs	2%	480 lbs	2800 f.s.	Combination electric-percussion (Navy Type)	Tracer B. D. F. (Navy Type).
16″ Howitzer R. R. Mount	C. S. Shell Mk. IV.	1660 lbs	14%	225 lbs (Maximum)	1900 f.s. (Maximum)	1914 Frict.	Mks. III, IV; M. C. B. D., Mk. III, Semple Type.
D. P. Shell	M. 1917	"					

C. S. Common Steel.

H. E. High Explosive.

D. P. Deck Piercing.

P. D. F. Point Detonating Fuze.

M. C. B. D. Major Caliber Base Detonating (fuze).

Bursting Charges: Cast T. N. T. and amatol, either 80–20 or 50–50, are used in projectiles under 10 inch in caliber. Cast T. N. T., explosive D, and amatol are used in projectiles of 10-inch caliber and above.

All projectiles having base detonating or combination fuzes are issued fuzed; all others are issued unfuzed.

ANTI-AIRCRAFT AMMUNITION

CANNON	TYPE	PROJECTILE WEIGHT lbs.	BURSTING CHG. % total wt.	PROPELLING CHARGE	MUZZLE VELOCITY	FUZE
75 mm Gun	Shell Shrapnel	14.3 15	10% 270 balls	1.5 lbs. 1.5 lbs.	1700 f.s. 1700 f.s.	21″ Combination 21″ Combination
3″ Gun	Shell Shrapnel	15 15	11%	6 lbs.	2600 f.s.	21″ Spec. Time 21″ Combination
4.7″ Gun	Shell Shrapnel	45 45	15%	11 lbs.	2600 f.s.	Time Det. Mk. II. 21″ Combination

49 Gr. Percussion primer used in 75 mm. Gun.

110 Gr. Percussion primer used in 3″ and 4.7″ Gun.

5″, 6″ and 155 mm. Guns, using special ammunition equipped with Waltham Mechanical Time Fuze (Ohlson design), are used in anti-balloon firing.

APPENDIX II

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446	Cartridge Cloth.
450	Powder, smokeless, for cannon.
451	Powder, smokeless, for small arms.
452A	Armor piercing, deck piercing, and torpedo projectiles.
452B	Common steel shell and shrapnel.
452C	Cast iron target-practice projectiles.
470	Army black powders.
476	Fuzes.
509	Ammonium picrate.

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