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REVIEW OF ORDNANCE MATERIEL

1938

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PREFACE

This Review of Ordnance Materiel has been prepared for use as the basis of studies, lectures, etc. It has been made complete in order to fully cover the entire phase of research and development in Ordnance materiel, including the present standard weapons, and is not intended to be delivered as a lecture in the form in which it is written. A lecturer can select appropriate parts to fit his subject, the length of time available, and the kind of audience being addressed. Each section is complete in itself, and, if desired, one or more sections can be combined to fit a given subject.

The numbers given with the slides are Ordnance photograph numbers, and these numbers should be used when requesting slides or photographs from which the slides have been made.

SECTION A - INTRODUCTION

The Ordnance Department is that branch of the Army which is charged with the design, development, procurement and supply of munitions of war for the Army, and with the maintenance of these articles while they are in use.

Ordnance materiel includes, in a general way, small arms and cannon of all sizes, and ammunition for them; also tanks, tractors, aircraft bombs, and military pyrotechnics.

In order to enable the Ordnance Department to more fully carry out its functions, it has two main divisions, one of which, known as the Manufacturing Service, is charged with the procurement of munitions; and the other, called the Field Service, is charged with the supply of finished munitions to troops and the maintenance of the materiel in serviceable condition.

Besides these two main divisions, there is a Technical Staff, which is a group of officers who have had special experience in ordnance design, and who act for the Chief of Ordnance in approving new designs, testing new types of ordnance, and in maintaining contact with civilian engineering societies, the Navy, and the line branches and General Staff of the Army in all matters pertaining to new types of ordnance.

An important part of the Technical Staff is the Ordnance Committee, which is composed of officers representing the Ordnance Department, representatives from all other branches of the Army, and also representatives from the Navy. This committee meets once a week and investigates and recommends action on all important projects and designs, and approves programs for testing all new materiel.

The fact that all new designs must be passed on by this committee composed of representatives from all branches of the Army, insures that full consideration of the requirements of the using services will be given to every item manufactured or supplied by the Ordnance Department.

This idea was first originated in this country by the Ordnance Department, and has worked so successfully under the direction of the War Department that similar committees have been set up in all other supply branches.

Before taking up a detailed description of the new types of ordnance, it is desired to outline briefly the steps involved in the design and development of a piece of ordnance.

When it appears that a new or improved type of ordnance is required, the chief of the using service concerned, with War Department approval, outlines in a general way the characteristics required, after which the Ordnance proceeds to design an article fulfilling those general specifications.

The line branch concerned, as well as any other interested branches, through their representatives on the Ordnance Committee, are kept informed of the progress and are in position to make known their desires during the design period.

After the design is completed, a pilot model is built and given an exhaustive test at the proving ground, as a result of which it is either pronounced satisfactory or else is modified or redesigned until it appears to the Ordnance Department to fulfill the requirements.

After completing the Ordnance tests, the new article is turned over to the line branch for a service test; and no new article of ordnance can ever be adopted until it has passed the service test by the using branch. Of course, as a result of this service test, the line branch may recommend changes. It sometimes happens that the line may desire features which are impracticable to incorporate for mechanical or other reasons, and in such cases it is obvious that some compromise must be effected. As a matter of fact, it is seldom possible to design an article which will meet the ideals of either the using service or the Ordnance Department.

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SECTION B

SMALL ARMS

RIFLES

U. S. Rifle, Caliber .30, M1903 (Springfield)

Slide No. 1 (Ordnance Photo No. 7183)

Springfield Rifle and Springfield
Rifle with Pistol Grip

While European practice tends to minimize the importance of the rifle, substituting therefor the light machine gun, the U. S. Army adheres to its old time policy of considering the rifle the basic weapon and amplifying its fire power by machine guns of all types. The fire power of the individual soldier, is increased by replacing the hand operated rifle with the semiautomatic rifle.

The springfield rifle, which is still the basic arm until replaced by the semiautomatic rifle, is the same rifle as adopted over thirty years ago, with the exception of the addition of a pistol grip to the stock, and other minor modifications.

The following are the most important dimensions of the rifle:

Bore	.30 inch
Number of grooves	4
Depth of grooves	.004 inch
Pitch of rifling	1 turn in 10 inches
Length of barrel	23.8 inches
Length of rifle complete	43.2 inches
Total weight, without bayonet	8.7 lb.
Weight of bayonet	1.0 lb.

The cal. .30 M1917 rifle was adopted on the entrance of this country into the World War to supplement the M1903, which could not be produced in sufficient quantity. Facilities for the large production of the M1917 existed because it was being produced for the British Government by contractors in this country. To adapt it for our use it was necessary only to alter the British .303 barrel to take the M1906 cartridge. The principal points in which the M1917 rifle differs from the M1903 are the receiver sight without windage adjustment, the barrel length of 26 inches and the weight without bayonet of 9.2 pounds. The 1917 rifle cocks on the closing movement of the bolt. The M1917 rifles are now held in reserve.

U. S. Rifle, Caliber .22, M2.

Slide No. 2 (Ordnance Photo No. 1566)
U. S. Rifle, Caliber .22, M2.

In order to train with the rifle economically, there was developed after the World War a caliber .22 rifle similar to the Springfield rifle in weight and appearance, except that it is equipped with the Lyman receiver sight and a sporting type of pistol grip stock. Its reception throughout the Army has been favorable to the extent that an improvement has been made in the original design so as to improve the accuracy, prevent malfunctions and decrease the cost of maintenance. These improvements consist of changing the chamber, bolt and magazine so as to provide for better handling of the cartridge.

Semiautomatic Shoulder Rifle

Slide No. 3 (Ordnance Photo No. 7600)

Types of Semiautomatic Shoulder Rifles.

The need for a shoulder rifle which will reload itself each time a shot is fired without the necessity of having the soldier disturb his aim or increase his fatigue by working the bolt handle, has become more pressing with the increasing importance of fire power against ground troops, rapidly moving armored vehicles and low flying planes.

The design of a rifle which will utilize part of the power generated by the explosion of the cartridge to perform mechanically the operations of opening the bolt, extracting the fired cartridge case, and reloading the rifle, has been most difficult. Rifle designers of the world have been working on this problem for several decades, and while some fairly successful hunting guns on this principle are on the market, a satisfactory military rifle of this kind has never been perfected to the extent of re-arming the troops of any first class power.

The first efforts in this country to produce a military semiautomatic rifle were directed toward maintaining the caliber of the Springfield rifle in order to simplify supply and because of the general satisfactoriness of the caliber .30 cartridge. A great many models were developed which, when tested by the combat arms, invariably broke down from overheating and damage to parts. These models were heavy and clumsy. Nevertheless, the various combat boards found that a semiautomatic rifle was demanded because of the increased fire power and reduction in training time obtained.

After test and consideration of many models of semiautomatic rifles, an attempt was made to avoid some of the outstanding difficulties by reducing the caliber of the weapon. Two types were produced and tested, with a degree of success which lent support to the idea of going to a smaller caliber.

However, a consideration of all factors entering into a change so radical resulted in a decision to intensify the effort to produce a caliber .30 weapon equally as satisfactory as the caliber .276 models.

Accordingly, a design of caliber .30 weapon following generally the principles of the Garand caliber .276 semiautomatic was produced and tested. The preliminary tests were so successful that the work was continued and the design perfected. The weapon, now known as the "Rifle, Caliber .30, M1" has been standardized and is being produced in quantity. The rifle is a gas operated arm, designed by Mr. John C. Garand, an employee of the Ordnance Department at Springfield Armory. Slide No. 3 shows this rifle both as a caliber .276 and as a caliber .30. The chief difference between the two designs is that the caliber .276 has a bloc clip of 10 rounds, while the caliber .30 has 8 rounds. One of the special features of the Garand is that the cartridges are held en bloc, that is, the entire clip is placed in the gun without removing the cartridges from the clip. When the last round is fired the clip is ejected automatically.

The M1 weighs about 9 pounds and has a maximum rate of fire of about 75 rounds per minute. Its ballistic characteristics are the same as the M1903 since it uses the same ammunition.

PISTOLS

U. S. Pistol, Caliber .45 M1911 and M1911A1

Slide No. 4 (Ordnance Photo No. 7711)

The caliber .45 automatic pistol, Model of 1911, remains the service side arm. This weapon proved itself in the World War and fulfills all the present requirements. In 1925, several changes in the automatic pistol were made to improve the balance and to prevent the hammer of the pistol from striking the hands of the firer, which was an annoying defect in the earlier models. In this new pistol the trigger was somewhat shortened in order to enable firing to be performed with greater ease, and the shape of the grip was changed in order to aid instinctive pointing. The pistol, with these slight modifications, is known as the Caliber .45 Pistol, Model 1911A1.

The successful manner in which this pistol has fulfilled requirements since 1911 is due to the fact that its design does not require closely-fitted mechanisms. On the contrary, large clearances between its parts are the rule, and as a result it continues in operation under adverse conditions of heat and cold, dirt, etc.

A requirement was set up for a caliber .22 automatic pistol to be used in pistol training in the same manner as the .22 rifle for rifle training. A model (the "Ace") developed by the Colt Company has been tested but has not yet been adopted as standard.

AUTOMATIC AND MACHINE RIFLES

Slide No. 5 (Ordnance Photo No. 7704)

Browning Automatic Rifle, Caliber .30, M1918
Browning Machine Rifle, Caliber .30, M1922

The Browning Automatic Rifle, Cal. .30, M1918, was, until the recant development of the semiautomatic shoulder rifle, probably the most efficient small arm of its weight and caliber in existence. It is a gas-operated weapon, weight about 16 pounds, using a 20-shot magazine. It fires on the forward or closing motion of the breechblock, reducing recoil disturbance to a munimum, and the forces operating the breech mechanism are so correctly applied that the gun is very reliable and durable.

Photo of Browning Automatic Rifle,
Cal. .30, M1918A2

The automatic rifle possesses many of the characteristics of the light machine guns so popular in Euorpe. To meet an infantry requirement for an automatic rifle with the equipment of an arm of the latter nature, the M1918 was equipped with a bipod and a hinged buttplate, in this form successfully fulfilling requirements for such an arm. It has been standardized as the M1918A1.

For a weapon heavier than the automatic rifle and one capable of developing more sustained fire, a class of arm called the machine rifle has been developed. The Browning Machine Rifle M1922 differs from the M1918 only in the heavy finned barrel and the bipod and stock rest. This was illustrated in Slide No. 5. This class of weapon has not, however, been included in the list of current equipment.

MACHINE GUNS

The number of machine gun types is now so great that it is advisable to have some knowledge of the accepted requirements as they now stand. A condensed listing is as follows:

Watercooled machine guns, Cal. .30 and .50.

Fixed and flexible aircraft machine guns, Calibers .30 and .50.

Fixed and flexible aircraft machine guns, heavy barrel, Caliber .50.

Light machine gun, Caliber .30.

Heavy barrel machine gun, Caliber .30.

Subcaliber machine gun.

Machine gun mounts, Caliber .30 and .50.

Antiaircraft machine gun mounts, Calibers .30 and .50.

Pack machine gun mounts, Calibers .30 and .50.

Photo of Mount, Tripod, Machine Gun,
Cal. .30, M1917A1

It is generally considered that the most successful machine gun from the standpoint of procurement, supply, training and field use is the Browning Machine Gun, Caliber .30, M1917, which is the standard heavy watercooled machine gun of the U. S. Army. This gun is still in the same form in which it was used in the latter stages of the World War by Regular Army divisions, except that the rear sight has been improved and the receiver strengthened. This weapon at the time it was originally tested, and in service use, established new records for serviceability and durability.

The U. S. Machine Gun, Caliber .22, M1, was developed for training purposes, using the Caliber .30, M1917, and converting it to caliber .22 on the Williams principle, a modified blowback using a movable chamber accelerated by gas pressure. It provides similar training at 1000 inches as would be given by the caliber .30, as stoppages, vibration, etc., are very much the same, and it has become a very popular training weapon.

Until recently the standard machine gun mount was the Tripod Machine Gun, M1917. This well-known tripod is very strong and durable, but did not satisfy a demand which has lately arisen for a mount with lateral mil clicks as well as vertical, and able to fire at high angles. To meet this demand the Mount, Tripod, Caliber .30, M1917A1, was produced and, after thorough test, standardized.

In this mount the elevation and traversing are easily controlled by the gunner by means of click handwheels, by which he can move the center of impact positively and at will. The mechanisms first manufactured were without means of compensating for wear, which became serious in service, but this has now been corrected.

The advantage of the High-angle provision in the mount is that it makes it possible to get antiaircraft fire instantly, without the pause required for setting up an adapter. Operating as a "free" gun in antiaircraft fire, the mount gives more stability to the gun than any other method so far devised, as the gun is held at the trunnion in front and a bracket in the rear, rigidity in a vertical plane being obtained by the support given the side plates of the cradle at the elevation clamp. This prevents torsion and side movement, so that the cone of fire is not dispersed to the extent common in cradles not provided with side plates supported at their lower edges by an elevation clamp which can be tightened just enough to give free movement without locking. This "all-purpose" cradle requires the use of tracer ammunition for anti-aircraft fire control, the gunner making no attempt to use his sights. Consequently, the gun can be kept low and stable since the gunner does not have to be lower than the gun.

Photo of Mount, Wheeled, Machine Gun, M1.

However good for antiaircraft fire our machine gun mount may be, it requires to be set up before use, and there is therefore a requirement for some means by which ground troops on the march can defend themselves when attacked by low flying aircraft. In order to meet this menace, it is expected that the future machine guns will normally be transported mounted and ready to fire. On the Mount, Wheeled, Machine Gun, M1, the gun can be transported set up on the tripod and in condition to fire instantly. The construction of the wheeled mount is clearly shown in the slide. It is mounted on wheels and adapted to be limbered behind the ammunition cart. Recent changes combine the features of the wheeled mount with those of an Infantry cart. The new design is now undergoing test.

Photo of Gun, Machine, Browning, Caliber .30, M1919A4, on Mount, Light Machine Gun, M2.

At present the requirement for a heavy barrel caliber .30 machine gun is filled by the M1919A4 Browning machine gun. This is also issued to the Cavalry as a limited standard for light machine gun, for which it takes the Mount, Tripod, Light Machine Gun, M2, which is the combination shown in the slide. Other than for Cavalry use, the principal requirement for a caliber .30 heavy barrel machine gun is for arming combat vehicles.

The M1919A4 can be fabricated from the basic mechanism of the obsolete Tank Machine Gun, M1919, or alternatively from surplus M1917 guns. The heavy barrel in light machine guns such as this, is necessary to proper cooling of the gun since water is not used.

Photo of Gun, Machine, Aircraft,
Browning, Caliber .30, M2.

During the War the Army airplanes were armed with the Marlin machine gun, which was used for fixed installations where the guns were mounted on the forward part of the plane and synchronized to fire through the propeller blades. The Lewis aircraft machine gun was used as the standard flexible gun for the use of observers.

Lewis Aircraft Machine Guns Mounted
in Observer's Cockpit.

During the latter part of the War the Browning Machine Gun was produced as an air cooled model for use as a synchronized gun. It was designated as Browning Aircraft Machine Gun, M1918, and has been used as the synchronized gun from just after the War up to the present time.

Neither of the two guns above mentioned was ideal for the purpose for which they were used, as each one of these guns was more or less of a makeshift, having been primarily designed for an entirely different use and then converted for use in aircraft.

However, immediately after the War the Ordnance Department began working on a project for making an improved aircraft gun which would be suitable for all uses, such as flexible installations, wing installations, or synchronized guns firing through the propeller. The result of this development is the Browning Aircraft Machine Gun, Caliber .30, M2, which is stronger, lighter and adapted to more uses than any other aircraft gun so far developed. It will feed either from the right or the left.

The result of the great success of the Caliber .30 M2 as an aircraft gun has been that the M2 design has been used in all guns of new development, both .30 and .50.

Photo of Browning Machine Gun, Caliber .50, M1921, on A.A. Tripod Mount M1

The lessons of the World War indicated that a machine gun of heavier caliber than the standard caliber .30 would fill an important place in both aircraft and antiaircraft armament.

Accordingly, a gun operating on the Browning principle was designed to handle a caliber .50 cartridge. This gun was developed and standardized in two different types, the watercooled type for ground and antiaircraft use, and the air cooled type for mounting in an airplane.

The mechanism of this gun is almost identical with that of the Browning Machine Gun, Caliber .30, Model 1917. The gun weighs 66 pounds without water, and 86 pounds with the water jacket filled. The rate of fire is approximately 500 rounds per minute, with a muzzle velocity of about 2700 feet per second.

However, the Model 1921 watercooled gun was never adopted for general ground use although it has been found to be a very effective antiaircraft machine gun, and until recently replaced by the M2, has been the standard Coast Artillery Antiaircraft Machine Gun.

Photo of Browning Machine Gun, Aircraft, Caliber .50, M2, fixed or flexible.

The most recent development of caliber .50 design is along the lines of the caliber .30, M2, aircraft gun. The pilot model of the new caliber .50 was first made heavy barreled and air cooled so as to be suitable for anit-tank or tank use and yet be portable and adaptable for pack transportation for the Cavalry. Because all other Browning Machine Guns are not suitable for recoil action barrels of great diameter, the M2 was made exceptionally wide in the trunnion block so as to provide room for heavy barrels. This gun weighs 70 lbs. and the weight of the tripod is about 40 lbs. The barrel will stand a satisfactory burst of fire without serious damage from overheating, and the barrel can be changed in about 10 seconds to provide a cool barrel. Headspace is adjusted automatically from the front as the barrel is screwed into the barrel extension. The M2 design provides either right or left hand feed and is also used in tanks, combat cars, etc.

Photo of Browning Machine Gun,
Caliber .50, M2, Watercooled.

The success of Caliber .50, M2, heavy barreled gun provided the means for standardizing all caliber .30 machine guns of the M2 design, thus providing right and left hand feed, improved functioning, with lighter weight than the older types of the Model 1921, together with interchangeable parts in the case of all M2 designs. The watercooled antiaircraft gun was therefore changed to the M2, and at the same time a much heavier barrel was provided than had formerly been used in watercooled guns. By using wide trunnions and an extension of the water jacket around the muzzle of the barrel, and by placing the front bearing on the muzzle of the barrel instead of only in the water jacket, watercooling around the breech of the barrel and at the muzzle was much improved. These changes so improved the cooling of the caliber .50 antiaircraft gun that the accuracy life of the barrel has been greatly prolonged. This weapon when used as a free gun with spade grips, is called "flexible" and when utilized on a mount such as the Navy type of pedestal mount with a shoulder rest, remote control, and an aircraft back plate, is called a "fixed" type.

In order to further ammunition development, especially to obtain higher velocity without objectionable increase in smoke and flash, considerable development work has been done on 45" barrels for the caliber .50 machine gun. As a result of tests, the 45" barrel has been adopted for all guns except aircraft guns.

Photo of Browning Machine Gun, Cal., .50, M2, Watercooled, on Tripod Mount, A.A., M1E2, complete with attached sight.

Photo of Browning Machine Gun, Cal. .50, M2, Watercooled, on Tripod Mount M25E2, complete with attached sight.

Photo of Browning Machine Gun, Cal. .50
M2, on Pedestal Mount T26E2.

The standard antiaircraft mount for both .30 and .50 machine guns is the Machine Gun Antiaircraft Tripod Mount M1. This mount is not stable enough for the caliber .50 gun, though excellent for the caliber .30. Moreover, it is high, unwieldy, and the tripod legs interfere with the movement of the gunner in azimuth. These faults are in some degree the inescapable result of getting the gun high enough for the gunner to get behind it to look through the regular sights. It should be remembered that the subject of machine gun antiaircraft fire control is still unsettled, and it has not even been possible to decide whether to use tracer control or sights, though for caliber .50 guns the use of sights seems to be favored. On the Tripod Mounts M1E2 and T25E2, on preceding slides, the sights shown are those of the Machine Gun Antiaircraft Control Equipment Set T1, an apparatus now under test by the Coast Artillery which uses a lead computer to set the sights. The M25E1, M25E2, and M26E1 Mounts have a synchronized trigger mechanism having a timed relation to the frequency of the gun.

Multiple mounts, including a type with four caliber .50 machine guns, were proved unsuccessful for antiaircraft missions by the Coast Artillery.

Photo of Mount, Machine Gun, Tripod, Caliber .50, T21.

Photo of Mount, Tripod, Caliber .50, M3.

No ground-type tripod for caliber .50 machine guns has been standardized. The caliber .50 M1921 machine gun had a tripod like the caliber .30 M1917, but it was unsuccessful due to the great recoil and vibration of the caliber .50 gun. There is now a development type, the T21 shown in the slide, which contains the same "all purpose" type cradle that has already been shown in the Tripod Mount, Caliber .30, M1917A1. Vehicle mounts, both caliber .30 and caliber .50, such as scout cars, etc., wherever practical will use the same type cradles.

There is, however, now a standard caliber .50 light machine gun mount, the Tripod Mount, Caliber .50, M3. It is the pack mount used by the Cavalry. Its similarity to the Tripod Mount, Caliber .30, M2, already shown, is evident.

SMALL ARMS AMMUNITION

Slide No. 22 (Ordnance Photo No. 5495)

Types of Caliber .30 and Caliber .50
Small Arms Bullets.

This slide shows the different types of caliber .50 and caliber .30 bullets. The slide is self-explanatory, but attention is invited to the bases of the old and new service bullets.

Ball Ammunition.

The chief difference in the new M1 service bullet and the service bullet, Model 1906, is the shape of the base of the bullets, the M1 being tapered at the base and the Model 1906 being flat. This change, with the corresponding increase in weight of about 23 grains, increased the maximum range from about 3400 to 5500 yards by decreasing the air resistance, as the muzzle velocity of the M1 bullet is about 50 f.s. less than the muzzle velocity of the Model 1906 bullet, the pressure being about the same or less. The M1 cartridge was developed as a result of the World War, and the lack of range of the Model 1906 which, while perfectly satisfactory for rifle fire was inadequate for long range machine gun barrage fire. The M1 cartridge also uses a more progressive burning type of powder and the bullet jacket is of nonfouling gilding metal instead of cupro nickel.

It has been necessary to manufacture a quantity of caliber .30 M1906 ammunition for use in range firing at posts whose range facilities are not safe with the caliber .30 M1 cartridge.

Tracer Ammunition.

The simplest and sometimes the most effective method of directing machine gun fire against aerial targets, fast moving tanks, etc. is by means of tracer ammunition which shows the path of the bullet. In use a certain percentage of the ammunition in the belt, say every fifth cartridge, is a tracer. The tracing mixture of the tracer bullet is composed of ingredients which are ignited by the powder gases when the cartridge is fired, and burn with a bright flame. Various colors of tracer have been used, but under average conditions red shows up the best.

The tracer trajectory closely approximates that of the corresponding ball cartridge within the range in which the tracer burns. The length of trace of the caliber .30 is about 900 yards, and of the caliber .50 about 1800 yards.

The greatest difficulty in the use of tracer control in antiaircraft fire is to determine what part of the observed trace is at the target. In caliber .50 experiments have been made with two-color tracers, that is, tracers which change color. It was intended that the point of change of color would assist the gunner in locating the plane along the trajectory. No great success was attained, however.

Armor Piercing Ammunition.

Slide No. 23 (Ordnance Photo No. 7712)
Penetration of Caliber .30 A.P. Bullets.

Slide No. 24 (Ordnance Photo No. 7713)
Penetration of Caliber .50 A.P. Bullets

Armor piercing bullets are necessary to penetrate armor plate with which tanks, armored cars and other war vehicles are equipped, as the ordinary service bullet, while it will penetrate a considerable amount of mild steel, will not make a dent against armor plate unless it is exceedingly thin. The caliber .30 armor piercing bullet will penetrate a half-inch of armor plate at 100 yards, or one-fourth inch at 500 yards at normal impact. The caliber .50 armor piercing bullet will penetrate an inch of armor at 100 yards and one-half inch at 1000 yards. The caliber .30 armor piercing bullet was made flat based while the caliber .50 armor piercing bullet was made boat tailed.

By means of high velocities or by means of improved armor piercing bullets of increased velocity it is possible to materially increase the penetrations shown on the charts for the caliber .30 and caliber .50 armor piercing bullets. An opening small enough to admit light through a plate is often sufficient to disable the personnel of an armored vehicle by the effect of "bullet splash", i.e., molten lead and particles of bullet jacket.

High Velocity

Slide No. 25 (Ordnance Photo No. 7512)
A Type of High Velocity Bullet.

Test of the Gerlich high velocity type of bullet abroad and in this country directed attention to the improved armor piercing ability of high velocity types of bullets and, in the case of the Gerlich type, the reduced time of flight at longer ranges for antiaircraft fire. The Gerlich bullet, which is along the lines of the type shown, has wide bands which are intended to fold into the recessed body as the bullet passes through the tapered barrel. It attains high velocity initially, as it utilizes the maximum peak of the powder pressure at the breech by the bullet passing through a cylindrical rear portion of the barrel where the initial forcing resistance has been reduced to the minimum. As the bullet passes through the tapered portion of the barrel, the bands are folded down so that when it emerges from the barrel the bullet has the usual conventional form. This is necessary for ballistic reasons, as interior ballistics require a low sectional density and exterior ballistics a high sectional density.

The Gerlich bullet and rifle had some success when tried in this country, and its principle is attractive, but the production of either the bullets or the barrels in great quantity would seem to be quite out of the question. This line of development was therefore not attempted. Other methods can be made to yield a measure of results, the chief difficulty being that the attainment of maximum velocities still requires the use of bullets so light that they do not hold their velocity well.

INTERMEDIATE CALIBER MACHINE GUNS

Since the World War the calibers of machine guns have been increased so that they are now extensively used in the smaller cannon calibers, in order to meet the attack of aircraft or ground armored vehicles.

The largest caliber machine gun using small arms types of bullets, considering such factors as high cyclic rate of fire, trajectory, weight, size, flexibility, mobility and cooling problems, appears to be the caliber .50. The smallest intermediate caliber automatic antiaircraft cannon using artillery types of projectiles, considering the same factors as above, appears to be the 20 m/m types which are so numerous abroad. European nations apparently prefer the 20 m/m types to the caliber .50 type, although the caliber .50 type is very much superior to the 20 m/m with regard to volume of fire, either intensive or sustained. In this connection, rates of fire usually given for intermediate caliber automatic cannon are fallacious. One of the most successful of the European 20 m/m types permits only about 100 rounds per minute, due to the 20 round capacity of the magazine, although 350 rounds per minute is claimed. None of the air cooled types will fire more than 100 rounds in a minute without overheating.

<u>Disadvantages of Increased Calibers for Machine Gun Cannon</u>. The advantages of increasing the caliber of automatic weapons are so obvious that the cost of obtaining these advantages is overlooked. The large calibers give great striking energies and in the intermediate automatic cannon allow for the use of explosives with resulting material and moral effect. They also provide much better tracing and observation impacts, and of course the impact covers a greater area. However, each small increase in caliber is attended by astonishing increases in the amount

of heat involved and in the weight and size of both the gun and its ammunition.

As the caliber increases, the weight, length, size and vibration of an automatic gun also rapidly increase and in much greater proportion than might be expected. Vibration in cannon caliber automatic weapons, due to the weight of the moving parts, is very serious. This, with the small capacity of the magazines and slow rate of fire actually obtained, makes tracer observation, particularly for antiaircraft fire, of much less value than is the case with the high rate of fire and long bursts of the caliber .50 machine gun.

Slide No. 28 (Ordnance Photo No. 7732)

Comparison of Small Arms Ammunition

Slide No. 27 (Ordnance Photo No. 7525)

Comparative chart showing increase in heat to be disposed of as the caliber of automatic weapons increases.

In addition to the above disadvantages there is the cost and difficulty of procurement of intermediate caliber ammunition which must be produced by the same methods as artillery ammunition, while the caliber .50 types are produced on the same enormous scale as rifle and machine gun ammunition.

Notwithstanding all these disadvantages, the increased rate at which mechanization has progressed has created an urgent demand for more powerful automatic weapons. As the result of lessons drawn from the Spanish

War and elsewhere, tanks are being provided with heavier armor even at the expense of some speed. The Ordnance Department has produced and studied every important weapon of this sort produced in Europe, some photographs of which are shown above.

As a result of its own tests the Ordnance Department concludes that the 20 mm caliber is not as effective as desired, more satisfactory effectiveness having been shown by the Hotchkiss 25 m/m. This has resulted in the decision to develop the caliber .90.

Below is shown the Browning 37 m/m Automatic Gun, M1, on the T4E1 Mount. This is a very successful gun, developed some time ago by the Colt Company but hitherto handicapped by the extreme instability of available mounts. The T4E1 mount entirely removes this objection, and the weapon is now one of great power.

SECTION C

ARTILLERY WEAPONS - GENERAL

Nineteen years have elapsed since the Caliber Board reported on its sutdy of the armament, calibers and types of materiel, kinds and proportions of ammunition and methods of transport of artillery to be assigned to a field army. The Board stated the military characteristics that seemed desirable in the new artillery to be developed and frankly labeled these military characteristics "Ideal". The Board also indicated what other conservative steps should be taken and frankly labeled these "Practical".

Consequently, when the Ordnance Department undertook to develop the light field gun, light field howitzer, medium field gun, medium howitzer, heavy field gun and heavy field howitzer in 1919 the conservative features were emphasized rather than the ideal with the exception that the 75 m/m Gun and 105 m/m Howitzer were provided with a carriage capable of elevating the pieces to 80 degrees. The traverse, however, was limited to 30 degrees and the wheels were provided with solid rubber tires. In the case of the medium artillery, the 4.7" Gun M1920 and the 155 m/m Howitzer M1920 were installed on a carriage that was practically interchangeable for both weapons. A transport wagon was provided also so that either of these cannon could be hauled separately. In the case of the 155 m/m Gun and 8" Howitzer M1920, the carriage was also interchangeable and the transport wagon was provided. All of these of the M1920 series were provided with solid rubber tires.

The Caliber Board had recommended certain auxiliary weapons for a field army such as the pack howitzer, the light gun-howitzer to be used as an Infantry accompanying gun, a heavy trench mortar, a long range field gun of about 8" caliber, a long range field howitzer of about 9-1/2" caliber. In [illegible], a 75 m/m pack howitzer was designed to be disassembled into four pack loads. A 155 m/m mortar that was loaded through the breech and was rifled was mounted on a platform and top carriage that could be hauled on wheels or could be taken apart for transport by men. The development of an Infantry accompanying gun-howitzer for field artillery was suspended pending the outcome of experiments with a similar type of weapon for use in the Infantry, i.e., the Infantry howitzer. Studies of the mobile 8" Gun and of the 240 m/m Howitzer were undertaken but were suspended due to the higher priority of the light, medium and heavy artillery weapons pertaining to organic field artillery.

All of these pilots that were manufactured had been tested by the Ordnance Department and the Field Artillery Board by 1925. In the meantime, the progress of motorization of field artillery units was still in the experimental stage, but at that time it was evident that the Army would have to depend upon commercial tractors in view of the impractical results that had been experienced with the Ordnance Department's experimental high speed tractors for the three classes of artillery. Self-propelled mounts for the 75 m/m Gun, 105 m/m Howitzer, 4.7" Gun, 155 m/m Gun and the 8" Howitzer had also been tried and discarded as impractical. In the case of the division artillery, the Field Artillery adhered to the principl that the materiel should be horse-drawn and this influenced the design of the carriages and caused steel tires to be favored instead of the solid rubber tires, because it was evident that commercial tractors of that era would travel no faster than horses. Shields and aprons were included on the divisional weapons but were omitted from the medium calibers. In 1925 the Field Artillery decided that the medium howitzer should be drawn in one load and that the weight of the materiel could be increased materially because it was felt that the weight of the carriage for the howitzer that would give 16,000 yards would be greater than a medium tractor could haul safely. In the case of the 155 m/m Gun - 8" Howitzer Carriage M1920, the Field Artillery had decided that it was necessary to divide the load into two parts for transport by heavy tractors, i.e., 10-ton capacity and that the total weight should be subdivided into two loads of approximately the same weight.

Thus, nearly one-half of the nineteen years since the Caliber Board outlined the development program was devoted to trial of the possibilities of obtaining increased ranges that were deemed necessary. In the case of the divisional gun and howitzer it was necessary to experiment with axle traverse as well as split trail types of carriage. In the case of the 75 m/m Pack Howitzer the Field Artillery concluded in 1922 or 1923 that the power of the pack howitzer should be increased to the maximum that was possible and yet transport the howitzer and carriage on six mules with loads not exceeding 225 pounds per pack load, exclusive of the saddle. The 75 m/m Gun M1 and 75 m/m Gun Carriage M1 were adopted as standard in 1925. The 75 m/m Pack Howitzer M1 and the 75 m/m Pack Howitzer Carriage M1 were adopted as standard in 1927. The pack load accessories were designed for the aparejo at the time and when the Pack Artillery started to experiment with the Phillips pack saddle it was necessary to redesign the pack load accessories so that they could be used with either type of saddle. Hence, the pack equipment was not finally completed until 1930. The 105 m/m Howitzer M1 and the 105 m/m Howitzer Carriage M1 were adopted as standard in 1928. The redesign of the 155 m/m Howitzer Carriage M1920 was undertaken in 1925 to make it a single load type, which resulted in the 155 m/m Howitzer T1 and the 155 m/m Howitzer Carriage T1 which, however, were ultimately rejected by the Field Artillery as remarked below. The redesign of the 155 m/m Gun-8" Howitzer Carriage M1920 was undertaken in 1928 in general accordance with the recommendations of the Field Artillery Board that the materiel be divided into two loads for transport. The 155 m/m Gun - 8" Howitzer Carriage T1 was laid out and a half-size wooden model was constructed in 1929, but this line of development was then suspended to proceed with a single unit type which resulted in the 155 m/m Gun - 8" Howitzer Carriage T2 that is capable of being drawn at high speeds. This became the 155 m/m Gun - 8" Howitzer Carriage T2E1 which mounts the 155 m/m Gun T4 or 8" Howitzer T3 interchangeably, and four of which are now undergoing service test. The development of the 155 m/m Trench Mortar was suspended in view of the low priority that such weapons had in the field army organization.

In 1929 the development of the "Ideal" or all-purpose field gun was undertaken. Two pilots, both of which mounted the 75 m/m Gun M1925E1, known as the 75 m/m Gun Carriages T2 and T3, were constructed and tested in an effort to determine the military characteristics of the so-called all-purpose gun carriage. These were tested in 1930 and 1931. In 1932 the Chief of Field Artillery submitted a set of military characteristics for the carriage which were used as the basis for designing the 75 m/m Gun Carriage T2E1. These carriages were completed in 1933 and were transferred to the Field Artillery for test in February, 1934, after an extensive test as antiaircraft materiel at Aberdeen Proving Grounds. They proved mechanically successful to a remarkable degree, but decision by the using service against the use of all-purpose materiel resulted in the cancellation of this project. The 155 m/m Howitzer T1 and the 155 m/m Howitzer Carriage T1E2 were rejected by the Field Artillery in 1932 because it was necessary to dig a deep pit to clear the howitzer in recoil at height elevations and in view of the experience that had been obtained in the use of pneumatic tires on the 155 m/m Gun - 8" Howitzer Carriage T2.

The scarcity of funds has until recently prevented more rapid progress in the designing and testing of the modern field artillery units and it may seem that the accomplishments of the fifteen years following 1919 were very small, but the trend of efforts in recent years indicates that it is fortunate that the War Department was left still in the position to redesign all of the materiel to take advantage of rapid advances in wheeled types of prime movers. The War Department has also recently stressed the necessity for improvement in the design of divisional artillery to combat rapid moving ground targets, and the changes of design that are necessary for high speed transport and for rapid wide traverse have been intensively investigated during the past four years. In 1931 the Field Artillery actually initiated the experiment of using trucks to draw the 75 m/m Gun M1897. The carriage was equipped with pneumatic tires and commercial truck wheels by means of adapters. The experiments were so successful that the National Guard undertook to reequip its field artillery units with trucks to replace horses in 1933. Later in the year, as a result of the allocation of P. W. A. funds, the motorization of a portion of all branches of the Army was undertaken and this required the adoption of adapters with pneumatic tires for the 75 m/m Gun Carriages M1897 and M1917. Such adapters were successfully developed and adopted, resulting in the standardization of the carriages involved as 75 m/m Gun Carriages M1897A4 and M1917A1, and later the M1916A1. The Ordnance Department and Field Artillery have been experimenting with means of improving the bearings on the 155 m/m Howitzer Carriage M1918 and the 155 m/m Gun Carriage M1918 so that these carriages could be towed at high speeds behind trucks. In the case of the 155 m/m Gun Carriage the experiment is fairly satisfactory. The 155 m/m Howitzer Carriage M1918 requires modification to tow it behind trucks as the limber had to be eliminated. This change was made by the addition of a drawbar. The solid rubber tires on this carriage proved unsuitable for traveling at high speeds, and consequently it was necessary to provide pneumatic tires as well as improved bearings. The carriage completely modified with drawbar, wheel bearings, and pneumatic tires, has been standardized as the 155 m/m Howitzer Carriage M1918A1. Firing platforms to provide wide traverse are now under development.

These efforts to improvise equipment on the old war-time materiel to equip it to be towed at high speeds have been proven but it does not improve the military characteristics for firing. In 1932 the design of the 75 m/m Gun Carriage T5 for the 75 m/m Gun M1897 was undertaken. In this carriage it was proposed to provide for high speed transport, 90° traverse, and a modern sighting system that could be used with a panoramic sight to fire at rapidly moving ground targets. This design progressed through several stages to the 75 m/m Gun Carriages M2 and M2A2, which have now been issued. In 1932 the development of a split trail carriage with pneumatic tires for the 75 m/m Howitzer M1 was also undertaken, with a view to adopting this howitzer and carriage for Cavalry Divisional Artillery, the M1897 gun having been found too heavy for use in horsed Cavalry divisions. From experience with the resulting designs, the 75 m/m Howitzer Carriages T1 and T2, the 75 m/m Howitzer Carriages M3 and M3A1 were standardized for this use only. In 1933 the development of a split trail carriage for the 155 m/m Howitzer M1918 was requested by the Chief of Field Artillery. Though delayed by the necessity of proceeding with the development of the 155 m/m Howitzer Carriage M1918A1, this carriage was produced in 1935 as the 155 m/m Howitzer Carriage T3 and has now progressed to service test. All of these modernization projects were requested with the serious intention of obtaining funds, when the development warranted adoption of these modern carriages, to equip the active field artillery organizations with modern carriages for the World War types of cannon.

Most recent developments are in the direction of entirely new weapons the need for which has been brought out by recent undeclared wars in different parts of the World. One of the most important of these is an anti-tank gun, the 37 m/m Gun T3 on 37 m/m Gun Carriage T1, a small and light but very powerful piece, utilizing the lessons learned from recent European weapons and expected to develop into a completely satisfactory gun for this purpose. Another new arm is the 37 m/m Automatic Gun M1 on 37 m/m Gun Carriage T2, an automatic gun of power equal to the Anti-Tank Gun T3 but intended for antiaircraft use. The M1 Gun has been in existence for nearly fifteen years, but there has not been until very recently a carriage sufficiently stable to permit its effective use.

In these nineteen years of development, the technique of manufacture of field artillery guns and field artillery carriages has been revolutionized. The cold working of steel forgings for cannon has been successfully perfected for all calibers up to the 155 m/m Gun. Centrifugal casting of cannon tubes has been developed for all calibers up to 105 m/m Howitzer. The welding of trails, top carriages, bottom carriages and recoil mechanisms has been developed so that it is practicable to construct a carriage without any steel castings if desired and modern carriages are so constructed in most of their parts. These three processes are all conducive to reduction of weight in Field Artillery materiel but new demands as to military characteristics have also been made in the meantime and most of these demands call for an increase in weight. Consequently, the new materiel being produced with these new processes is probably heavier than the earlier experimental models would have been had they been constructed by these new processes, due, as was stated, to the increased demands for performance. The oil industry has developed new processes of blending lubricants for the needs of the automotive industry. In general, some of these new lubricants have been found to be quite useful in recoil mechanisms, and tests in the last five or six years indicate that it is possible to fire in much colder weather than was possible during the World War. Corrosion-resisting steel or iron has been tried for recoil mechanisms and it reduces the corrosion menace very appreciably, but machining difficulties caused abandonment of its use.

SECTION D

VARIOUS MODELS OF FIELD ARTILLERY

FIELD GUNS

In dealing with the rather complicated subject of post-war development of Field Artillery materiel, it will be of assistance to remember that the development in each caliber has in general taken the following forms:

(1) Modification of existing materiel for high speed transport, and other improvements.

(2) Development of modern carriages for the existing guns.

(3) Development of new guns and carriages.

Reference to Chart I in the back cover of this review will help to keep the subject in order.

The French 75 m/m Gun M1897 has been the equipment of our Field Artillery since 1917. The French carriage, of course, is limited to 6° traverse and 19° elevation, which limits the range to 9200 yards with the Mark IV Shell. Since the gun and recoil mechanism have been found very suitable by the Field Artillery, a great part of all the 75 m/m development has consisted in endeavors to provide a suitable modern carriage for the gun and recoil mechanism. Of these the least radical was the addition of a panoramic sight in 1928 which made the M1897M1A1 Carriage, the addition of a hand spike to the French gun in 1934 which made the M1897M1A2 Carriage and the combination of these two improvements in 1935 resulting in the 1897M1A3. Nothing much has come of this development since more radical improvement is required by modern conditions.

A principal line of development was, as has been said, a modification of the M1897 Carriage for high speed transport. Beginning in 1932 the Ordnance Department developed seven carriages for this purpose, the M1897 M1E2 - E3 - E5 - E6 - E8 - E9 and E12, the last in 1934. In 1933 the Martin-Parry Corporation became interested in the problem and produced the M1897M1E4 - E7 and E10. The last of these became at the end of 1934 substitute standard under the designation M1897 A4. In 1938 this carriage was transferred to limited standard. The Ordnance designs were rejected by the Field Artillery.

The basic idea of all these designs was the adaptation of modern pneumatic tires and anti-friction bearings to the M1897 carriage. A considerable variety of detail resulted, one of the principal points to be decided being whether or not the carriage should be sprung for easier riding. The final decision was that while springing made an easier riding carriage it was not necessary, and therefore, was not adopted. The using service showed a preference for the carriage without shield and the M1897 A4 as originally adopted was without shield and apron. By direction of the Chief of Field Artillery these parts were replaced on both the carriage in service and those under modification.

In 1933, while these modifications of the M1897 Carriage were being developed, other experiments looking toward the transport of the carriage by truck instead of on its own wheels in the conventional way were being carried out at the instance of Field Artillery and Cavalry. The 75 m/m Gun Truck Mount T6 was a pedestal mount for the French gun on the commercial truck on a 22 foot long wheel base. The mount was designed to slide on the chassis so the gun could be fired either to the Front or to the rear. Another simpler device was the 75 m/m Gun Carriage T9, which was simply a modification of the Calss "B" Truck to accomodate the 75 m/m Carriage M1897 so the gun could be fired either to the front or to the rear. This development was undertaken to provide a cheap means of increasing the mobility of the French 75 m/m Gun for special missions. Both these truck mounts were tested at Fort Bliss, Texas, but the high speed developments which resulted in the M1897 A4 Carriage caused these truck mounts to be dropped.

In 1934, while the high speed modifications of the M1897 carriage were still in progress, there was designed the first of a series of completely new carriages to mount the M1897 gun and recoil mechanism. The high speed carriages culminating in the M1897 M4 satisfactorily solved the problem of high speed mobility, but they made no progress toward the improvement of the limited elevation and traverse of the M1897 carriage. The new 75 mm Gun Carriage T5 was designed to correct this lack. It elevates the M1897 Gun to 45° and traverses 90°, thus utilizing fully the power of the gun. The maximum range of about 13,000 yards which this elevation gives the M1897 Gun is considered sufficient by the Field Artillery for their requirements.

The T5 carriage was followed by the T5E1, T5E2, T7, and T7E1, designed to remove defects in the T5 and to solve most satisfactorily the problem of firing from pneumatic tires on the split trail carriage. In the latter type there are four points of contact with the ground, and therefore, some means must be provided to support the carriage on three points. The T5 supported the front of the carriage on a non-adjustable prop inserted between the carriage and the ground. In the T7 this prop was made adjustable to facilitate emplacing of the carriage on soft ground. All four of these carriages can be fired with the trails closed, with a traverse of about 40°. The T7 carriage was standardized in 1937 as the M2 and M2A2, and is now manufactured and issued to the extent permitted by available funds.

The discussion so far has covered the modification of the M1897 Carriage for high speed transport, and the design of a new carriage for the M1897 Gun. The third line of development, the design of an entirely new 75 m/m gun and carriage, is of much earlier origin than the two already covered. The Caliber Board recommendations of 1919, followed by the Field Artillery and Ordnance Department practical specifications initiated in 1921 a line of development which covered 75 m/m gun carriages and combination 75 m/m gun-105 m/m howitzer carriages, box trail and split trail. By 1925 the split trail carriage with maximum elevation and maximum traverse each of 45° had emerged as the most suitable. In 1926 the 75 m/m gun carriage M1, embodying those characteristics, was standardized. It was designed for horse or tractor draft, since high speed transportation by a towing truck was not yet contemplated. The gun, in accordance with the recommendations of the Caliber Board, fired a 15-lb. shell to a maximum range of 15,000 yards.

In 1933, shortly after the initiation of high speed modifications on the M1897 carriage the problem of modernizing the M1 Carriage was taken up. The M1E1 Carriage incorporated pneumatic tires and anti-friction bearings, as well as an increased traverse of 90°. This, as well as all the other carriages of the M1 series, solved the problem of providing a three-point suspension of the carriage while firing by pivoting the axle at the center, in accordance with the same principle as the 155 m/m G.P.F. Gun. The development proceeded through the models M1E1, E2, E3, E4 and E5; but in 1936 the Field Artillery canceled the requirement for 15,000-yard range in favor of the 13,000 yards which could be provided by the M1897 gun with sufficient elevation. This change of requirement resulted in the destandardization of the M1 Gun and its reversion to experimental status. This is equivalent to abandonment, at least for the present.

The Field Artillery in the Hawaiian and Philippine Departments are equipped with the British 75 m/m Gun and Carriage M1917. In 1933, for the same reasons as in the case of the French gun, a parallel line of development was undertaken to adapt this carriage for high speed transport. The 75 m/m Gun Carriage M1917 E1 incorporated both rubber tires and firing segments. In the M1917 E2 Carriage those firing segments were removed as unnecessary. Further modifications were made in the M1917 E3, and in 1935 the carriage was made limited standard as the M1917 A1. Its principal features are the same as those of the M1897 A4, also limited standard.

During the war a limited number of 75 m/m guns and carriages M1916 were produced. This piece had a maximum elevation and traverse each 45° and fires the same ammunition as the French and British 75 m/m guns. In 1936 a modification of this carriage, similar to the high speed adaptations already discussed was adopted, and the carriage made limited standard under the designation M1916 A1.

All of the foregoing weapons are purely Field Artillery materiel. However, between 1931 and 1935 the service was agitated by the question of whether Field Artillery materiel should be adapted to attack airplanes and rapidly moving ground targets, as well as the ordinary targets of the divisional field gun. The initiation of this question dated back to the Caliber Board, which had recommended that the ideal light field gun be equipped with a carriage permitting 80° elevation and 360° traverse. The development of such a carriage was undertaken in 1929 and in 1932 two designs, a T2 and a T3 were produced for actual test. As the result of experiment with these two designs a battery of T2E1 carriages was completed in 1933 and in the following year was tested at Fort Bragg. This materiel was remarkably adaptable. It could be fired with the trails closed or extended or with the carriage arranged for 360° traverse. It could be emplaced on a 15° slope and had on-carriage fire control equipment arranged for connecting to a director for antiaircraft fire or for firing at moving ground targets. The gun is the same as for the M1E1 Carriage, being therefore more powerful than the M1897 but not as powerful as a 3" antiaircraft gun. The test of these carriages was marked by an entire absence of mechanical difficulties, and the materiel was one of the highese developed ever turned out by the Ordnance Department.

In 1935 the Field Artillery reviewed the requirement for all-purpose materiel and came to the conclusion that it was not desired. The development was, therefore, abandoned.

The Caliber Board recommendations contained a requirement for a 4.7" Gun for Corps Artillery. This requirement was maintained until 1932, when it was canceled. The 4.7" Gun M1922 on 4.7" Carriage M1931 was designed to fill this requirement, and before the development was suspended, had been quite thoroughly tested. The weight of projectile was 50 lbs., maximum range at the maximum elevation of 45° was 20,000 yards and total traverse was 60°. The features of a pivoted axle to secure three-point support of the carriage while firing, equilibrators with the gun trunnioned near the breech, and variable recoil will be noticed. The digging of a pit was not required. If this carriage were to be put into use today it would be necessary to adapt it to high speed towing, as it is not too large to be so handled, having a weight, without limber of 10,350 lbs.

The 155 m/m Gun and Carriage M1917 and M1918 used during the World War are still in service. The M1917 materiel is of French manufacture and the M1918 of American manufacture. The gun fires a 95-lb. shell to about 17,450 yards at maximum elevation of 35° which is permitted by this carriage. The total traverse is 60°. Weight in firing position is about 26,000 lbs.

The M1918A1 Carriage differs from the M1918 in a modification to the wheel bearings to permit higher speed towing. No attempt has been made to install pneumatic tires as the present solid rubber tires have been satisfactory at the towing speeds so far attempted.

The Coast Artillery Corps also use the 155 m/m Gun M1918 in various harbor defense problems and in many situations a 60° traverse is not sufficient. The Engineer Corps has designed a concrete emplacement for this carriage that will alllw the whole carriage to be moved through 180°. To adapt the standard carriage to fit the emplacement it is only necessary to remove the standard spade plates from the trails and attach plates fitting the curved rail embedded in the concrete emplacement. A number of these emplacements have been installed in the Panama Canal Department.

The latest model of 155 m/m Gun is the T4 mounted on the 155 m/m Gun -8" Howitzer T2E1. This carriage is provided with pneumatic tires and wheels for traveling; it is not fired from these wheels but is lowered to the ground by self-contained jacks. The range is about 26,000 yards, the traverse 60°, and the maximum elevation is 65° because the carriage was designed to mount an 8" howitzer also. Due to the length of the gun it is retracted on the trail when traveling, in the same manner as the 155 m/m M1918. The howitzer, being shorter, travels in battery. The weight of this material is about 31,000 lbs. limbered and 28,150 lbs. in firing position. It has been tested successfully with prime movers on the road at speeds up to nearly 50 miles per hour.

This gun and carriage, with the heavy Carriage Limber T2E1, were classified as limited procurement types for extended service tests in 1934 and four units are under service test at Fort Bragg. On June 30, 1938 the Ordnance Committee recommended that the carriage be adopted as standard for the 155 mm Gun.

HOWITZERS.

This well-known piece of Ordnance equipment was acquired for the use of our troops in the Philippine Insurrection, during which it proved very useful. It has been in service in the Philippines, the Panama Canal Department, and the United States.

Upon completion of sufficient 75 m/m Pack Howitzers M1, to re-arm two battalions, the 2.95" Mountain Gun equipment was declared obsolete in 1932. In 1937 it was reclassified as limited standard for use in the Philippine Department only.

In 1930 a 75 m/m Pack Howitzer and Carriage M1 were issued to a battalion in the Panama Canal Department and to one in the United States. It proved a very popular piece of Ordnance. The maximum elevation is 45° and the total traverse 6°. The maximum range is 9,200 yards, which is a very favorable performance on a weight of 1305 lbs. in traveling position. The howitzer is fired from wheels and was designed to travel on wheels also when desired. This method of transport was declared obsolete in 1934 for the Army, and is now used only by the Marine Corps. In Army use the materiel is divided into six loads for packing on mules.

The photograph above shows the arrangement of the six pack loads for the 75 m/m Howitzer and Carriage M1 as arranged for the Phillips pack saddle. The pack load accessories were designed to be used either on the Phillips pack saddle or aparejo. Ammunition is packed on mules in the three-round bundles which are now standard.

This 75 m/m Pack Howitzer Carriage was tested by the Field Artillery to determine whether it was suitable for use as an Infantry accompanying gun, but it was not acceptable as such. The limited traverse of 6° was one of the faults that made it unsuitable for firing at rapidly moving targets. The first Cavalry Division at Fort Bliss, Texas, has investigated over a considerable period of time the mobility of horse materiel and has found that the 75 m/m Gun M1897 and the limbers and caissons that go with it are too heavy to accompany Cavalry on the march. All of these factors lead to the design of the 75 m/m Howitzer Carriage T1. This carriage gives to the 75 m/m Howitzer M1 a maximum elevation of 45° and a total traverse of 45°. The pneumatic tires on the wheels are spring supported when traveling, but in the firing position the wheels are cranked upward and the front of the carriage rests on the low pedestal in contact with the ground. The weight in firing position is about 1900 lbs.

Development of this carriage proceeded through the Models T1, T2, M2 and M2A1, and M3 and M3A1. The latter is now standard for Cavalry Divisional Artillery only. The light limber M2 and light caisson M1 were developed and standardized for use with this materiel.

During the World War the 155 m/m Howitzer Carriage M1917 was used as the divisional howitzer. The 155 m/m howitzer has been reinstated in Tables of Organization for these missions, pending the development of the 105 m/m howitzer that was undertaken in 1919 and progressed to the point of establishing a design as standard for horse-drawn artillery. The 105 mm Howitzer M2 and Carriage M1 were designed to fire a 33-lb. projectile to a maximum range of 12,000 yards. The elevation permitted is -5° to $+65^{\circ}$, and the total traverse is 45°. At the high elevations it is necessary to dig a pit 6" deep for the recoil parts when firing at maximum elevation. It will be noted that the wheels are the standard 56" steel tired type, because this carriage was adopted as standard prior to the penumatic tire era for artillery.

After about two years' experience with batteries of this materiel at Fort Bragg, Fort Benning and Fort Sill, the Chief of Field Artillery requested a redesign to incorporate high speed characteriestics, and also requested elimination of the pit to clear recoiling parts and the shields. The 105 m/m Carriage M1E2 was produced as a high speed modification in 1934, and in 1937 the M1E3 was laid down as a study only. This type of carriage was then abandoned.

In 1936, the 105 m/m Howitzer Carriages T3 and T4, differing only in their elevating mechanisms were designed to meet the requirements of the Field Artillery both for high speed transport and elimination of the necessity of digging a pit at any elevation. This carriage is not at all like the M1, since it employs equilibrators and the piece is trunnioned to the rear of the breech block. Total weight in firing position is 5000 lbs. Both carriages were tested in 1938. The subject of the 105 m/m howitzer remains of great interest due to the action of the German Army in replacing the 77 m/m field gun with this caliber howitzer.

The 155 m/m Howitzers M1917 and M1918 were used for both divisional and corps artillery during the World War. This is a French (Schneider) design, and the M1917 Carriages are those procured in France during the World

War. The M1918 Carriages are those that were manufactured by the United States during the World War. The principal differences in the two types of carriages are that the wheels of the M1918 have solid rubber tires instead of steel tires as in the M1917 and the shield of the M1918 is straight instead of curved.

This howitzer fires a 95-lb. projectile to a maximum range of 12,400 yards. Maximum elevation is 42° and total traverse 6°. This has been a very satisfactory piece, well liked by the using service.

In 1933 the initial experiments toward adapting this materiel to high speed transport, using trucks as prime movers, were initiated. They consisted in providing a draw-bar for limbering truck to a prime mover, forced lubrication of the wheel bearings. There was no other change. A year later, however, the M1918E4 Carriage was produced which incorporated anti-friction bearings in the wheel and pneumatic tires. This was standardized in 1936 as the 155 m/m Howitzer Carriage M1918A1.

The 155 m/m Howitzers M1917 and M1918 can be given wide traverse by mounting on an entirely new carriage or by use of a firing platform. The latter method is inexpensive and quick and for that reason some effort has been expended on finding a successful solution in that direction. In 1937 the firing platform T1 was constructed and tested.

and from experience gained the firing platforms T2 and T3 were constructed and tested in 1938. The T2 platform, of steel, performed satisfactorily but was heavier than desirable. The T3, constructed of aluminum, was sufficiently light but failed during firing test. Effort is being continued in the direction of removing the weakness of the T3 platform.

The other solution of the problem of increasing the traverse for the 155 m/m Howitzers M1917 and M1918, namely, a new split trail carriage, was embodied in the 155 m/m Howitzer Carriage T3. This was constructed in 1936, and after Proving Ground test was turned over to the using service for service test which it is still undergoing. It appears to be a very successful design, the only objection which can be advanced against it being the expense of replacing present carriages with new ones, retaining only the howitzers and recoil mechanisms.

The 155 m/m Howitzer Carriage T3 permits a maximum elevation of 65° and a total traverse of 60°, with a weight in firing position of 10,200 lbs. All of the carriage was new, only the howitzer and recoil mechanism being retained of the old materiel. It is not necessary to dig a pit for firing at any elevation.

The Firing Platforms T2 and T3 and the Carriage T3 represent the latest advances toward satisfactory 155 m/m howitzer materiel, though they use the wartime howitzer and recoil mechanism. Earlier attempts took the form of an entirely new hotitzer and carriage, but, as will be outlined below, these efforts have not been successful to date.

The first step for providing a 155 m/m howitzer and carriage meeting the requirements of the Caliber Board was the M1920E which, in accordance with the requirements of the Board, was intended to mount the 155 m/m howitzer-4.7" gun interchangeably. In fact it was identical with the 4.7" Gun Carriage M1920E. During test it was found that the stresses when firing with the howitzer were greater than the 4.7 inch gun carriage could stand, and the project of a combination carriage was abandoned.

In 1925 the development of a new pilot was begun and the 155 m/m Howitzer Carriage T1, mounting the 155 m/m Howitzer T1, was produced and tested. The T1 Howitzer can fire a 95-lb. projectile to a maximum range of about 16,000 yards. The carriage permits an elevation of 65° and a total traverse of about 58°. It is necessary to provide a pit for the recoiling parts when firing at elevations above 45°. The materiel weighs 14,250 lbs. in the firing position, and with limber and wheel shoes the total weight is 18,400 lbs. The pilot that was tested by the Field Artillery Board was considered unsuitable for adoption, primarily due to the necessity of excavating the pit and the inconvenience of serving the piece under such conditions and also due to the fact that the wheels were not suitable for high speeds.

On the rejection of the T1 and T1E1 Carriages, it was proposed to redesign them to remove these objections, but until recently the development of the 155 m/m Carriage T3 took precedence. It is now expected, however, that the design of a pilot carriage to mount a howitzer similar to the T1 and to be without the defects of the T1 and T1E1 Carriages can soon be undertaken.

During the war the American Army procured a number of Mark VI and Mark VII 8" Howitzers of British manufacture, designating them M1917 and M1918, respectively. These fired a 200-lb. projectile to maximum ranges of 10,760 and 12,600 yards, respectively. They were mounted on box trail howitzer carriages used with firing platforms. None of these howitzers is now in service; the materiel is in storage.

In 1919, the development of a new carriage for the 155 m/m gun and 8" howitzer was undertaken, and at the time the question of total weight of materiel in traveling position imposed a requirement that the cannon be transported separately from the carriage. The pilot carriage for the 155 m/m gun and the new 8" howitzer had been constructed and was tested by the Field Artillery Board. The Board concluded that it was necessary to continue the development on the basis of tranporting the cannon and carriage separately, in order to utilize tractors of the 10-ton type. Consequently, the Ordnance Department redesigned the materiel with a view to improving the carriage, and particularly the transport wagon. A wooden model of the new design was made and examined, but a pilot was not manufactured because it was realized that the problem of separating the cannon from the carriage was a serious handicap. Therefore, studies were prepared for a single type of materiel, and pneumatic tires and high-speed wheel bearings were utilized, due to the realization that trucks had improved sufficiently to warrant the belief that this type of prime mover would be used where materiel could be transported on good roads. The carriage is quite satisfactory, for firing the 8" howitzer at 65 degrees elevation, at a maximum range of about 18,000 yards. The 155 m/m Gun - 8 inch Howitzer Carriage T2 was tested with the 8 inch Howitzers M1920 and M1920MIE1. The 8" Howitzer T3 is under manufacture to be tested on the 155 m/m Gun - 8" Howitzer Carriage T2E1 already described. This carriage, satisfactory for the 155 m/m Gun T4, is also satisfactory for the T3 howitzer, which at 45° elevation has a maximum range of about 18,000 yards. It will be noticed that this is the only instance in which a combination gun-howitzer carriage of the type recommended by the Caliber Board had proved finally successful.

Thiw howitzer was acquired during the World War. The design of the howitzer and the carriage was procured from the Schneider Company, and about 330 howitzers were manufactured. The carriage provides 20 degrees traverse and a maximum elevation of 60 degrees. Due to its great weight it was separated into four major loads for transportation, and it requires two trailers to haul the erecting equipment necessary to emplace it or to remove it from the firing position. During the proof firing of the first few howitzers that were manufactured, it became evident that the chase had insufficient strength; several expanded excessively during proof firing. Consequently, it was decided to increase the thickness of the walls of the howitzers as much as possible beyond the jacket. Some of the forgings that were on hand had not been rough machined, so that it was possible to make howitzers 184 to 330 with the heavier chase. These stronger howitzers were designated M1918M1. However, the record of the M1918 type, i.e., the origianl design, has a bad cloud on it as five of these howitzers burst during the proof and one of them burst recently after over 200 rounds had been fired. Consequently, it is probable that the M1918 howitzers, serial numbers 1 to 183, will not be issued. A plan is under consideration to reline these model 1918 tubes to make them 8" caliber. While the Caliber Board recommended the development of a 240 m/m howitzer having approximately 25,000 yards range, this project still remains suspended and it is doubtful that such a howitzer will be developed in the near future.

This slide shows a concrete emplacement for the 240 m/m howitzer carriage M1918A1 for use in certain sea-coast defense projects. This emplacement provides for all-around fire, and utilizes all of the carriage except the regular platform for field emplacements.

MISCELLANEOUS FIELD ARTILLERY MATERIEL.

For years the Ordnance Department has had to contend with the difficulties incident to attempting to fire the sub-caliber guns in the various field guns. The principal causes of complaints were damage to the bore of the cannon and the flare and blow-backs, etc., incident to punctured primers due to faulty head space. Consequently, a scheme for attaching an ordinary rifle to the various cannon was undertaken. This slide shows the rifle mount that was provided for test. However, the requirement for subcaliber equipment smaller than 37 m/m for the Field Artillery has been eliminated so the caliber .30 type is no longer used.

The same difficulties encountered with the .30 caliber subcaliber tubes were experienced with the interior types of 37 m/m subcaliber tubes, and these remain standard only for the 75 m/m guns M1916 and M1917. For most of the field guns in our service the standard subcaliber equipment is now the 37 m/m Gun M1916 on 37 m/m Subcaliber Mounts M1, M2, M4, M5, M6, M7, and M8, depending on the kind of bracket provided to fit the type of gun involved. Thirty-seven m/m Sub-caliber Mount T15 is under development for the 75 m/m Gun Carriage M1916A1.

The Field Artillery Trainer M2 was developed to meet the requirements of the Chief of Field Artillery for a means of training officers in methods of firing. This consists of the breech action of a single shot caliber .22 rifle with a short smooth bore barrel with suitable mount. The projectile is a 1" steel ball which is loaded from the muzzle, and fired by means of a blank cartridge, breech loaded. The smooth bore barrel is adjustable so the velocity of the projectile can be adjusted to give approximately one-hundredth of the range of the 75 m/m Gun M1897. The mount provides for attaching the standard panoramic sight and it has an angle of site mechanism and a maximum elevation of 45° and total traverse of 45°. The normal equipment is a battery of four, complete with panoramic telescopes and a gunner's quadrant and the necessary ammunition. The object of this type of equipment is the provision of an inexpensive means of practicing the art of conducting field artillery fire that will enable an officer to gain experience to make better use of the regular allowances of ammunition for training.

This trainor has been issued as regular equipment to the Regular Army and the National Guard and has proved highly successful.

SECTION E

INFANTRY CANNON

WORLD WAR TYPES

Having no infantry cannon on our entrance in the War, we adopted the French 37 mm. gun as our M1916. This well-known weapon has a number of favorable characteristics, among which are its fairly light weight (360 pounds in firing position on wheels, 180 pounds on tripod), its accuracy, and its convenience in use due to its traverse of 42.5°. But it is not nearly powerful enough, its 1.23-pound projectile being given a muzzle velocity of only

1204 foot-seconds and a range of 3700 yards at the maximum elevation of 21.5°.

It is a limited standard type and is still the only small rifled cannon issued to our Infantry and Cavalry.

For pack transportation in certain Infantry organizations a slightly modified materiel is now used, designated M1916A1.

It was found that Cavalry organizations could not transport the M1916A1 carriage satisfactorily on horses. The Cavalry Board experimented with the problem and in 1931 a modification of the M1916 carriage was produced, now a limited standard under the designation M1916A2. In this model the height of trunnions was reduced, the trails shortened and telescoped and the wheels and axles omitted. The gun and carriage make only two loads, 89-1/2 pounds and 57 pounds, and can be transported on a single horse satisfactorily even at the gallop. It requires some of the weight of two men to make the carriage stable.

The American Army also had to adopt a European arm to fill the need for an infantry weapon for indirect fire, the British 3" Trench Mortar Mark I (Stokes) being furnished. This muzzle-loading, smooth-bore mortar is extremely simple and portable, and its 12-pound H. E. shell is very effective. Its unstabilized projectile, however, has a very short maximum range (only 750 yards) and a large dispersion. It has recently been found that the 81 m.m. mortar ammunition can be fired in this old materiel by modification of the firing pin, and the modified mortar is now standard under the designation Mark IA2.

In the stabilized warfare in France there were in use trench mortars in calibers up to 6 inches, but there is now no requirement in our army for such large trench warfare weapons.

POST WAR DEVELOPMENTS.

Development work to remedy the lack of power of the 37 mm. Gun M1916 culminated in the 37 mm. M2 materiel, the final development of the type. This fires a 1.25-pound H.E. shell or a 1.45-pound armor-piercing shot at 2000 and 1850 foot-seconds, respectively, with a maximum range of 5500 yards. Maximum elevation is 21° and maximum traverse 67.5°. In firing position on wheels the total weight is 400 pounds, and on tripod 306 pounds.

It is apparent that there is a material increase in power over the M1916, but the velocity of the Caliber .50 machine gun or the 37 mm. Automatic Gun M1 is not approached. Furthermore, due to the small diameter of the 37 mm. projectile the development of an explosive armor-piercing shell was not successful, and the armor-piercing projectile had to be made solid. Also it was the consensus that the equipment is too heavy to be transported satisfactorily for use as an antitank weapon. These deficiencies resulted in the gun and carriages being obsoleted, and the army reverted to the limited standard M1916.

In 1919, in response to the demand for a single weapon to supersede both the 37 mm. gun and the Stokes mortar, the development of a dual-purpose weapon was undertaken. By 1921 it had become evident that the Infantry howitzer and the different types of ammunition required for the several different classes of missions were not practical, so this line of development was abandoned in favor of an improved 37 mm. gun (which ended in the M2) and some other kind of mortar. Then it was necessary to make and test the breech-loading rifled 2.24" mortar and the 75 mm. mortar, with 6-pound and 12-pound shell, respectively. The larger one was chosen for future development.

Extensive tests of this rifled type of mortar and the ammunition developed for it proved that there was little hope of satisfactory accuracy at the shortest ranges at which the Infantry said it must be used. Consequently the experiments were continued with the breech-loading mortar with a smooth bore and projectiles with vanes on them, in attempting to improve the accuracy and increase the maximum range. The end product was the 75 mm. Mortar M2.

This smooth-bore mortar fires a vaned projectile of 10.5 pounds weight to a maximum range of 2000 yards. Its elevation is from 43.5° to 82°, it has a total traverse of 15.5° and its normal recoil is 10 inches. The weight in firing position is 396 pounds, and in traveling position with Cart M2, 1180 pounds. For man transportation the mortar and carriage divide into four loads of which the heaviest is the trail, 106 pounds.

Only 16 of these units were manufactured, the adoption of the 81 mm. Mortar M1 then causing its obsolescence.

While tests were going on in this country, the Edgar Brandt Establishment in France had attained what was actually desired by our War Department by merely refining the design of their ammunition and the Stokes mortar, base plate and bipod, the ammunition improvement being the most important. Therefore, four Stokes-Brandt Mortars and Mounts M1930 and a quantity of the three kinds of ammunition were procured and tested by the Infantry, Field Artillery, Cavalry and Ordnance Department in 1931 and 1932. The results were highly satisfactory, and the mortar and mount were adopted as standard in 1932, manufacturing rights being purchased from the Brandt Company.

This is a refinement of the 3" Stokes Trench Mortar Mark I. Principal differences are the addition of a collimator sight and a cross-leveling device, and the heavier base plate of slightly different design. The principal characteristics of the weapon are the following:

Weight of projectile	7 pounds (M43)	15 pounds (M45)
Bursting charge	1.2 pounds	4.5 pounds
Muzzle velocity	695 ft. sec.	390 ft. sec.
Maximum range	3300 yards	1300 yards
Minimum range	545 yards	220 yards
Maximum elevation	80 degrees	
Minimum elevation	45 degrees	
Traverse	8.5 degrees	
Normal recoil	None	
Weight in firing position	126 pounds	

Recent tests with a slower propelling charge powder have resulted in firing the M45 shell to 1800 yards; attainment of greater range was prevented by the failure of the folding vanes with which this model shell is equipped. The M43 shell loaded to 11 pounds weight has been fired to a range of 2800 yards. From these tests it is apparent that the ranges given in the tabulation above can be materially exceeded with the present M43 shell and an improved M45.

For simplicity, lightness, and large ratio of weight of projectile to weight of gun, weight of projectile to weight of complete round, and weight of bursting charge to weight of projectile, the 81 mm. Mortar M1 is a remarkable arm.

For the missions between the ranges of usefulness of hand grenades and the 81 mm. mortar H. E. shell which were met by the rifle grenades, the Ordnance Department initiated the development of a light 42 mm. mortar to fire small vaned projectiles and the ground pyrotechnic signals in Item 12181 and 12219, OCM. However, before a pilot 42 mm. mortar could be made, the Edgar Brandt Establishment furnished a 47 mm. mortar for demonstration purposes, which was favorably considered as being suitable for use in the Infantry. The Cavalry expressed a desire for a mortar lighter than the 81 mm. mortar for attacking machine guns, but required greater maximum range than is possible with the 47 mm. type. Consequently, a 60 mm. mortar and some ammunition was procured from Edgar Brandt. The Infantry Board and the Cavalry Board tested both of these light mortars. In February, 1938, action was taken to recommend adoption of the 60 mm. mortar and to reject the 47 mm. mortar. The 60 mm. mortar must be transported on pack horses in the Cavalry. Adoption of the 60 mm mortar for the Cavalry will eliminate the requirement for the 37 mm Gun M1916 and 37 mm Gun Carriage M1916A2 now issued to Cavalry (horse) regiments.

At the same time, the present demand for an antitank gun, capable of penetrating 1-1/2 inches of armor plate at 1000 yerds will probably necessitate the supply of a 37 mm. 3000 foot-second gun.

SECTION F

RAILWAY ARTILLERY

8-Inch Railway Gun

This carriage was built during the World War, for mounting guns taken from seacoast fortifications. Forty-seven units are in service. The gun has a maximum range of 21,300 yards with a 200-pound projectile. A 260-pound projectile can be used, and also, under favorable conditions of set-up, a 232-pound projectile, but the last is not very successful. The carriage provides 360° traverse, which makes this weapon suitable for seacoast purposes as well as for use with the field army.

The Caliber Board requirement for an 8" railway gun of greater power, led to the mounting of an 8"-45 caliber gun Mk. VI M3 (Navy) on the 12" Howitzer Railway Mount M1918, that mount, having proved unsatisfactory, as will be explained later. The 8" gun and the 12" mount combination then became the 8" Gun Railway Mount M1925E. The weapon was intended for use with the Field Army as well as for coast defense purposes. It was light enough to be handled with ease on practically all the railroads in this country. It was emplaced in the same manner as the 8" Barbette Carriage M1918 (Rwy), just described, and possessed the good points of that mount. At a powder pressure in excess of the maximum service pressure the 45 caliber gun fired a 200-lb. projectile a maximum range of approximately 35,000 yards. The carriage permitted 360° travers and 52° elevation.

Certain features of this mount were considered unsatisfactory and further development thereof was temporarily abandoned. In order to provide a thoroughly satisfactory 8" Mount, a project was then initiated to design and manufacture a pilot mount capable of receiving an 8"-55 caliber gun of Navy type. However, before the design work on this last named mount had been fairly completed, it was decided to resume development of the M1925E materiel. The mount was then resubmitted to the Coast

Artillery for a service test, after which it was concluded that, with certain modifications, it would be satisfactory. Action was then taken to incorporate those modifications in the M1925E Mount and, as thus modified, it was adopted as substitute standard under the designation 8" Gun Railway Mount M1. The modifications made included, among other things, a reduction of the maximum elevation to 45° and a rechambering of the gun. The gun so rechambered has been designated "8-inch Gun Mark VI Mod. 3A2". Its range with the present 260 lb. A.P. Projectile is 27,600 yards; with the new 260-lb. Semi-A.P. Projectile, 31,700 yards; with the 240 lb. H. E. Shell T2 - 33850 yards.

The anchorage device of this mount is of excellent design. It consists of outriggers to provide stability, and H-beams laid on the ties outside the rails to support cross ties on which the car body rests. The merits of the system are that no special track is required, the anchorage system is a travelling part of the mount, and the mount can be emplaced and prepared for firing in a very short time (about 45 minutes).

In view of the development of naval armament as well as the increased ranges of mobile artillery, a weapon of greater power is now required.

The Caliber Board requirement for an 8" Railway Gun of greater power caused the design of the 8" Gun on Railway Mount, Model 1925E. This weapon was intended for use with a field army as well as for coast defense purposes. It is light enough to be handled with ease on practically all the railroads in this country. It is emplaced in the same manner as the model 1918 just described, and possesses the good points of that mount. The 45-caliber gun fires a 200-pound projectile a maximum range of approximately 34000 yards. The carriage permits 360° traverse and 52° elevation.

Relatively low priority prevented the manufacture of this model in quantity. Later, however, there were made available a number of 45 caliber Navy guns without mounts. After careful consideration it was decided to adopt the 45 caliber gun, which could be mounted on the Model 1925E railway mount already developed. This was done, the mount being now substitute standard under the designation MI.

The Navy gun that was mounted was slightly modified in the powder chamber, its designation being now Mark VI Model 3A2. Its range with the present 260-pound A.P. projectile is 27,500 yards, with the new 260-pound semi-A.P. projectile 31,700 yards, and with the 240-pound H.E. shell T2 33,850 yards. No standard complete round has as yet been adopted.

12-Inch Mortars

In response to an urgent demand for heavy indirect fire weapons, ninety-one 12" 10-Caliber Seacoast Mortars were mounted on railway carriages during the World War. The railway car and the system of anchorage are identical with that of the 8" Railway Gun Mount, Model 1918. These mortars have a 360° field of fire at 20° to 65° elevation, and fire a 700-pound projectile about 15,000 yards. They are, in many respects, a valuable type of armament.

This howitzer is 20 calibers in length and fires a 700-pound projectile 21,000 yards. The mount is a war-time project, but it never emerged from the experimental stage. Lack of stability led to a discontinuance of its test as a howitzer mount and it was used for the 8" Gun

Railway Mount, M1925E, now the 8" Gun Railway Mount M1. Further development of the 12" railway howitzer has been suspended as there has ceased to be a requirement for this weapon.

Sliding Railway Mounts.

During the War a number of 10" and 12" guns were mounted on railway carriages of the sliding type. These carriages were a Schneider design, produced under the pressure of urgent necessity for mounting certain French heavy guns, and the design was taken over for our use to augment the available supply of heavy railway artillery. These mounts were extremely simple, having neither recoil nor traversing mechanism. The mounts, which were very strong, were lowered to the track, and slid back several feet on firing. A specially prepared track was required, and the track had to be curved to provide traverse. These mounts were remarkably satisfactory in use, and were well liked by all who served with them. Their construction, however, made them unsuitable for firing at moving targets, for which reason the mounts, together with the 10" guns, were scrapped. The 12" guns are in store for possible future use.

A number of 14" Gun Railway Mounts, Marks I and II, were also constructed during the war by the Navy Department and later taken over by the War Department. The guns were equipped with cradles and recoil mechanisms and could be fired from 0° to 15° elevation with no special track emplacement, in which case the mounts moved to the rear on their trucks with brakes set. The guns could be fired also from 10° to 43° elevation, provided a special track emplacement, allowing the guns to recoil into a pit, was constructed. As in the case of the 10" and 12" mounts above mentioned, the limited traverse of these 14" mounts rendered them unsuitable for firing at moving targets. The mounts were therefore finally scrapped and the guns placed in store for future use.

12-Inch Railway Gun.

This mount was manufactured during the World War from designs of the French 305 m/m Railway Mount. It mounts a U.S. Army Gun Model 1895 taken from fixed carriages in the harbor defenses. When fired, the mount is secured to a structural steel platform and wedged up to remove the weight from the trucks. Traverse of gun is 10°, the elevation 38°; range, with 700 pound projectile, 30,000 yards, and rate of fire one shot in three minutes. There are 12 of these mounts in service.

The Westervelt or Caliber Board Report, paragraph 51, states in effect that the design of carriages for super guns "should be studied with a view to obtaining a universal barbette mount that could be emplaced in the present seacoast emplacements, in simple auxiliary emplacements and with trucks under it forming a railway mount." This is an attempt to meet that requirement.

The gun and car are those shown in the previous slide. The base ring, racer, and rollers of a 10-inch Disappearing Carriage, Model 1896, form the turn table. The outer supporting ring was added to resist the over turning movement. Tests at the Proving Ground indicate very satisfactory performance. However, the materiel has never been tested by the using arm and hence no action taken to similarly equip more of the 12" mounts. Since the 14" Railway Mount, Model 1920 appears to meet these requirements and also permits a rate of fire of one shot per minute, it is not now likely that the pivot mount will be carried any further. The requirement for it, however, has not yet been rescinded.

<u>14-Inch Gun.</u>

At the present stage of Ordnance development, it appears that this is the largest mobile mount practicable. The 14-inch, 50-caliber gun fires a projectile weighing 1560 pounds a maximum range of approximately 45,000 yards, and the rate of fire is one shot per minute. The carriage permits of 30 degrees elevation and 360 degrees traverse on the emplacement; on the track 7 degrees traverse is possible. The carriage is so constructed that the gun may be fired from a temporary emplacement on the track, prepared with steel beams to support the weight on the road bed, and outriggers to provide stability. In such an emplacement the trucks are relieved of their loads.

The mount can also be run onto a prepared emplacement, which it is anticipated will be the usual method of employing this piece. The virtue in a weapon of this type is that with a number of prepared emplacementsalong the seacoast advantage can be taken of its mobility to provide ample defense with relatively few guns. Four of these mounts have been completed.

SECTION G

SEACOAST ARTILLERY

PREWAR

For thirty years prior to the World War, our seacoast artillery was the most highly developed materiel in our service. Even now guns of this era are the only armament in many of our seacoast fortifications. They are notable for strength and durability, and (except for their firing devices) for reliable functioning with limited upkeep. These favorable characteristics are now nullified by their lack of sufficient range for present requirements.

The two models (of this period) to be described are representative, and are among the most useful of those still in service.

The 14" Disappearing Carriage, Model 1907, M1, mounts a 40-caliber 14" Gun, which fires a 1560 pound projectile at a muzzle velocity of 2170 feet per second, with a range of 21,200 yards at the maximum elevation of 20°. This comparatively short range is due to the limited elevation, which will be discussed below. Traverse of the carriage is generally limited by the emplacement.

The Buffington-Crozier disappearing carriage is peculiarly American, the scattered examples of disappearing carriage in other nations being arranged on different principles.

Our disappearing carriages, of which the above described Model 1907M1 is typical, carry the gun at the upper ends of heavy gun levers, the fulcrums of which move to the rear on rollers while the lower ends raise a heavy counterweight. The gun is loaded in the convenient recoiled position, after which the counterweight is allowed to return the gun to the firing position; it is not necessary to depress gun to load. The recoil not absorbed by the counterweight is taken up by oil cylinders, but no recuperator cylinders are required.

This type of carriage affords maximum concealment from naval observation and maximum protection from low angle fire. Under modern conditions, however, these advantages have become much less important and the great disadvantage of the disappearing carriage, its low maximum elevation, has caused its abandonment as a type for future manufacture.

The 12" Mortar M1912, on Mortar Carriage M1896, MIII, is 15 calibers long and fires a 700 pound projectile to a maximum range of 17,900 yards. Other weights of projectile are also used, the heaviest being the 1046 pound with a maximum range of 11,300 yards. The other models of mortars in our service are only 10 calibers long, and have ranges of 14,600 and 9,200 yards with the two projectiles named. Mortar projectiles are deck-piercing rather than armor-piercing on account of their steep angle of fall.

Our seacoast mortar carriages (except the last, the M1908) are neither barbette nor disappearing, but a simple arrangement of a hinged lever carrying the mortar at is upper end, with recoil cylinders behind the trunnions and counter-recoil springs below. The mortars are emplaced in pits and fire between elevations of 45° and 65° or 70° only. The field of fire is covered in a series of zones, each of which requires a separate weight of charge, propelling charges being suitably divided for this purpose. The difference between mortar fire and direct fire is apparent.

With the passage of time and for various reasons, one or several additional weights and types of projectile in each caliber have been adopted for each of our older seacoast guns. The storage, handling, and supply of these different projectiles and their propelling charges at the battery become, in some cases, a serious nuisance or worse.

WORLD WAR

During the World War a considerable number of seacoast guns were dismounted for use on other carriages of various types, notably the 5" and 6" wheeled mounts, 8", 10" and 12" railway mounts.

One of the few important developments in purely seacoast artillery, however, was the 12" Barbette Carriage, M1917.

This carriage mounts the 12" Gun, M1895 M1, which is a 52 ton gun of 35 calibers length built, like most seacoast guns, for a maximum powder pressure of 38,000 pounds per square inch. With the 900 pound projectile the range is 28,200 yards at the maximum elevation of 35°; other weights of projectile may be used. The gun is carried in a cradle in which are contained the recoil and spring recuperator cylinders. Elevation is by power, or by hand if necessary. Traverse is 360°. It will be noted that this carriage was the first example of the general form taken by post-war major-caliber fixed armament.

POST-WAR

Most of the seacoast development of recent times occurred shortly after the World War, from designs initiated during or immediately after the war.

The 16" Gun on barbette carriage is now used for major harbor-defense assignments as far as the supply will permit, but this gun and carriage will remain of considerable importance in some defenses for some time to come.

The 16" Disappearing Carriage, M1917, is the highest and final development of the disappearing carriage. Only one was built. An attempt was made to attain modern high elevations, and in fact 30° was obtained. The 16" Gun, M1919, which is mounted, is a 50 caliber gun firing a 2340 pound projectile, and the elevation of 30° given by the carriage results in a maximum range of about 43,000 yards, which is within about 7,000 yards of the maximum range of this gun at any elevation. Maneuvering is by power.

The carriage contains no innovations of design, the expedient of placing the recoil cylinders in the counterweight, which was tried in some late prewar disappearing carriages, not being resorted to. Its high maximum elevations were obtained by using the utmost design effort in the proportioning of the various parts of the carriage. It does, however, have the unusual feature of overhead cover for the gun crew, a matter which has had some discussion of late.

The 16" Howitzer Carriage, M1920, mounting the 16" Howitzer, M1920, is our only modern harbor-defense weapon designed primarily for high angle fire, though some of the 16" gun carriages to be described have equal elevation. The carriage is quite similar to these 16" gun carriages. The howitzer is a 25-caliber weapon, which is carried in a cradle with hydraulic recoil and air counter-recoil cylinders and to which the carriage can give elevations of from -7° to 55° and traverse of 360°. It fires a 2100 pound projectile to a maximum range of about 24,500 yards, the weight of propelling charge being only 296 pounds. The howitzer is elevated, traversed and loaded by electric power and the operation of the breech block is assisted by compressed air and springs; but in case of failure of the power or air supply, all these operations can be performed by hand.

The recoil system of a barbette carriage, such as this, is not as readily exercised as is that of a disappearing carriage. The latter may be tripped and retracted at will, and the recoil cylinders and other parts examined in both the firing and the recoil positions. To give modern barbette carriages having air counter-recoil mechanisms this valuable means of insuring continued serviceability over long periods of infrequent firing, orders have been issued for the periodic exercise of the mechanisms. This is performed by elevating the piece and gradually releasing the recuperator air, which has a normal initial pressure of 2,000 pounds per square inch, until the position of full recoil is reached. After the piston rods and other usually inaccessible parts have been cleaned the air is replaced, usually from bottles, which returns the gun to battery. While upkeep of certain vital parts is obviously advantageous, the exercise itself is of great value to a little-used mechanism.

The 16" Barbette Carriage, M1919, M1, mounting the 16" 50 Caliber Gun, Mark II M1 (Navy), is the standard heavy seacoast materiel. It is quite similar to the M1919 Carriage which mounts the 16" - 50 Caliber Gun, M1919 MII, or M1919 MIII (Army), the principal differences being that the latter carriage permits a maximum elevation of 65° against 55° for the former, and the two differ in the number and arrangement of their hydraulic brake and air recuperator cylinders. In each, all the operations of loading and maneuvering are performed either by power or by hand. A number of both types are in service. The Army gun, using a charge of 832 [illegible]nds of powder, fires a 2340 pound projectile 49,200 yards at a muzzle velocity of 2700 f.s.

With the same charge it fires a 2100 pound projectile 44,700 yards at a muzzle velocity of 2750 f.s. The Navy gun uses a charge of 672 pounds, fires the 2100 pound projectile 44,700 yards at a muzzle velocity of 2750 f.s. These maximem ranges are attained at approximately 48° and 46° in the Army and Navy guns respectively.

An idea of the magnitude of the weights and forces involved in a carriage of this caliber is given by the following:

Weight of gun and carriage	1,100,000 lbs., nearly
Weight of recoiling parts	400,000 lbs., nearly
Total trunnion pull	2,200,000 lbs.

Additional Carriages, M1919M1, mounting the Navy gun, are manufactured from time to time as need arises and as funds become available.

The above are all purely seacoast guns. However, the Coast Artillery uses as seacoast guns some pieces which were primarily designed for other purposes. Among these are the 8" Barbette Carriage M1, mounting the 8" Gun, Mark VI, Model 3A2, and the 155 Gun, M1918, used by tractor-drawn batteries.

The 8" Barbette Carriage M1 is a by-product of the 8" Gun Railway Mount M1, being in effect the latter mount less the railroad car. A limited number of these are being manufactured for fixed emplacements. They mount the 8" Gun, Mark VI, Model 3A2, which is a 45 caliber Navy Gun slightly modified in the powder chamber. This makes excellent medium caliber seacoast materiel. Range with the present 260 pound A. P. projectile is 27,600 yards, with the new 260 pound semi-A.P. projectile 31,700 yards, and with the 240 pound H.E. Shell T2, 35,850 yards.

This is the standard armament for tractor-drawn Coast Artillery Regiments, as well as the standard heavy field gun used as Army Artillery. It is the same as the 155 Gun used during the World War except for modification to the wheel bearings to permit high speed towing. It weighs 25,960 pounds in firing position, has a maximum elevation of 35° and maximum traverse of 60°, and fires a 95 pound projectile to a maximum range of 17,460 yards.

In many harbor defense situations, the 60° traverse is not sufficient. The Engineer Corps has designed a concrete emplacement for this carriage that will allow the whole carriage to be moved through 180°. To adapt the standard carriage to fit the emplacement it is only necessary to remove the standard spade plates from the trails and attach plates fitting the curved rail embedded in the concrete emplacement. A number of these emplacements have been installed in the Panama Canal Department.

SECTION H

ANTIAIRCRAFT ARTILLERY AND FIRE CONTROL

One of the outstanding accomplishments in the field of Ordnance since the World War is the development of greatly improved antiaircraft artillery and an entirely new materiel for antiaircraft fire control.

ANTIAIRCRAFT ARTILLERY

In order to obtain high velocities, the 3" guns for mobile mounts have been increased in length to 50 calibers. The 3" fixed guns remain 55 calibers in length. The 105 m/m antiaircarft gun is 60 calibers long. They are all equipped with semi-automatic breech mechanisms. All present standard 3" antiaircraft guns have removable, cold worked liners; the 105 m/m guns have single piece, cold worked, tubes. A 3" antiaircraft, single piece, cold worked tube with removable breech ring is now under development.

All our 3" guns (with the exception of those on the M1918 mount) fire the standard 12.7 pound shell at a muzzle velocity of 2800 feet per second, and have a normal rate of fire of 25 rounds per minute. Their vertical range is about 9700 yards and maximum horizontal range about 14,200 yards, but the maximum time of flight of 30 seconds permitted by the mechanical time fuze M43 limits the vertical and horizontal ranges to approximately 9200 yards and 10,600 yards, and the 21 seconds of the Mark III A1 and other powder train fuzes limits the ranges somewhat more. All models of 3" guns on fixed mounts use one model of fixed ammunition, and all on mobile mounts another, the difference being in the size of the cartridge case. Fixed guns have the larger powder chamber and in addition are adapted to higher velocities, but are not loaded to the higher velocities because of the erosion problem.

There are four models of fixed 3" antiaircraft mounts in our service, the M1917, M1917MI, M1917MII and the M3A1. They are characterized by hydro-spring recoil mechanisms and guns balanced at the trunnions, and are simple, reliable mounts which function with very little maintenance. The M1917 was found difficult to load at high elevations, was slow in elevating and traversing, and was not arranged for director control. These defects were corrected in the 1917MI.

The M1917MII mount is the M1917 modified to make it the equivalent of the 1917MI. The modification is made as directors become available, and all the M1917's on hand are eventually to be modified. The latest model of 3" antiaircraft gun mount to be manufactured is the M3 type. It differs from the M1917MI only in that the cradle design is modified to receive a gun (M4) which is slightly larger in diameter than those in the M1917MI mount and the trunnions are equipped with roller bearings.

The standard mobile materiel is the 3" A.A. Mount M2A2 mounting the 3" A.A. Gun M3. The questions of stability, mobility, and manouverability are of the greatest importance in a mobile gun carriage, and all three of these points have been accounted for in this very satisfactory mount. The mount is, in the travelling position, a two-axle trailer equipped with pneumatic tires and electric brakes, capable of high road speeds and good cross-country mobility with a towing vehicle of sufficient power. Its total weight in travelling position is 16,800 pounds. To place in firing position, the mount is raised on quick-motion jacks, the bogies withdrawn, the folding outriggers extended, and the mount lowered and leveled, which operations can be performed in less than 12 minutes. To obtain 85° elevation without the necessity of high side frames and resultant instability, the trunnions are placed near the breech and the muzzle preponderance overcome with pneumatic equilibrators. This mount is further notable for the method of manufacture, the top carriage and pedestal being made of welded 1/4" nickel steel plate and comparatively few castings used. Without this construction its weight would be much greater.

The trailer load formed by the 3" A.A. Mount M2A2 makes a very large and powerful towing truck necessary. This, with considerations of mobility, has resulted in the design of experimental single-axle mounts, of which the 3" A.A. Mount T4 is the most recent. Due to the weight saving in discarding one bogie, as well as weight savings in the T9 Gun, T4 Recoil Mechanism and elsewhere, the total weight of this materiel in travelling position is only 10,750 pounds, against the 16,800 pounds of the M2A2. A single axle mount of this light weight is more mobile than a heavier 2-axle mount, and is handled by a towing vehicle of smaller size. Except for the axle arrangement the general scheme of construction of this mount is the same as that of the M2A2 some differences being that the top carriage is lower (the trunnions being placed at the breech of the gun instead of a short distance from it, and variable recoil being provided) and the four outriggers are shorter and in two sections each instead of three. The T4 recoil mechanism is designed for fabrication by welding.

Another approach to the problem of maximum mobility was the 3" A.A. Gun Truck Mount T1, which consisted of a gun mount built as lightly as possible and mounted on the chassis of a Garford truck with the usual arrangement of outriggers. The performance of this mount as to mobility was excellent, but certain other considerations, among which was the fact that the truck was always required and was not available for general use while the gun was emplaced, led to its rejection by the using service.

A few years ago there was produced for the Field Artillery a battery of "All-purpose" guns, consisting of guns and mounts adapted to every artillery mission within their caliber, including antiaircraft. An account of this development is given in the section on Field Artillery models.

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The 105 m/m Antiaircraft Gun M3, the standard in this caliber and the only antiaircraft gun of caliber larger than 3" in our army, is a monobloc cold-worked gun with removable breech ring similar to the standard 3-inch guns. It is 60 calibers in length, the longest gun in calibers ever made in this country, and is the most powerful antiaircraft weapon yet tested by our service. It fires a 33 pound projectile at a muzzle velocity of 2800 foot-seconds to a height of 14,000 yards or a maximum horizontal range of 20,000 yards. The rate of fire is 15 rounds per minute. The increased weight of the shell provides a large increase in the effective volume of burst and also reduces the time of flight at all ranges.

An automatic rammer system is provided to load the complete round of ammunition which weighs about 65 pounds. The rammer mechanism is so constructed that the rammer head is thrown to the rear during the recoil of the gun, compressing the air in the rammer cylinder. To load the gun it is only necessary to place the complete round on the loading tray and pull the rammer lever. The gun is equipped with semiautomatic breech mechanism which closes as soon as the round of ammunition is pushed home, at the same time locking the rammer head out of position. During counter-recoil the breech block opens automatically and ejects the empty cartridge case.

The 105 m/m A.A. Mount M1 resembles in design the 3" A.A. Mount, Model 1917MI. Like the latter, it has a sleeve type cradle balancing the gun at trunnions, hydro-spring recoil mechanism with constant recoil, 80° elevation, 360° traverse, and indicators for director fire control.

ANTIAIRCRAFT FIRE CONTROL

The antiaircraft problem is an exceedingly difficult one. Given an airplane somewhere in the sky we must find out how far away and how high it is, its direction and speed, and then we must compute the future azimuth and quadrant elevation in order that at the expiration of the time of flight for that position the fast moving plane and projectile will meet at the same point; and moreover the fuze range must be computed and the fuze set so that the projectile will burst at exactly the right time.

This problem is badly complicated by the great speed of the target, and by its ability to change its direction in any of three dimensions with very great rapidity. This means that the time element enters so importantly into the problem that the computations must be instantaneous and continuous, and that the gun laying and the fuze setting must be accomplished at the same moment that the computation is made.

Intensive research of this problem, which began during the World War and has continued without a break to the present time, has resulted in the adoption of the director system of fire control. The director, the fundamental instrument in this system, is a computing machine which continuously computes the future position of the target and determines the gun and fuze settings necessary for fire. The guns are continuously laid to these settings without any attempt on the part of the gunners to track the target. The only other essential parts of the system are the height finder, which determines the altitude or slant range of the observed target, and the data transmission system which automatically and continuously makes available at the guns the gun and fuze data furnished by the director. Inspection of the layout will show that, by making use of junction boxes and multi-conductor cables, all the necessary interconnections in the system are made in a realtively simple manner.

It might seem that the director has an impossible task in automatically computing the target's future position at every instant and the gun data necessary to hit that position, and doing it without the consumption of time. Nevertheless this is done and by the application of comparatively simple mechanical principles. In our present standard directors, the observed motion of the target is reproduced on a small scale within the instrument, its direction and speed determined by resolution and measurement, and its future position found by applying to its present position the displacement found as a product of its speed and the time of flight, after which the gun and fuze data corresponding to this future position are determined by a mechanism whose various parts reproduce mechanically the essential elements of the firing table. The parts of the director being interconnected by gear trains or otherwise, once the machine is in operation it gives results without any time lag. The data furnished by the director are instantly shown at the guns.

The first modern directors in our service, the M1 and M1A1, were of Vickers (British) design and manufacture. Since the production of the first successful American director, the M2, by the Sperry Gyroscope Company, efforts have been directed toward a simpler, lighter, and less expensive director. The present standard instrument, the M4, is a remarkable example of these qualities.

The size and weight of earlier directors made necessary special provision for their use with mobile batteries. For this purpose the pneumatic-tired Instrument Trailer M1 was developed; this is supported by levelling screws when the director, permanently fixed thereon, is in use. Power units and cable reels are also permanently mounted, and space is available to carry the height finder and observing instruments. While equal in mobility to the guns in the battery, this trailer made necessary an additional towing truck as powerful as those for handling the guns. The latest Directors M3 and M4 can be manhandled and carried in cargo trucks; hence the Instrument Trailer M1 is retained only for use with the earlier Directors M1A1 and M2.

In operating the director, there is one quantity which must be determined independently and that is the height of the plane. The standard instrument for altitude determination is the Height Finder M1. This makes use of the human faculty of stereoscopic vision or depth perception, spreading the effective distance between the eyes to 4 meters, the base of the instrument. This extends depth perception to so great a range that it is possible for the operator to make use of it in placing the image of the target at the same apparent distance as the reticle in the instrument. As shown by the plate, the stereoscopic height finder is similar in appearance to the coincidence range finder, which is not suited to use on aerial targets. Of course what the instrument actually measures is slant range, but by an optical-mechanical triangle solving mechanism it is made to indicate altitude. With a carefully selected and trained observer its accuracy is comparable to that of the altimeter, and it possesses the great advantage of being a single instrument.

One of the older methods of determining the height of target involved the use of two instruments called altimeters, spaced several hundred feet apart and equipped with tracking telescopes and with scales for measuring the horizontal and vertical angles of the target. One of the instruments is provided with additional scales and pointers which, after the angular measurements obtained on the other instrument are set off, indicates the height. This method gives good accuracy and the instruments are light, simple, and trouble-free, but there is the obvious disadvantage that they may be tracking different targets, and further disadvantages are the time required to occupy the baseline, the necessity of maintaining communication between its ends and the greater danger of blinding. The altimeter is, therefore, used only as an auxiliary instrument to the stereoscopic height finder, or as a primary instrument only when there is no height finder available.

The third essential part of the fire-control system, the data transmission system, connects the height finder with the director and the latter with the guns. An alternating current self-synchronous system is employed, so-called because no matter what relative positions the various transmitting and indicating parts may have been placed in when not in operation, they immediately assume correct repeating positions when power is turned on. The system is an adaptation of a commercial one used in compass repeaters, etc. and depends for its operation on the well-known electrical laws concerning the forces acting on conductors in magnetic fields. In brief, the transmitter and indicators or receivers are basically alike, each consisting of a small bipolar 3-phase alternator, the stator of which is excited from common source of 110 volts, single phase, 60 cycle alternating current, or the arrangement of rotor and stator may be reversed. Under these conditions, any angular displacement of the rotor of one unit, as the transmitter, will be transmitted to and duplicated by the rotors of the other units if the latter are free to move.

A complete data transmission system includes the necessary cable, a source of power, built-in transmitters in the height finder and director, a main junction box, and a gun distribution box and elevation, azimuth and fuze indicators for each gun. In operation, the director automatically receives altitude from the height finder and transmits future azimuth, elevation, and fuze setting to the guns. At each gun, the indicators are geared to the respective parts to be controlled. The director continuously moves one pointer in each indicator and the gunner traverses or elevates his gun, or sets his fuze setter, to move the other pointer so as to keep it in coincidence with the first.

It can be seen that the operations just described will result in gun laying and fuze setting entirely under the control of the director, but it is also apparent that a special kind of fuze setter is necessary. The continuous fuze setter M8 (mobile and fixed gun ammunition) is standard for this requirement. In this machine the position of the pawls which set the fuze is indicated by a pointer which is a part of the fuze indicator, a mechanical connection between the two machines being provided, and an operator, by turning a handwheel, keeps the pawls so set that the pointer mentioned is kept in coincidence with the pointer controlled by the director. The round is inserted in the bell mouth and another operator turns a crank one revolution, which effects the fuze setting. If after the initial setting the projectile remains in the fuze setter, its fuze setting is kept continuously corrected by the operation of the matching handwheel.

This design of continuous fuze setter will take any 3" ammunition, it being necessary only to change the setting pawls and graduated dial to accommodate different fuzes. This fuze setter also has the indicator built on and directly geared to the setter mechanism and thereby not requiring a connecting shaft.

The detection of airplanes from the ground at night presents new problems and requires additional apparatus. To locate planes flying at high speed in the dark appears at first thought to be a problem incapable of solution. However, a special apparatus has been developed by the Ordnance Department for locating airplanes by sound. This instrument, called the sound locator, indicates the position of the moving plane and transmits it, by means of a data transmission system similar to that used between director and guns, to the searchlight controller which in turn transmits it to the searchlight. The latter two instruments are Engineer equipment. When the target is illuminated, it is tracked by the director and height-finder and firing conducted as by day.

The complete sound locator consists of two parts, both mounted on the same trailer. The first part, the horns, is operated by two listeners, one for angular height and one for azimuth, and has the obvious function of indicating the direction of the arriving sound. Its characteristics are sensitiveness, obtained by the size and proportioning of the horns and acute binaural perception obtained by their separation. The second part of the instrument, the acoustic corrector, has the function of correcting for sound lag. The velocity of sound being limited (about 1100 feet per second) the direction indicated by the horns is not that of the present position of the plane but that of some earlier position. The accustic corrector takes as arguments the azimuth and the angular height of the horns and an estimated altitude of target, computes the sound lag corrections to these quantities, and corrects them accordingly to give the present azimuth and angular height of the target. It is these data which are transmitted to the searchlight.

The sound locator can actually give the direction of a moving target up to a maximum range of about 10,000 yards, depending on conditions, though targets have been heard and identified at several times this range. The data it furnishes are within perhaps 1° of true direction; the width of a searchlight beam being about $1\text{-}1/4^{\circ}$, a searching action of the light is necessary which is provided for in the searchlight controller or "comparator".

ANTIAIRCRAFT MACHINE GUN FIRE CONTROL.

All the foregoing discussion applies only to antiaircraft cannon and their fire control. There remains a branch of antiaircraft firing which is most important, yet far from a solution as stabilized and as nearly satisfactory as that for antiaircraft cannon. This is the fire control for antiaircraft machine guns.

The particular difficulty of the problem is due to the fleeting target presented by a high speed airplane at low altitude. Attack aviation, which is the kind with which antiaircraft machine guns are most often concerned, is trained to take advantage of the ground and to so direct its attacks that it will arrive with the least warning and be under fire for the minimum time. The essence of the problem, therefore, is speed.

Four general methods of control have been developed:

(a) Individual sight control.

(b) Individual tracer control.

(c) Central tracer control.

(d) Central control with computed leads.

One of the earliest means of meeting the problem was the forward area sight, developed during the World War. It consists of a front sight for the machine-gun composed of concentric ellipses proportioned in accordance with several representative plane speeds. In use, the gunner immediately upon perceiving the target selects that ellipse which corresponds roughly to the estimated speed of the plane, and lays the gun so that looking through the rear sight he sees the target heading towards the center of the front sight and on the ellipse chosen. This sight has given fair results at times.

The idea of individual sight control at the gun has been elaborated in a number of ways. Generally the mechanism consists of a simple computing device, usually a cylinder with curves laid out on its surface and a movable pointer, so connected that when the estimated altitude and speed of the target are set in, the front sight is moved vertically and laterally according to the deflections required. A large number of such devices have been constructed in many different organizations of the using service and good results have at times been obtained but this line of development is not being much pursued at the present time.

An obvious means of controlling the fire of antiaircraft machine guns at the limited ranges at which they are used is the use of tracer ammunition. It would seem at first sight that it would be an easy matter simply to direct the machine gun so that the trajectory, as shown by the visible trace, would pass through the target, just as a stream of water from a hose is directed. The difficulty with this method is the practical impossibility of telling what part of the trajectory is nearest the target. This is due to the very short range at which the unaided human eyes can give depth perception. The problem is made more difficult by the fact that the brightest part of the trace is that closest to the gun.

A serious attempt was made to diminish these basic difficulties by the production of two-color tracers, which change color at about the mid-point of the trajectory. The idea was that the gunner could use the point of change of color as a guide in estimating what part of the trace was nearest the target. Tracers which do not begin to burn until at some distance from the muzzle of the gun have also been attempted but neither of these devices has yielded much success. It appears that the best results have so far been obtained by careful selection of gunners by trial, and, by the use of more precise methods of fire control by lead-computing instruments, giving the gunner an opportunity occasionally to see the tracers actually passing through the target as a training measure.

Notwithstanding the manifest shortcomings of the individual tracer method of control, it has the great advantages of requiring no apparatus and of being instantly available as soon as the gun can be fired. In war this method will probably be used against the majority of targets.

It should be noticed that this method is distinct from all others in that it does not require the gunner to get down behind the gun sights. As a result, if this method alone were to be used the machine gun mounts could be much lower. The necessity of providing high and, therefore, relatively unstable mounts for antiaircraft machine guns has made the problem of designing of such mounts much more difficult, and the mounts themselves much larger and heavier.

At stated above, the gunner is in a very poor position to observe the trace of his firing. On this account it is now generally prescribed that he stand upright behind his gun with his eyes as far above the line of fire as practicable so as to get the least effect of the near trace and also get a little perspective on the trajectory. An extension of this principle is the control of the sights of several guns by an observer placed in their midst, in which position he is more free of the above disadvantages. This is the third method listed at the beginning of this section.

The mechanism is a small control box into which the vertical and lateral lead estimators crank in their functions while observing the tracers, and these leads are transmitted by flexible shafts to the sights of the four machine guns in the group. The gunners then concentrate on aligning their sights directly on the target.

The method yields considerably better accuracy than individual tracer control, since the lead computers are not immediately behind the guns and also since the supply of skilled lead estimators in the barrery can be made to go forward by this method. But the method sacrifices the great advantage of individual tracer control which requires no apparatus to be set up. Since apparatus has to be set up by this method, it is not useful on the march but is available in position only.

Having once gone to the use of separate fire control apparatus, it is logical to take the further steps necessary to increase its accuracy over that possible with estimated leads. This is done by the use of a simple lead computer, which transmits firing data to the control box already described. A stereoscope for observing fire, and a differential spotting corrector (in the control box) are also provided, the whole forming the Machine Gun Antiaircraft Control Set T1.

This is much the most accurate of the four systems discussed, when circumstances permit its use.

It can be seen that antiaircraft fire control for machine guns has not been stabilized as to type as it has for antiaircraft cannon, and the efforts of the Service Boards and of numbers of interested officers are still being directed toward a fundamental solution.

SECTION I

ARTILLERY AMMUNITION - GENERAL

The subject of artillery ammunition is dominated by the unique nature of the ammunition problem. All phases of this problem stem from one of two considerations:

a. The tremendous quantities required in war.

b. The problems of production.

Many figures have been published in the past in connection with the first consideration. It is well known that the number of rounds per field gun per day rose from 8 at the beginng of the war to 35 or more at the end, artillery ammunition of all calibers being used by the British and French during the last year of the war at the rate of 12,710,000 rounds per month. The American government spent in this country about $2,282,000,000 for ammunition, and an additional sum for ammunition obtained overseas. The amounts involved were so far greater than any of previous wars that comparison worthy of the word is almost out of the question. It may be noted, however, that our Civil War, characterized both by advanced tactical developments and by being fought, like the World War, principally with munitions manufactured in a great industrial mobilization rather than with peacetime reserves, saw the consumption of 5,000,000 rounds of artillery ammunition by the Union Army in the whole four years.

Another side of the quantity question which is less frequently mentioned is the influence of the availability of ammunition on the conduct of the war. The fact is that the increase in the rate of consumption mentioned above was not due primarily to the development of artillery tactics, but was simply the reflection of the fact that artillery ammunition could not, by any exertions, be made available any faster. Until May, 1917, the shortage of ammunition had the greatest influence on the decisions as to what operations could be undertaken, and on the losses suffered in the operations that were undertaken, and on the success attained.

It is useless to examine the technical details of ammunition without bearing in mind the quantity in which it must be produced.

The second major consideration in the ammunition question, namely, the problems of production, is somewhat more closely connected with the technical features of ammunition which are brought out in the accompanying reviews. The principal of these problems are, in addition to great quantity:

a. The noncommercial nature of ammunition.

b. The difficult technical problem.

c. The excellence of manufacture required.

d. The manufacturing coordination required.

The noncommercial nature of ammunition is manifest long before wartime production is begun. There being no ammunition industry, except small arms and commercial explosives, it is necessary for the Ordnance Department to train its own technicians and operatives of every sort. Neither can it avail itself except indirectly of the findings of industry, but must carry on its own development work in this extremely technical subject.

The difficult technical problem which ammunition presents is due to the facts that its functioning time is excessively brief and that it is destroyed in functioning. This ammunition situation has resulted in the invention of ingenious instruments for measuring the factors involved, but even these cannot bring the subject down to the level of most mechanical problems, in which the material can be examined during and after functioning as well as before. Much experimentation to gain the simplest basic information is the inevitable result.

Excellence in manufacture is required because of the small factor of safety allowed in the design of ammunition, which in turn arises from the necessity of getting the utmost out of it. A percentage of failures which might be allowable in some other classes of material could not be tolerated in ammunition. If the cannoneer has reason to believe that his pull on the lanyard may result in instant detah to himself from a premature, his morale will be in a state to be imagined. That such a possibility is not too remote to be considered is shown by the fact that by May 5, 1915, 500 premature bursts had occurred in the firing of French guns. In the Tenth Army alone from May 9th to 16 of the same year, 76 pieces burst.

As to the manufacturing coordination required, it is not sufficient merely to set about the manufacture of as many as possible of each component with the expectation of then assembling them, as might be at first thought. Some components are much easier and quicker to manufacture than others, and it is, therefore, absolutely necessary to allow for this in manufacturing in great quantity. The test of suitability for manufacture in emergency was applied, before adoption, to all the standard types of ammunition to be discussed, but the problem of controlling production of the various parts in accordance with the speed with which they can be produced remains to be taken care of in war plans.

The information given in other sections on specific ammunition items can now be studied with some appreciation of the position of each in the ammunition problem.

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SECTION J

ARTILLERY PROJECTILES

The mission of the artillery is to inflict damage on specified targets at a distance from the firing battery. Its modus operandi for accomplishing this mission is firing projectiles at the target. Its efficiency in accomplishing its mission is, in general, dependent upon -

a. its ability to make the projectile strike the target which in turn is dependent upon maximum range and accuracy.

b. the extent of the damage inflicted on the target when it is struck by the projectile, that is, the effect produced by the projectile.

It seems logical, therefore, in a general discussion of projectiles such as this one, to consider them from these two viewpoints.

RANGE AND ACCURACY.

The range and accuracy that can be attained in artillery fire is to a very considerable extent influenced by the flight characteristics of the projectiles. In considering the flight characteristics of projectiles, we must distinguish between those projectiles which are fired from rifled cannon and those which are fired from smooth bore cannon.

Projectiles fired from rifled cannon.

At the beginning of the World War, projectiles designed to be fired from rifled cannon in general, had cylindrical bodies with flat bases which were perpendicular to the longituindal axis. A band of copper or copper nickel alloy surrpounded the body near the base to engage the rifling and thus impart to the projectile the rotation which is depended upon to prevent its tumbling during flight. The points of the projectiles were ogival in shape, the radius of the ogive being usually about two calibers. Typical projectiles of this kind are the 37 m/m, Mk I and 700 lb., Mk. VI which are shown in Slide No. J-1.

Slide No. J-1.

Notable exceptions to this rule were the armor piercing projectiles fired from the larger calibers of seacoast guns which were equipped with "false ogives" or "windshields" which gave them ogival points having a radius of about four to five calibers as shown in Slide No. J-2.

During the World War there was a continuous striving by all the combatants to obtain longer ranges from their existing guns and this led to concentrated development work on projectiles with a view to improving their form factors, that is, decreasing the resistance they encountered in passing through the air. The advantages of a long ogival point on projectiles moving at velocities greater than the velocity of sound, were already known from experience with small arms bullets, which for some years had been made with such points. This feature was first applied to existing projectiles for the larger caliber high-powered guns by providing them with false ogives or windshields. An example of this is the 150 m/m, Model 1914 high explosive with false ogive used in the German 150 m/m Gun which is shown in Slide J-2.

Slide No. J-2

The use of such false ogives, however, had its disadvantages among which were, difficulty of manufacture with the required degree of precision, difficulty of handling in the field, and difficulty of fuzing advantageously with existing types of fuzes. This led to the development of projectiles in which the bodies themselves had ogives of comparatively long radius. The necessity for using existing fuzes in many cases prevented the point from being given as favorable a shape as was known to be possible. This is illustrated by the 155 m/m High Explosive Shell, Mk. III, which was developed by the French during the World War and at the time of the Armistice was considered to be the last word. This projectile is shown in Slide No. J-3 equipped with the Point Detonating Fuze, Mk. III.

Slide No. J-3
(Ord. Photo No. 8403)
155 m/m High Explosive Shell, Mk. III
with Point Detonating Fuze, Mk. III.

The tapering of the bases to form the so-called "boat-tail", which in a general way was already known, was developed and put into use. It was found that the shape and dimensions of the boat-tail are quire critical and an incorectly designed boat-tail may give rise to excessive dispersion. The type of boat-tail in use at the end of the World War is shown in Slide No. J-3. The boat-tail has its greatest effect when the projectile is traveling at a velocity less then the velocity of sound. Its use is therefore indicated on projectiles whose velocity during reasonable portion of the trajectory may be below about 1100 ft. per second. In the case particularly of major caliber armor piercing projectiles, whose striking velocity must be well above this figure if any reasonable amount of armor is to be penetrated, it is questionable if any appreciable advantage is to be gained by the use of a boat-tail.

During the latter part of the World War, the importance of proper design of rotating bands came to be fully realized. It has been found that certain designs of rotating bands permit the lands of the gun to push strips of the band material to the rear. In such cases when the projectile leaves the muzzle of the gun, the powder gases which rush past spread these strips outward as shown in Slide No. J-4, producing what is known as "fringing", a condition which, if present to any appreciable extent, causes excessive dispersion.

Slide No. J-4

In the design of a modern projectile the profile of the rotating band is always carefully designed so as to prevent fringing. The engraving of a properly designed rotating band is shown in Slide No. J-5.

Slide No. J-5

The war-time developments which have just been described, were of course carried out very hurriedly and the optimum conditions could not always be determined in the time available. Since the close of the War, the Ordnance Department has actively carried out work to determine the basic laws governing the flight characteristics of projectiles. In this work considerable progress has been made but much more remains to be done.

Projectiles Fired from Smooth Bore Cannon.

Smooth bore cannon again came into use during the World War in the form of the Trench Mortar. The projectile fired from the 3" Stokes Trench Mortar used in our own Army, is shown in Slide No. J-6.

Slide No. J-6
(Ordnance Photo Number 8801)

No attempt was made to stabilize this projectile and it tumbled from the time it left the muzzle until it struck the ground. The result was that the maximum range that could be obtained with it was comparatively short and the dispersion comparatively large.

It was realized that some form of stabilization of the projectile would greatly improve the performance of smooth bore weapons, and accordingly the projectiles for our war time 6-inch and 240 m/m trench mortars were stabilized by means of fins attached to their base ends, as shown in Slide No. J-7.

Slide No. J-7
(Ordnance Photo No. 6914)
240 m/m Trench Mortar Shell.

The most highly developed war time shell for smooth bore guns which was stabilized by means of fins, was the French Brandt Shell which is shown on Slide No. J-8.

Slide No. J-8

In the stabilized shells which have just been described, the fins cannot be wider than the diameter of the projectile as they must pass through the bore of the gun. The efficiency of a stabilizing fin can be greatly increased by allowing it to extend only a short distance beyond the diameter of the body of the projectile, thus allowing a much shorter fin to be used. This principle was used in a war time German grenade thrower which is shown in Slide No. J-9.

Slide No. J-9
German Grenade Thrower

In this weapon the barrel is attached to the grenade and fits over a cylinder containing the firing mechanism, which is attached to the carriage where the barrel ordinarily is located. The fins are attached to the outside of the barrel and may therefore be as wide as is desired. This type of weapon and projectile is of course not practical for use in larger sizes, as a barrel is shot away with each projectile.

Smooth bore weapons using projectiles stabilized by means of fins have the great advantage over rifled weapons, in that they can be fired at angles of elevation up to 75° and more without becoming unduly inaccurate, as is the case with rifled weapons when fired at angles of elevation over about 65°.

Effects Produced vs. Type of Projectile.

There is no question but that for each particular target or type of target to be attacked, an optimum projectile can be developed which will give the maximum in effictiveness. If this were done the artillery would soon be supplied with a large number of special purpose projectiles, many of which would be quite inefficient for any purpose except the one for which they were particularly designed. The problem then would be to manage to produce and have at the firing battery at all times those projectiles which are suitable for the attack of the particular types of targets that may be assigned from time to time. Experience has shown that under war conditions this simply cannot be done. The practical solution of the problem is to develop projectiles which are fairly efficient against a number of kinds of targets. From this point of view we may group all targets likely to be attacked by artillery projectiles, into the following general classes:-

(a) Personnel.

(b) Light obstacles placed above ground, such as barbed wire entanglements, etc.

(c) Unarmored military material such as supply trains, repair installations, aircraft, etc.

(d) Armored targets (land and naval).

(e) Above ground structures such as buildings, bridgos, etc.

(f) Under-ground structures such as intrenchments, dugouts, etc.

Against personnel in the open or in "fox holes" a properly placed shrapnel is probably as effective as any projectile yet developed. Personnel in trenches are, however, relatively safe from shrapnel fire unless the trench can be enfiladed. Against the other classes of targets just mentioned, the shrapnel has little effect except possibly in the case of light obstacles and military materiel and even here it is a poor second when compared to the high explosive shell. Furthermore, to be effective, not only must the fire be properly adjusted for range and deflection, but the shrapnel must be burst at the proper place on the trajectory before it strikes the ground. This required considerable skill on the part of the artillery. Finally, if the shrapnel is to be effective, the angle of fall must not be too great (say not over 15°). This prevents the maximum range of any weapon from being utilized with this type of projectile.

These considerations will serve to point out that the shrapnel is rather a "special purpose" weapon, although the special purpose for which it is adapted is a very important one. Even so, whereas, at the beginning of the World War the shrapnel was considered as the most important projectile of the Field Artillery, it now has been so far pushed aside by the high explosive shell that its abolition has been seriously considered.

The laurels for general utility and simplicity of construction must be awarded to the high explosive shell. This projectile produces two effects; namely (a) fragmentation and (b) blast. The former is particularly effective against targets of class (a) personnel, (b) light obstacles (barbed wire, etc.), and (c) military material whereas the latter is principally depended upon for the demolition of targets of classes (e) and (f), namely, structures above ground and underground. Its general utility, more than anything else, has caused the high explosive shell to take the position of the most important projectile of the mobile and anti-aircraft artillery.

Targets which are protected with armor greater than about 1" in thickness cannot be successfully attacked with high explosive shell. Thin armor (under 1") can of course at times be penetrated by the fragments from high explosive shells, and under certain very favorable circumstances might even be penetrated by a high explosive shell itself. Nevertheless, the use of high explosive shells for the attack of armored targets cannot be considered as anything but a rather poor emergency measure.

For the attack of armored targets, armor piercing projectiles are indicated. In the design and construction of such projectiles everything else has to be sacrificed to produce the maximum of armor piercing qualities. As a result this type of projectile is a "special purpose" shell with only one virtue, that of being able to pierce armor. It must, however, be provided, for no projectile of more general use has as yet been found which will to any appreciable extent do the work which the armor piercing projectile is designed to do.

Another "single purpose" projectile is the canister. This projectile is of course useful only in attacking personnel in the open at very short ranges. It is, however, used in guns whose caliber is so small (37 m/m and 2.24" tank guns) as to preclude the use of shrapnel or time fuzed high explosive shell.

Numerous other types of projectiles have been proposed and experimented with. They have, however, not come into general use, usually because, although they performed some specific mission better than one of the projectiles which have been described, they were decidedly "single purpose" projectiles, and even the "single purpose" for which they were especially designed could be performed fairly well by one of the three types of projectiles which have been mentioned above.

No consideration is here being given to Star Shell or illuminating projectiles, as these are not intended for attacking targets but rather as an aid in the control of fire, and due to their construction had better be considered along with other pyrotechnics. Furthermore, at the present time the artillery arms of the Army have set up no requirements for projectiles of this type.

Shrapnel.

A shrapnel consists essentially of a comparatively thin-walled case in the case of which is contained a charge of black powder which, when ignited by the time fuze on the front of the case, expels the lead balls contained in the case between the base charge and the fuze. Under the influence of the base charge and the forward and rotary motion of the projectile, the lead balls are projected as shown in a general way in Slide No. J-10.

Slide No. J-10

It is evident from this diagram that as the angle of fall increases the area covered by the balls for a given height of burst decreases and the effectiveness is more and more influenced by the height of burst. It is thus apparent that the shrapnel is best adapted for use with small angles of fall.

This result is best arrived at by using comparatively low angles of elevation with a comparatively high muzzle velocity. The conditions under which shrapnel are fired in practice are such that their velocity in all parts of their trajectory is above the velocity of sound. Consequently the use of a boat-tail would result in little or no advantage and this feature has never been applied to shrpanel.

These same conditions, however, indicate that the use of an ogive with a long radius would be advantageous. This was tried in the 105 m/m high explosive shell, M1 which is shown in Slide No. J-11.

Slide No. J-11
(Ordnance Photo No. 8399)
105 m/m High Explosive Shell, M1, with P. D.
Fuze, T16.

This construction was found to result in inefficient distribution of the balls on expulsion and was abandoned in favor of the older type of construction using the relatively blunt nose as illustrated by the 75 m/m Shrapnel, Mk. with the fuze which is shown in Slide No. J.12.

Slide No. J-12

High Explosive Shell.

The so-called high explosive shell consists of a fairly thick-walled steel projectile, the cavity of which is filled with a bursting charge of a high explosive and fuze and explosive train for detonating this charge. The fuze may be in the nose or base of the projectile, depending upon the effect to be produced. When the bursting charge is detonated the wall of the projectile is broken into fragments which, when the projectile is burst in the open, are projected as is shown in a general way in Slide No. J-13. In addition to this shower of fragments, there is also the blast caused by the expanding gases produced by the explosive decomposition of the bursting charge.

Slide No. J-13
Distribution of fragments from a
high explosive shell burst in
the open.

If, in designing a high explosive shell, one had only to consider the effectiveness at the target, it seems probable that there might be two types in use - namely,

(a) one designed especially for blast effect having walls as thin as possible and containing the largest possible bursting charge.

(b) one designed especially for fragmentation effect, having walls of such thickness as would break up into the greatest number of fragments of optimum size and containing a bursting charge of such sizes as would give these fragments the maximum velocity.

However, the other factors which must be considered, such as strength required to resist the forces of setback in the gun and the centrifugal force due to rotation, flight characteristics, practicability of manufacture in large quantities under war time conditions, etc., have so far had such a great influence that types designed to achieve the maximum in these two effects do not differ sufficiently to warrant the difficulties involved in the production and supply of two such types. In general, however, it may be said, when effect at the target only is considered, that for fragmentation effect the shells of smaller calibers (75 m/m and 105 m/m) are more efficient than those of larger caliber (155 m/m, 8" and 240 m/m), and vice versa for blast effect those of larger caliber are more efficient than those of smaller caliber.

The effect (fragmentation or blast) it is desired to utilize and the location of the target will determine the type of fuze which must be employed and the gunnery technique that must be applied in the firing of High Explosive Shells.

<u>The Fragment Effect.</u>

If it is desired to utilize the fragmentation effect, it is important that the projectile be caused to burst in such a position relative to the target that the latter is covered by the "side spray" (see Slide J-13) of fragments.

Targets such as personnel, light obstacles (barbed wire entanglements, etc.) and military equipment located above ground, can be very effectively attacked by using a fuze which will burst the projectile before it penetrates into the ground (superquick fuze), and placing the projectile just short of the target as is illustrated schematically in Slide No. J-14.

Slide No. J-14

Fragment distribution from High Explosive Shell with superquick fuze burst on impact clearly show how the area covered by the fragments from the projectile increases as the angle of impact increases. It is self-evident from this Slide (No. J-14), that targets in depressions in the ground, such as trenches, shell holes or fox holes, targets on steep reverse slopes, etc., are relatively safe from high explosive shells fired in this, unless a direct hit is scored and the probability of this must be conceded to be small.

Targets in depressions in the ground can be reached by fragments in the side spray only when the projectile, with its axis not too far from parallel to the ground, is caused to burst above the target. This may be accomplished in two ways:

(a) at short ranges where the angle of fall is small enough to cause the projectile to ricochet. The use of a short delay fuze (about .05 sec.) will cause an air burst as shown in Slide No. J-15.

Slide No. J-15

(b) at longer ranges where the angle of fall is too large to cause the projectile to ricochet and still small enough to give the side spray a practically vertical direction. A time fuze may be used to burst the shell above the target as is shown in Slide No. 16.

Slide No. J-16
Attack of targets in depressions with
fragments from time fuzed H. E. Shells.

Similarly, if targets on steep reverse slopes are to be reached by the fragments from high explosive shells, a time fuze must be used and the shell caused to burst about as shown in Slide No. J-17.

Slide No. J-17
Attack of target on steep reverse slope
with fragments from time fuzed H. E. Shell.

In the attack of aerial targest by artillery located on the ground, the probability of obtaining a direct hit is so small as to be negligible, and therefore the use of an impact fuze in such cases is out of the question. The only thing to be done therefore, is to use a time fuze and attempt to place the burst so that the target will be in the field of the fragments produced.

The Blast Effect.

When exploded in the open, the balst effect of a high explosive shell is much more local than the fragmentation effect.

A general indication of the factors influencing the blast effect may be obtained by considering the following.

When a high explosive shell is detonated on the surface of the ground, practically no crater is produced. If, on the other hand, the shell is buried some distance under the ground and then detonated, a crater similar, in general, to that shown in Slide No. J-18, is formed.

Slide No. J-18
Crater produced by high explosive shell.

The size of craters formed by shells of several calibers when detonated at various distances under the surface of the ground, is shown in Slide No. J-19.

Slide No. J-19
Sizes of craters formed by high
explosive shell: 75 m/m,
105 m/m, 155 m/m, 8", 240 m/m.

When the shell is detonated at a depth greater than that at which a crater is no longer formed, it produces a hollow around the point of burst, as is shown in a general way in Slide No. J-20.

Slide No. J-20

From these data the following general conclusions can be drawn:

(a) The blast effect of a high explosive shell is comparatively small unless the shell has penetrated some distance into the target before it explodes.

(b) The effect produced by the blast is dependent upon the size of the bursting charge (caliber of the projectile).

Other data could be cited to show that these same factors influence in much the same way the blast effect of high explosive on targets such as buildings, bridges, etc., located above the ground.

It is obvious then, that when it is desired to make use of the blast effect it is necessary to so conduct the fire that the projectile will approach the target in such a manner that the necessary penetration can be secured. This is a relatively simple matter when attacking targets such as unarmored structures above the ground, for here, regardless of the angle of fall, the target will probably be penetrated. When, however, underground works such as trenches, dugouts, etc., are to be attacked, the problem becomes more complicated, as will be evident from the following considerations.

When a projectile strikes the ground at an angle of less than 125 mils (7 °), it will usually ricochet as is shown in Slide No. J-21. In this case, of course, no penetration can be secured and the blast effect will be negligible.

Slide No. J-21
Ricochet, angle of impact less than
125 mils (7°)

At angles of fall between about 125 mils (7 degrees) and 450 mils (25 degrees), the path of the projectile in the ground will be about as shown in Slide No. J-22. While some penetration is secured in these cases, it is not sufficient to secure the maximum results from the blast effect, and furthermore, the projectile may emerge from the ground before the delay element in the fuze has burned through.

Slide No. J-22
Penetration, angles of impact between 125 mils (7 degrees) and 450 mils (25 degrees).

As the angle of fall is increased to some 700 mils (39°) the tendency is for the projectile to remain under the ground but not to penetrate deeply. This condition is shown in Slide No. J-23. Under these circumstances the projectile will probably burst under the ground but not at a depth great enough to secure the maximum results from the blast effect.

Slide No. J-23
Penetration, angle of fall between 450 mils (25°)
and 700 mils (39°)

It is only after the angle of impact becomes greater than about 700 mils (39°) that the projectile can be depended upon to continue its course into the ground, as illustrated in Slide No. J-24, and penetration great enough to secure the maximum results from the blast effect, to be obtained.

Slide No. J-24
Penetration, angles of impact greater than
about 700 mils (39°)

In addition to the above, the striking velocity must be considered, for without sufficient striking velocity penetration also cannot be secured.

Fuzing and Firing.

The above discussion is intended to (1) illustrate the versatility of the high explosive shell, and (2) to show what must be done if it is to produce the maximum effect it is capable of producing. The latter can be summarized in a general way about as follows:

(a) Fuzes to give the proper action must be provided - namely,

1. Superquick action for fragment effect against personnel, light obstacles (barbed wire entanglements,

etc.) and unarmored military material above the ground.

2. Delay action for fragment effect against personnel in trenches, shell holes, fox holes, etc., at short ranges where the projectiles will ricochet.

3. Time action for fragment effect against personnel in trenches, shell holes, fox holes, etc., at ranges beyond which shells will ricochet, and personnel and military equipment on steep reverse slopes, and in the air.

4. Delay action for blast effect.

(b) The guns from which the shell are fired must be so arranged that it is possible to obtain high angles of fall at all ranges. This requires zoned propelling charges and carriages which permit high angles of elevation (as high as 65° can be used to good advantage.).

(c) In conducting the fire the projectile must not only be placed on the target but the fuze, and, so far as possible, the angle of fall necessary to produce the desired effect on the particular target being attacked must be used if the maximum possible results are to be obtained.

All of these considerations show that in the case of the high explosive shell it is the same as it is with so many simple general utility tools, its versatility is due in a great measure to the variety of ways in which it may be used and accordingly, its efficiency in performing a given mission is greatly dependent upon the skill with which it is used.

Location of Fuzes.

The fuze action most generally employed when use is made of the fragment effect of high explosive shell, is the superquick in which the fuze is actuated by impact and the bursting charge is caused to explode before the projectile has penetrated an appreciable distance into the object (usually the ground) which actuates the fuze. This action can only be secured in a fuze which is located in the point of the projectile. Therefore, all projectiles whose fragment effect is to be used at all, must be arranged to take fuzes in the nose. This applies to high explosive shells for all calibers up to and including the 240 m/m Howitzer.

Shell which are to be used only for their blast effect, such as those for the larger caliber long range guns, require only delay fuzes when firing for effect. Such fuzes can readily be placed in the base of the projectile. In adjusting the fire of such guns by the method of "high burst ranging" use must be made of fuzes giving time action. It is not considered practicable to make a time fuze for use in the base of a projectile and therefore the high explosive shell for these guns are also arranged to take the fuzes in the point.

Form of H. E. Shell for Rifled Cannon

The high explosive shell can be given almost any exterior form that may be required to secure desirable flight characteristics without seriously affecting its effectiveness at the target. Therefore, shortly after the close of the World War, a type of projectile was designed which, according to the information then existing, would give the maximum in range and accurcy. Typical of this design is the 155 m/m Common Steel Shell, Model E1, shown in Slide No. J-25.

Slide No. J-25
(Ordnance Drg. No. 75E-4-66)
155 m/m Common Steel Shell, Model E1.

Designs for a complete line of High Explosive Shells of this type for all calibers of mobile artillery were laid down and experimental lots were manufactured for use in a few guns.

Experience with these experimental lots showed that shells of the false ogive type did give a very considerable increase in maximum range over the shells in existence at the end of the World War when fired at high muzzle velocities such as are used in high power guns, whereas when fired at muzzle velocities such as are used in howitzers, the gain in maximum range was not worth mentioning.

Experience also showed that the shells of the false ogive type were much more difficult to manufacture in large quantities than the one-piece type, and furthermore, difficult to handle in shipment and use in the field.

These circumstances led to an attempt to improve the flight characteristics of the one-piece type of shell by further refinements in the details of design of the projectile body itself and by the use of a fuze which would give the ogive a better point. In preliminary experiments use was made of the War Time 155 m/m High Explosive Shell, Mark III, fitted with the M39 Point Detonating Fuze which gave a combination as shown in Slide No. J-26.

Slide No. J-26
(Ordnance Photo No. 8404)
155 m/m High Explosive Shell. Mk. III
with P. D. Fuze M39.

The results obtained with the three types of projectiles which have been described are shown in a general way by the curves shown in Slide No. J-27.

Slide No. J-27
(Ordnance Sketch No. G.A. 1537)
Range - muzzle velocity curves for 155 m/m Projectiles of various types.

Here the left-hand curve shows the maximum ranges obtained at various muzzle velocities with the shell and fuze current at the end of the World War. The right-hand curve shows the maximum ranges obtained at various muzzle velocities with the false ogive type of shell. The curve between these two shows the maximum ranges obtained with the War Time type of shell equipped with a fuze which gives the point a better ballistic shape. These curves show very clearly that whereas the false ogive type of shell in the 155 m/m caliber when fired at a muzzle velocity of 2800 f/s gives a maximum range some 5000 yards greater than is given by the War Time Shell with the War Time Fuze, it only excels the War Time Shell with an improved fuze by some 1300 yards, and that this advantage decreases as the muzzle velocity decreases.

As a result of such findings, it was decided that the advantages of the false ogive design over the one-piece design with a modern fuze were outweighed by its disadvantages, except possibly in extreme cases where it is desired to obtain the maximum attainable ranges regardless of cost. Accordingly, the one-piece shell with the modern fuze has been adopted as the Standard High Explosive Shell design for all calibers of mobile artillery. Projectiles of this type have been designed for use in the 75 m/m weapons, the 105 m/m howitzer and the 155 m/m weapons.

Should it ever be necessary to secure greater ranges than are given by the type of projectiles just described when fired at muzzle velocities that are developed by normal service pressures, it is proposed to make up a special round consisting of a specially designed projectile of the false ogive type and a powder charge which will give to this projectile the greatest muzzle velocity that the strength of the gun will permit. The firing of such a round will involve some sacrifice of safety for the gun crew and excessive wear of the gun tube must be expected. It should therefore be used only in special cases where the mission to be accomplished is sufficiently important to warrant the risk and cost involved. The design of such a projectile for use in the 155 m/m Gun has been laid down. This design is similar to the design of the 155 m/m Common Steel Shell, Model E1, which has already been referred to.

SECTION K

ARTILLERY FUZES

All artillery fuzes must be certain in action, safe in handling, and as free as practicable from deterioration in storage. The different needs which the various models of fuze fulfill result in considerable variation in actual structural features.

Fuzes are classified in the following ways:

a. By position in the projectile (point or base).

b. By mode of arming (centrifugal or inertia).

c. By mode of setting off (impact or time).

d. By mode of action (detonating or igniting).

In most cases the functioning of a fuze is facilitated by placing it in the nose of the projectile. Practically all artillery ammunition now in our service is point fuzed with the single exception of armor-piercing projectiles, which for obvious reasons have their fuzes in the base.

Section or Diagrammatic Representation
of Semple Plunger

All fuzes contain safety devices which prevent contact of the firing pin and the primer until subjected to forces which can hardly be applied except by firing. The withdrawal of the safety device which then occurs is called arming. Many fuzes of American design employ the well-known Semple plunger, which is essentially a flat piece of metal pivoted at right angle to the intersecting the axis of the fuze and with its center of mass behind the pivot but slightly removed from the axis of rotation. Centrifugal force incident to rotation of fuze causes the pivoted piece to turn and thus arm the fuze, but not until longitudinal acceleration has ceased and the projectile has, therefore, left the gun. Safety pins and springs prevent arming of the fuze in transportation or handling.

Other fuzes may contain arming devices operated by the linear acceleration of the projectile; such are called inertia fuzes.

In addition to the arming devices which prevent the premature functioning of the fuze itself, the detonating fuzes have devices for making them bore safe or detonator safe. These are additional arming devices which positively separate the detonator and the booster until subjected to the negative acceleration which occurs in the flight of the projectile outside the gun.

A fuze acts in one of two ways - by simply igniting the bursting charge by means of a flash set off by the fuze primer, or by detonating it, in which case a small charge of detonator explosive contained in the fuze is set off. Fuzes for shrapnel and black powder loaded practice shell are igniting only; all others are detonating.

WARTIME FUZES.

Longitudinal Section of
Point Detonating Fuze Mark III

Detonating Fuzes are in general divided into two classes, superquick and delay. The former are employed with shell against targets above ground. The Point Detonating Fuze, Mark III, is of this type; it functions by direct action when its head strikes the ground, and detonates the shell before the ogive penetrates the ground .0005 second later and while the shell is in a more or less upright position. No retardation of the projectile is required as with inertia type fuzes. The fuze is quite long in order to cause detonation of the shell as much above ground as possible. It is of French design, except for the interrupter which was added later. It is no longer standard for manufacture, but considerable quantities are on hand.

The firing pin head is kept from moving to the rear by a shear wire, and by two half rings which are kept in place by a brass spiral wound on. The angular acceleration of the fuze in the bore winds this spiral tighter and the fuze remains safe. Outside the bore the angular acceleration becomes negative and centrifugal force is able to unwind the spiral and throw off the half rings. By this simple and ingenious mechanism the fuze is not armed until it leaves the bore. The manner of functioning on impact is clear.

The fuze as described, however, is not foolproof. If the cannoneer when removing the water proof tinfoil hood which seals the head should also remove the spiral and half rings, the setback of the firing pin head on firing would be sufficient to shear the shear wire and function the fuze, giving a bore detonation. On this account the interrupter was added. The slight angle that it makes with the normal to the fuze axis should be noted. As a result of this placement the linear acceleration of the fuze in the bore of the gun overcomes the centrifugal force on the interrupter due to rotation, and only when the projectile leaves the gun and linear acceleration becomes negative is the interrupter thrown outward. This makes the fuze bore-safe against any premature functioning which may be initiated in the head of the fuze. It is not, however, "detonator-safe" in that the detonator is located below this interrupter and always in operable relation to the booster.

Longitudinal Section of Point Detonating Fuze, Mark IV

The Mark III Fuze being adapted for use in shell against targets above ground, there remains a requirement for a fuze for shell against targets which require penetration before detonation. The Point Detonating Fuze, Mark IV, also a French design, is for this use.

To meet a demand for variable penetration caused by the necessity of attacking a variety of field fortifications, the Mark IV Fuze is arranged to use any one of three interchangeable delay elements, one permitting the fuze to function "non-delay", one "short delay" (0.5 second) and one "long delay" (.15 second). The delay element is selected for use according to the target to be attacked.

This is an inertia fuze. On discharge the arming casing, normally held forward by the arming spring, is carried back and locked into the safety casing and there releases the prongs which lock the percussion plunger to the rear. This arms the fuze, since now the percussion plunger is free to carry the primer forward against the firing pin. Forward creep of the plunger during flight is prevented by the retard spring; on impact the inertia of the plunger is sufficient to overcome this small spring and carry the primer forward to the firing pin. The successive action of the primer, powder pellet, delay pellet, quick match, relay powder and detonator is apparent. In the non-delay element the delay pellet and quick match are omitted.

A development of the Mark IV Fuze consisted in an additional safety device in the nose, which converted it into the Mark V. This was not entirely successful, as it did not function in large howitzers giving low setback forces. Its use was largely limited to the 75 mm gun.

Longitudinal Section of 21-Second
Combination Fuze, M1907

The types so far discussed are impact detonating fuzes. Shrapnel requires a fuze with an entirely different mode of action - it must function before impact at the end of a predetermined time, it should function on impact, and it need be igniting only.

The 21-second Combination Fuze, for many years standard in shrapnel for divisional artillery, performs these functions well. It obtains its definite time of functioning from the burning of a powder train, the effective length of which may be set as desired. It contains percussion elements also, so that in the event of striking the ground before the end of the time set the fuze will function on impact.

The arrangement to secure a powder train of variable length consists of two time-train rings, in each of which a groove not entirely around the circumference is filled with compressed black powder. The combined length of the two grooves is 7". The lower ring is moveable and graduated in such a manner that if any time of flight between 1 and 21 seconds is set to the index which is on the upper ring and body, the time required by the flame to pass by the shortest way through the combined trains of the two rings will be the time set. Ignition of the time train at the beginning of flight is accomplished by a concussion element, which consists of a primer held in a concussion plunger in front of a fixed firing pin. On discharge the setback of this plunger is sufficient to overcome the resistance of a split ring and carry the primer against the firing pin. Its flash ignites a pellet at the beginning of the upper time train. When the flame reaches the end of the set length of effective time train, it ignites the powder in the annular magazine in the base of the fuze, and this flame ignites the base charge of the shrapnel through a flame tube in the axis of the projectile. The powder gas produced by the burning time trains is vented under the head of the closing cap. When the fuze is set at O its time of functioning is only that required to burn the pellets at the end of the upper and lower time trains, and the magazine, and practically a muzzle burst is the result. This can be used to give a canister effect.

A setting of "S" places the solid metal between the ends of the upper time train over the vent to the lower time train, and the similar solid metal of the lower time train over the vent to the magazine. Ignition of the fuze while in this position results in the burning of the upper time train only. This is the setting at which the fuze is kept at all times except when about to be fired, and is also the setting to give an impact burst.

Functioning on impact is secured by a plunger which holds a firing pin behind a percussion primer. This firing pin is part of a Semple centrifugal plunger and, therefore, does not take the armed position until the shrapnel leaves the gun. On impact the plunger body overcomes the resitance of two small spring plungers and carries the firing pin forward to the primer, which is connected to the magazine.

The fuze, which is issued fixed in the loaded shrapnel, is protected until use by a light brass cap attached to the head of the projectile with a soldering strip. This cap is removed before firing.

The 45-second Combination Fuze, Model 1907, of the same pattern as the above, is used for shrapnel of larger caliber than 75 mm. or 3-inch. It is now seldom required. For antiaircraft shrapnel and shell the 21-second Time Fuzes, Mark III, Mark IIIA1, and Mark IIIA2 were formerly standard. These are similar to the 21-second Model 1907, except for the omission of the percussion element. Since a powder train time element loses in accuracy and its calibration changes when fired to high altitudes, mechanical time fuzes for this use have been developed.

POST-WAR FUZES.

Longitudinal Section of Base Detonating
Fuze, Mark X.

After the war a great development program was initiated on all kinds of fuzes but more especially Point Detonating Fuzes. However, the first design to be stabilized and remain stabilized to the present time was a base detonating fuze, the Mark X. This is a delay-action, bore-safe fuze, containing the booster. It is standardized for all major caliber armor-piercing projectiles.

The arming and firing mechanism is a hollow cylindrical plunger carrying a Semple centrifugal plunger on which is the firing pin. During the passage of the projectile through the bore its longitudinal acceleration prevents movement of the Semple plunger, but thereafter centrifugal force causes the latter to turn until the firing pin is in line with the primer. On impact the momentum of the cylindrical plunger carries the firing pin forward to fire the primer, and in turn the delay pellet, detonator and booster.

This fuze is made positively bore-safe (more properly called detonator-safe) by the locating of the detonator in a rotor which holds it away from the delay pellet and the booster. Centrifugal force tends to unlock the rotor and turn it so that the detonator is in line with the delay pellet and the booster, but frictional forces caused by the linear acceleration of the projectile together with the location of the center of gravity of the rotor and both linear and angular acceleration cease, prevent this and only after the projectile leaves the gun does centrifugal force cause action. When the rotor does turn into the armed position, it is locked there and so remains no matter what forces act on the projectile. This is an obviously necessary provision in a fuze where the rotor might move to the manned position as a result of impact of the projectile and before the delay tram had burned through.

THE POINT FUZE SYSTEM.

Drawing of the Standard Point
Fuze Contour.

It has been mentioned that a fuze development program was initiated after the close of the World War. This was necessary because of the remediable defects of the war-time fuzes. The latter perform more or less satisfactorily the work for which they were designed, and together covered the whole range of performance then required of point fuzes. But they possess the defect of making necessary the use of more than one kind of fuze with a given ammunition. This forces the supply in the field of a greater number of fuzes than projectiles, and makes necessary the fuzing of shell by the battery personnel in accordance with the requirements of the moment. Also since the ballistics of a given shell are different with each fuze, it is necessary to carry a firing table for each and compute firing data accordingly. In addition, since the ballistics of ammunition with time fuzes was not the same as with impact point fuzes, the battery could make little use of high burst ranging, thus losing a method of fire adjustment which is often very convenient and advantageous.

These considerations caused the Caliber Board at the end of the World War to lay down the requirements which fuzes for ammunition of post-war design should meet, and the Ordnance Department undertook the task of providing them. A few years ago the work done was reviewed, the whole matter restudied and the Point Fuze System was evolved. Its most important feature is that it makes point fuzes ballistically and mechanically interchangeable to the maximum possible extent. This is brought about by making all point fuzes to a standard external contour and weight, and by standardizing the boosters to correspond. The standard contour was made to accord with modern projectile shape, particularly the 75 m/m, with provision with proper operation of time fuzes in modern fuze setters. All fuzes with their attached boosters are likewise standardized in weight. There are only two models of booster, and these differ only as necessary to function properly when used in guns and howitzers respectively. It will be appreciated that the Point Fuze System is one of the most important ammunition developments since the World War.

The specific type requirements laid down by the Caliber Board have been somewhat revised and extended and the following are now required types. (The models not available to meet these requirements are shown in parenthesis.)

a. A combination superquick and delay impact fuze. (T16)

b. A combination superquick and delay impact fuze. (Low arming resistance for howitzers). (T16E1)

c. A combination superquick and time fuze with burning time of 25 to 30 seconds (T14)

d. A mechanical time fuze for anti-aircraft use with burning time of about 30 seconds. (M43)

e. A time fuze with burning time of about 77 seconds, if possible with provision for impact function (to be used for high burst ranging). (T17)

f. A combination instantaneous and delay fuze for large caliber projectiles, of the false ogive type. (T16E1 adapted)

Longitudinal Section of Point
Detonating Fuze T16

The Point Detonating Fuze T16 was developed under the Point Fuze System to fill the first requirement above, a combination superquick and short delay impact fuze. It is issued assembled to the shell with its standard M20 booster, and may be readily set for delay or superquick action as desired.

The fuze consists of two unit assemblies, a superquick element and a delay element, with an interrupter between the superquick element and the detonator. These unit assemblies are themselves standardized and interchangeable. The superquick element is similar to that of the Mark III, except for improvements in the firing mechanism and the upper detonator. The firing mechanism is a development of one which has been used by the Ordnance Department in experimental work since the early 1900's. Its distinctive feature is the substitution of a collapsible cap for the shear wire and the placing of the firing pin head in a recess protected by a diaphragm. The upper detonator is so small that if accidentially fired it will not fragment the head of the fuze, and it transmits its impulse to the detonator by means of small metallic particles instead of by a detonating wave. There is a clear passage down the center of the fuze for these particles, except for the interrupter.

The interrupter is identical in principle with that in the Mark III fuze, but has the additional feature of being controlled by a setting sleeve. When the sleeve is in one position the interrupter is free to function in a normal manner and a clear passage is open to the detonator, giving superquick action. When the sleeve is turned 90° it locks the interrupter in the unarmed position, preventing explosion of the detonator by the superquick element and giving opportunity for the functioning of the delay element by its own firing mechanism which is operable at either setting. The fuze may thus be set either for superquick or delay action at will.

The T16E1 fuze is identical with the T16, except that with the low rotation obtained with howitzers it has been found necessary to provide a lock to keep the delay action plunger in the armed position.

Longitudinal Section of Combination
Superquick and Time Fuze T14.

The Combination Superquick and Time Fuze T14, which fills the requirement for a fuze of this type, has the standard superquick element in the point, and in the body of the fuze a powder train time element. This powder train element was developed from the old 21-second train, the most important improvements being the use of outside venting, the recessing of the felts between the setting rings, the use of setting grooves instead of lugs on the time-rings for greater reliability and the addition of a pull pin through the concussion element to insure safety in handling and trasnportation. The arming resistance is lower than that of the 21 second combination fuze in order to permit use in low zones of howitzers. It should be noticed that the powder train fuze lends itself to combination with a superquick element for the reason that an open passage down the axis of the fuze can be readily provided. This is not the case with the mechanical time fuze because of the fact that the escapement must also be on the axis of the fuze.

Longitudinal Section of 25 Second
A. A. Time Fuze T13.

Notwithstanding the development of antiaircraft mechanical time fuzes, some lack of certainty as to sufficient production of them in time of war has resulted in the provision of an antiaircraft powder train fuze. The T13, which is being held against the possibility of such a need, contains simply the time element just described for the T14 but without the superquick element of the latter. An antiaircraft fuze should obviously be so arranged that it will not function on impact if the time element fails.

Longitudinal Section of A. A.
Mechanical Time Fuze, M43.

Mechanical time fuzes are not entirely new. The Chelsea and the Waltham are two that were given extensive trial by this country during and after the World War. These were similar to a Krupp type tested prior to the War. But great difficulty was experienced in obtaining a fuze which would be both satisfactory in functioning and capable of being produced in quantity. The right to reproduce the Junghans, a German design, was acquired and from it were developed the Antiaircraft Mechanical Time Fuze M2 and finally the present M43, which successfully meets both the technical requirements mentioned.

The basis of this fuze is a movement somewhat resembling that of a watch, designed to be both rugged and easily manufactured, and with a very rapid escapement. It has a maximum running time of 30 seconds and is intended for antiaircraft fire, for which reason it contains no impact mechanism. It gives very precise results and its timing is not affected by altitude. It represents a realization of aims which have been pursued for a long time.

Longitudinal Section of Combination
Mechanical Time Fuze T17

This was developed to fill the requirement for a fuze for high burst ranging. In artillery fire there is frequently a need for an adjustment point which can be put up by the firing battery at any time and at any range desired. An air burst meets this need and adjusting fire on such a point is called high burst ranging. High power artillery requires for this purpose a fuze of much longer time than the regular time fuze, and this must be a mechanical fuze as it has not been possible to produce a satisfactory powder train fuze with a burning time as great as 77 seconds. It is desirable but not absolutely necessary that this fuze function also on impact.

The Mechanical Time Fuze T17 is as much like the M43 as it can be made. It was necessary to change one gear to obtain the greater running time, and to modify the safety elements to secure arming in large guns and howitzers in which the setback and rotational forces are comparatively low. An attempt has also been made to satisfy the requirement for inclusion of an impact firing mechanism.

Longitudinal Section of Point Detonating Fuze T18.

The foregoing covers all the fuzes for which there is any requirement at present. It is of interest to note, however, that a number of simplified assemblies of the components contained in the Combination Superquick and Delay Fuze T16 are possible. There is no official requirement for any of these but it is possible that there may be an emergency requirement for certain single-purpose fuzes which can be so made up. If the delay element of the T16 is simply omitted there results a Single-Purpose Superquick Fuze, the T18. An obvious use for such a Single-Purpose Superquick Fuze is in chemical shell, which are issued fuzed and in which a delay element is entirely wasted.

Should a single-purpose delay fuze be required, it could be had simply by omitting the superquick element of the T16 fuze, or alternatively by replacing the unit assembly delay mechanism of that fuze with a simple delay element in line with passage from the superquick element. This latter assembly gives the Single-Purpose Short Delay Point Detonating Fuze T24.

Longitudinal Section of Booster M20.

All the foregoing fuzes used alone give initiating action. When used in high explosive shell in which detonating action is required, a booster must be added. The standard Booster M20 is a self-contained unit in which the booster, the detonator, and the detonator safety mechanism have been incorporated. It screws on any of the fuzes described. Detonator safety is secured by placing the detonator in a rotor whose axis is offset from that of the unit itself. The arrangement is such that only when the rotor is in its armed position is the detonator in line with the tetryl pellet to the booster and able to transmit a detonating wave to it. Until the moment of firing the rotor is locked in the unarmed position by a centrifugal pin controlled by a setback pin; the rotor is again locked after arming to prevent failures when a fuze giving delay action is used. The whole mechanism resembles that contained in the Base Detonating Fuze, Mark X.

The lower-zone charges of large howitzers do not give sufficient setback to arm the device just described. Therefore, in the Booster M20E1, issued for use in such calibers, the rotor is locked with a straight centrifugal pin, and also by a cotter pin which is removed before the assembly operation. Large caliber shell are fuzed with arrangements of this sort for the reason that only in small calibers are the forces on the fuze great enough to permit an automatic device to be transportation-safe and also certain in action. It is also difficult to pack large caliber projectiles sufficiently well to avoid damage to the fuze mechanism. Only small caliber shell are issued fuzed.

EMERGENCY FUZES.

Longitudinal Section of Point
Detonating Fuze, M46

The Point Detonating Fuze Mark III was the best fuze used during the World War, and in fact was one of the outstanding developments of the war. Its principal defects were its arming mechanism and its excessive length, which made shell fuzed with it unstable at the lower velocities. On account of its simplicity and availability it was the fuze in which the superquick element described under the Point Detonating Fuze T16 was developed. The resulting Point Detonating Fuze M46 was thus a by-product of the development of later fuzes. It functioned extremely well.

There being on hand a large number of loaded Mark III Fuzes and component parts for same, and also a large quantity of wartime shell which would be the first used in emergency, the T19 was standardized as the M46 and is now the standard for use with wartime shell when superquick action is desired. To meet the need for a corresponding short-delay fuze, a suitable delay element was inserted in the body of the M46 fuze above the detonator giving the Point Detonating Fuze M47.

Longitudinal Section of Point
Detonating Fuze M47

At the beginning of an emergency the shell and fuze used would be those then available. As manufacturing programs get underway these would be changed to the latest adopted types. All components of ammunition, however, will not become available with equal promptness and, therefore, any program for ammunition issue must include a schedule of models for issue in accordance with the components available at each epoch. The above row of figures shows the various combinations which could be made of the fuzes, boosters, and shell which will be available in 75 m/m caliber. From left to right they show the various combinations which will be possible as the various components of the ammunition become available. The first is the present standard assembly. Of the other assemblies shown, except the last, the only one likely to be supplied is either the fourth or the fifth. The fourth has the advantage of slightly greater simplicity of manufacture, but the fifth is practically interchangeable ballistically with the sixth or final type.

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SECTION L

EXPLOSIVES

In artillery ammunition, the principal uses for explosives are -

a for bursting charges in projectiles and bombs.

b for expelling charges in shrapnel.

c in booster charges for carrying the detonating wave from the detaonator to the bursting charge proper.

d in detonators for initiating the detonating wave.

e in the delay elements and time trains of fuzes.

For each of these uses there are required explosives which have suitable characteristics and the characteristics required vary with the uses. In some instances, the required characteristics are of directly opposing natures. It is therefore evident that a number of explosives will be required for the production of artillery ammunition and that each must be carefully selected to meet the requirements of the purpose for which it is to be used.

Bursting Charges.

For the bursting charges of projectiles, the explosive which has been used longest in our service is Ammonium Picrate (Explosive D). This explosive is amply insensitive to withstand the shock of setback in the gun and even the shock of impact on armor plate when loaded in projectiles of the largest calibers. Its most undesirable characteristic is that it cannot be melted and cast into the cavities of the projectiles. It must instead be pressed into place and this requires elaborate and costly facilities. It is therefore now only used to form the bursting charge for armor piercing projectiles for which use, however, owing to its extreme insensitiveness to shock, it has not yet been displaced.

For the bursting charges of high explosive projectiles and bombs, where the shock that must be withstood is less, the standard explosive for some years has been TNT (trinitrotoluene). This explosive melts at a temperature that is above that which is ever reached by the atmosphere and below that of boiling water, and it can therefore very readily be loaded into the cavities in projectiles and bombs by the melting and casting method.

Very large amounts of TNT would be required to make up the bursting charges for all the artillery projectiles and bombs that will be required in a major emergency. Considerable delay will be encountered in developing the necessary production of toluene and in the erection of new facilities for the manufacture of TNT. It is therefore necessary either to provide for "stretching" the available TNT by mixing with it some other explosive or to provide substitutes which may be used in place of TNT at such a time.

During the World War, "stretching" was resorted to, the stretching medium being Ammonium Nitrate and the resulting mixtures being called "Amatol". Mixtures of two proportions were used; that is -

50/50 Amatol being 50% NH_4NO_3 with 50% TNT

80/20 Amatol being 80% NH_4NO_3 with 20% TNT

The 50/50 Amatol, when hot, is fluid enough to be poured into the cavities in the projectiles and bombs, and for all practical purposes may be considered the equivalent of straight TNT as a shell and bomb filler. The 80/20 Amatol, on the other hand, while it is plastic when it is heated, cannot be poured. The difference in fluidity is due to the fact that only the TNT content of the mixture melts in the process of heating. It must therefore be loaded into the projectiles and bombs by the hand tamping method or by means of machines especially constructed for the purpose. For use in fragmentation projectiles and bombs, it must be considered as being inferior to TNT, but when used in missiles whose principal function is demolition, it will compare favorably with straight TNT. The principal advantage of the 80/20 mixture is the large amount of TNT which is replaced by the Ammonium Nitrate. It is planned to again use these mixtures for bursting charges at any time that a shortage develops in the supply of TNT.

Ammonium nitrate, because it can be produced in greater quantity and at a lower cost than any other explosive, is the most important of all explosives. Other explosives and processes are important chiefly as they make ammonium nitrate suitable for various uses.

Projectiles loaded during the World War with straight TNT and 50/50 Amatol, especially when stored in a warm climate, in many cases exuded a thick brown liquid. This exudate has been found to consist of low melting mixtures of TNT with various substances which were present in the charges as impurities. Investigation has indicated that projectiles which exhibit this exudation are, as a general rule, not dangerous to use but are prone to detonate with low order and even to fail to detonate at all. These investigations also indicate that if the TNT which is used is limited to that which is sufficiently pure to have a solidifying temperature of at least 80.2°C., and certain precausions are observed in the loading, these exudation troubles will be eliminated.

Although the supply of toluene available from by-product coke ovens appears to be sufficient for military requirements, there is a very considerable commercial requirement for toluene, which must be met, even in war time. Furthermore, although new processes for the production of toluene by (1) the hydrogenation of petroleum, (2) the polymerization of petroleum refinery gases, (3) polymerization of propane and butane obtained from casinghead gases, and the "cracking" of petroleum products, have developed rapidly during recent years, none of these processes are as yet producing toluene in large quantities. While there is no reasonable doubt that an ample supply of toluene can be made available in an emergency, time will be required to construct the necessary facilities for its production as well as for its conversion to TNT. It is therefore likely that if Amatol is used wherever possible, there will be a shortage of TNT during the early months of an emergency. To provide a substitute for use particularly during this period, an explosive known as "Tridite" has been developed. Tridite is an eutectic mixture of trinitrophenol (picric acid) and dinitrophenol which can be poured when heated. In its action it may be considered the equivalent of TNT. Its principal advantage is that the facilities required for the manufacture of its constituents are relatively simple and can be provided quickly and that the raw materials from which they are made are readily available in large quantity. It cannot have other than emergency use because of the difficulty and hazard of loading, which arises from the highly poisonous nature of dinitrophenol.

Expelling Charges for Shrapnel.

The explosive used in the base charges of shrapnel for expelling the balls from the case, has always been and still is, black powder. The black powder used for this purpose differs from commercial black powder in that it contains potassium nitrate instead of the cheaper sodium nitrate instead of the cheaper sodium nitrate which is used in the manufacture of the latter. It is, as a result, less hygroscopic and it explodes with greater brisance.

Booster Explosives.

During the World War, Tetryl (trinitrophenylmethylnitramine) was adopted by the Ordnance Department as the standard booster explosive. Experience with this explosive since that time has shown it to be highly satisfactory for the purpose. Manufacture of this explosive was started in the United States during the World War, and much of the product made at that time was not in the crystalline form considered most desirable. Since then, the manufacturing process has been perfected and the stocks of tetryl left in the hands of the Ordnance Department at the end of the World War were reworked before being loaded into ammunition. A small plant for manufacturing tetryl by the improved process is now in operation at Picatinny Arsenal. Sufficient facilities for the manufacture of tetryl in wartime can be found.

Detonator Explosives.

The initiating explosive used by the Ordnance Department in detonators, has for years been mercury fulminate. This explosive has several deficiencies which have long been recognized. Furthermore, the mercury required for its manufacture is a strategic material. For a number of years, a more or less active search has been conducted to find a satisfactory substitute. Lead Azide has been used for this purpose in Europe for a number of years and has, according to all reports, given very satisfactory results when properly made and used. Its use by the Ordnance Department was prevented by the circumstance that it was not manufactured in this country and the Ordnance Department did not care to purchase the process and install the necessary manufacturing facilities just to supply its own small requirements. In 1931, lead azide became commercially available in this country and experiments with its use in artillery ammunition were immediately inaugurated. These experiments have been very satisfactory, indicating that detonators made with lead azide will be more efficient and less subject to deterioration than those in which mercury fulminate is used. Lead azide is not, however, suitable as an initiating explosive to be set off by shock or friction, as in primers.

Powder for Delay Elements and Time Trains.

Up to the present time, the only material which has been used with any success in delay elements and time trains is black powder in some form. Its principal deficiencies for this use, stated in general terms, are that (1) its normal burning rate is faster than is desired, and (2) its burning rate varies with the temperature and the pressure under which it burns. Many attempts have been made to produce powders having improved burning characteristics. These attempts have involved such things as (1) altering the proportions of the three normal constituents of black powder, sometimes accompanied by the addition of other constituents; (2) substitution of other materials for one or more of the standard constituents of black powder; (3) altering the manufacturing process; (4) development of powders of an entirely different chemical nature. These attempts have, however, as yet produced nothing more satisfactory than (1) the standard black powder having substantially the composition -

Potassium Nitrate - 75%

Charcoal - - - - - 15%

Sulphur - - - - - 10%

with the addition of a very small amount of inert material to act as a slowing agent, and (2) a powder of substantially the above composition in which powdered coal is substituted for the charcoal. These compositions alone, or blends of the two, are being used until something better is developed.

Powders having more desirable burning characteristics than those just described are greatly needed by fuze designers, and research work with a view to their development is actively under way.

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SECTION M

PROPELLANTS AND PROPELLING CHARGES

PROPELLANTS:

The relatively short perforated grain is characteristic of our propellent powders, no other major power employing it as standard. Control of the burning characteristics of powder in this form is readily accomplished by altering the number of perforations (usually one or seven) and the initial burning area. The latter is varied by controlling the size of the grain and thus the average thickness between the principal burning surfaces (the outer surface and the surfaces inside the perforations).

The chief advantage of the short-grain type is that it can be put through the principal manufacturing operations, particularly the blending procedure, with very great facility as compared with the long-grain types. Also it can be loaded readily, or stored in bulk in simple containers. The main disadvantage in its use is in connection with its ignition, the random orientation of the short grains offering a baffling effect to the ignition flame. This difficulty can be minimized by improvements in the design of the ignition system, and in large caliber guns, by "stocking" the grains (see "Propelling Charges for Major Caliber Guns" below).

Although the short perforated grain is our standard design, it may be expedient to utilize the strip grain form for light cannon in the early stages of an emergency. This type of grain can be made on rolling machinery already in use in certain commercial industries. Such a plan will maintain the supply of powder needed while the plants for producing the standard types are being expanded.

The straight nitrocellulose composition of the smokeless powder used prior to and during the World War has been improved upon in recent years. This earlier type, although relieved of as much as practicalbe of its ether and alcohol in the manufacturing process, gradually loses more of this residual solvent during its service life This loss of solvent introduces appreciable changes in the ballistic properties of the powder. Furthermore, the regular nitrocellulose powder is more hygroscopic than is desirable, the absorbed moisture also affecting ballistic properties as well as hastening decomposition by hydrolysis.

The Caliber Board, which met at the end of the World War to make a study of the armament, calibers, and types of materel and ammunition for use of a Field Army, recognized the need for developing powders with improved characteristics. Their report recommended the development of relatively non-hygroscopic powders, with muzzle-flash elimination also desirable in all weapons where practicalbe.

MUZZLE FLASH:

A great deal of study and experimental work has been done to determine the causes, general nature and methods of avoiding muzzle flash. It is now known that this phenomenon is the burning of the emitted hot gases after they mix with the oxygen of the air. It is thus related to the inflammable nature of the gases (chiefly CO), to the temperature of these gases, and to the deficiency of oxygen in the smokeless powder composition itself. Accordingly there are several methods of attacking the problem of preventing or eliminating the occurrence of muzzle flash from cannon.

Even though a large amount of work and study has been put into the effort to develop flashless powders for all cannon, it has been found that in weapons above the medium calibers the extra amount of smoke inevitably produced is as troublesome as the muzzle flash had been. Hence the practice at present is to use essentially the same composition in all weapons where it is suitable ballistically. The primary merit, then, for such a composition is its relatively non-hygroscopic property. The additional desirable feature, flashlessness, is enjoyed in the following weapons:

37 m/m Gun, M1916

75 m/m Gun M1897

75 m/m Pack Howitzer

105 m/m Howitzer

105 m/m A. A. Gun

155 m/m Howitzer

Beginning with the 155 m/m Gun, the approved compositions are non-hygroscopic (NH) but not flashness (FNH). Also in the 3" A. A. Guns flashlessness has not been achieved without producing undesirable quantities of smoke. As a general rule it may be said that the tendency to produce muzzle flash is greatest in the weapons of larger caliber and higher power.

PROPELLANT FOR TRENCH MORTARS:

The standard type for Trench Mortars is an easily-ignited fast-burning flake powder. The total charge is contained in from 4 to 6 celluloid capsules which are designed to fit securely into "seats" between the fin blades at the rear of the projectile.

Development work is in progress to improve upon the design of the entire propelling charge, with a view to avoiding the tedious work of hand-assembling such a design as capsules. It might also be added that some difficulty has been experienced with the capsules cracking in storage or handling, and with lids coming partly or wholly unsealed, spilled powder resulting in either case.

The design which has given very promising results in tests to date consists simply of sheet powder cut into discs of such size that the discs themselves fit into the fin "seats", without the necessity for any container at all. Extensive handling and storage tests, as well as ballistic performance tests, are planned for this disc type to completely determine its suitability.

PROPELLING CHARGES FOR MAJOR CALIBER GUNS:

An outstanding improvement in ballistic performance of major caliber propelling charges was achieved some years ago by adopting the "stacked" charge, where the individual powder grains are mechanically placed in layers with their logitudinal axes parallel to that of the charge itself. This design betters the ballistic uniformity perhaps largely by facilitating the passage of igniting flame and hot gases from end to end of the entire charge. Furthermore, the compactness of the charge leaves space for the free flow of these gases around the outside of the charge.

The stacked type of charge has been adopted for guns of 8 inch and greater caliber, except in one or two minor instances where other practical considerations outweigh ballistic performance.

PROPELLING CHARGES FOR FIELD HOWITZERS:

A propelling charge plan of issuing two designs of charge for each size of howitzer was developed some years ago, and has worked out very satisfactorily indeed. In the case of a 7-zone weapon, for example the 155 m/m Howitzer, the two designs may be described as follows:

(a) A charge for zones 1 to 5 only, employing a much quicker powder granulation than could be used in the full 7-zone charge. The result is greatly improved ballistic uniformity - particularly in the lowest zones.

(b) A charge for zones 5, 6 and 7 only, employing the regular granulation of powder. The zone 5 section is made up in one bag, thus greatly simplifying the manufacture of the charge.

Both types (a) and (b) are issued for use in the field, in the proportions which are estimated as reasonable from tactical considerations. The ratio for purpose of war reserve supply has been set at two charges of type (a) and one charge of type (b).

MISCELLANEOUS OTHER SEPARATE-LOADING PROPELLING CHARGES:

The smaller seacoast guns use chiefly laced core-ignited type charges. The 12 inch mortars have zoned charges, the Model 1890-1908 employing an aliquot-part design of charge. The 240 m/m Howitzer uses an aliquot part charge. The 16 inch Howitzer has a special base-increment type of charge, the base section being loaded and handled separately from the increment sections. A full charge consists of a base section and 3 increment sections.

The 155 m/m gun uses a base-increment type of charge, but here the two are tied together. Each section is wrapped tightly to produce a firm charge of uniform diameter throughout its entire length.

Quite recently the ballistic performance of this weapon has been considerably improved by a slight increase in the potential of the NH powder, the exact composition now being the same as that already used in the major-caliber weapons. The increase in potential of the powder permits a lowered weight of charge and therefore a propelling charge of decreased diameter. This appears to improve ignition conditions considerably, as the early production lots of this design have given excellent velocity uniformity.

PRIMERS AND FIXED AND SEMI-FIXED AMMUNITION:

The adoption some time ago of the flexible system for primer designs has proven quite practical. In this system there is only one type of primer-head, percussion-element. Onto the threaded portion of this head is screwed the igniting element or body part, loaded with black powder. It is this igniting element which is the flexible feature of the assembly, as its design can vary over a wide range to fit the requirements of the propelling charge to be ignited. The length of the primer body and the size and spacing of the vents can be varied over wide ranges. Also the loading of the body with black powder has some flexibility.

By the above described means the general igniting effect of the primer can be controlled to meet the conditions with each propelling charge. The intensity and point of delivery into the powder charge are, of course, the principal flame characteristics which affect the ballistic performance of the round.

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SECTION N

BOMBS AND BOMB FUZES

Bombs to be dropped from aircraft are among the newest of military weapons. At the beginning of the World War they were almost unheard of. Four years later they were in daily use by all belligerents in many different forms and had definitely demonstrated their usefulness. The earliest bombs were little more than tin cans filled with dynamite and they were simply thrown overboard by the pilot or observer. The developments, however, went ahead very rapidly and by the time of the Armistice all belligerents were using bombs specially constructed and loaded for the purpose, stabilized by means of fins to improve the accuracy of their flight, and equipped with fuzes which contained safety features designed to prevent premature or accidental explosion. As the sizes of the bombs increased it became necessary to provide specially constructed bomb racks for attaching the bombs to the planes and for releasing them at the proper time.

By the Summer of 1918 the British were using bombs weighing 1600 lbs. for attacking industrial centers, harbor works, etc. The railroad station in Karlsruhe is reported to have been destroyed by one of these bombs. The rapidity with which this development work was carried out naturally did not permit great refinement of design to be attained.

After the close of the war work was undertaken to develop materiel embodying the improvements which experience in the manufacture and use of the war time material had shown to be desirable.

For the purpose of this discussion, it is convenient to classify bombs according to the effects they are designed to produce, into the following classes:

a. Fragmentation

b. Demolition

c. Chemical

d. Practice

Fragmentation Bombs.

Fragmentation bombs of war time construction were usually made of cast iron, the fragmentation of which was poor and the bombs were inefficient. The best fragmentation bomb of war days was the 17-lb. Mk. II, which is still the limited standard type and which was made from rejected 3-inch artillery shell. As this was made of forged steel and was particularly designed for effective fragmentation, the efficiency was relatively high. The present standard 30-lb. M5 bomb is formed by cutting rings from heavy walled steel tubing, and assembling them over a thin walled metal tube which contains the explosive. It will be obvious that such construction establishes in advance two dimensions, width and thickness, of the fragments obtained on explosion, thus resulting in much greater uniformity in fragment size, with great increase in the efficiency of the bomb. An alternative method of construction of the bomb body is to employ a spirally wound coil made from rolled bar stock, the effectiveness of which is found to be just as good as the body made from rings. These bombs are stabilized by means of fins and are intended for use in high altitude.

Slide No. N-1
(Ordnance Photo No. 8135)
Section of Bomb Fragmentation, 30-lb., M5.

The tactics of attack aviation in conducting bombing attacks at very low altitudes requires the use of a bomb which will permit the plane to get out of the danger radius of its own bombs prior to their detonation, and at the same time insure their functioning in the most effective position on the ground, - that is, vertically. Numerous efforts to meet this requirement have finally resulted in the development of the parachute type bomb which can be released safely at altitudes of from 70 to 100 feet by planes traveling at 200 to 250 miles per hour with practical certainty of effective functioning of the bombs on the ground, and with safety to the bombing airplane. The parachute also secures functioning of the bomb in a nearly vertical position, in which position it is four or five times as efficient as when horizontal. The present bombs for this purpose are the 17 lb. T2 and T2E1.

Slide No. N-2
Section of Bomb Fragmentation, Low Altitude, T2E3

<u>Demolition Bombs</u>.

Demolition bombs used during the war were of the streamlined type, such contour being considered desirable for stability in flight, and consequent accuracy. Typical bombs of this type are the 100-lb. to 1100-lb. bombs shown at the left in Slide No. N-3. The difficulty of manufacturing satisfactory bombs of this type led to experiments with bombs of cylindrical shape, the early forms of which are typified by the 2000-lb. and 4000-lb. bombs shown at the right in Slide No. N-3.

Slide No. N-3
(Ordnance Photo No. 8139)
Demolition Bombs of World War and
early post war designs.

Since the war the design of stabilizers, or fins, for bombs has been developed to the point where the streamlined shape is no longer found necessary. As a result, cylindrical bodies have been adopted for all the later designs of demolition bombs. An example of the newest design of cylindrical bomb with the latest type of stabilizing fin is the Demolition Bomb, 600-lbs, M32, which has been adopted as standard and which is shown on Slide No. N-4.

Slide No. N-4
(Ordnance Photo No. 8148)
Demolition Bomb, 600-lb., ~~M32~~.71

The present standard methods of manufacturing bomb bodies are the "pierced billet," as in shell manufacture, and the "cupped plate," as in the commercial manufacture of gas cylinders. Other methods of manufacture such as welding circumferentially nose and tail forgings to a longitudinally welded tube or cylinder, or swaging in a commercial seamless tube to form the nose and tail sections of the bomb have been and are being investigated, and are considered promising.

The advantages of the present construction over the streamlined built-up type formerly used are:-

(a) Greater strength due to eliminating of numerous and inefficient welded joints and seams.

(b) Easier to maneuver in transporting and in the field.

(c) Easier to procure under war time production, as the facilities of the tube, pipe and welding industries in common use are utilized.

(d) Great reduction in cost of procurement due to simplicity of design and utilization of commercial facilities.

The 4000-lb. bomb shown in Slide No. N-5 is believed to be the largest ever actually built and tested by any nation. It has not been standardized since there appears to be no present need for a bomb of this size and power. The destructive effect produced by this bomb can be more or less judged by the crater it produces as shown in Slide No. N-6. The destructive effect of several bombs of lesser size, with the increased chance of hitting the target which is provided by carrying several bombs instead of one, have thus far eliminated the 4000-lb. bomb from serious consideration by our Air Corps.

At the present time our standard demolition bombs are the following:

100	pound	M-30
300	"	M-31
600	"	M-32
1100	"	M-33
2000	"	M-34

Slide No. N-5
(Ordnance Photo No. 8138)
Demolition Bomb, 4000-lb.)

Slide No. N-6
(Ordnance Photo No. 8137)
Crater produced by 4000-lb. Demolition Bomb.

Chemical Bombs

Longitudinal Section of
Chemical Bomb, 30-lb., M1.

There is at present the chemical 30-lb., M1 bomb for use by attack aviation and it contains slightly more than 30% HS. This bomb was designed under the requirement that it must be capable of safe-dropping on ordinary soil from 7000 feet, which requirement explains the comparatively low weight of filler.

Practice Bombs

A comprehensive system of practice bombs has been planned which will provide for training in all phases of the gunnery of bombing. For this system the following are required.

a. Practice bombs for training in marksmanship.

b. Practice bombs for training in operation of bomb racks.

c. Practice bombs for training in loading the bomb racks on airplanes.

d. Service bombs for final training.

Slide No. N-7
Photo of Bomb Practice, 100 lb., M38.

For practice in marksmanship, a non-explosive and comparatively cheap bomb which can be used without danger on ranges of restricted size, that can be made available at nearly all Air Corps stations, and that can be supplied in relatively large numbers with the funds that are made available for practice bombs, is desirable.

A practice bomb successfully filling these requirements was first made of sheet metal and designed to be filled with water. A small bottle of smoke-producing compound in the tail assembly marked the location of the hit with a smoke cloud.

This idea has now evolved into the present limited standard 100-lb. practice bomb, M38. This bomb weighs empty only 14 pounds, and when filled with wet sand approximately 92 pounds. A bottle containing 2 pounds of FS is assembled in the tail end of the bomb; on impact the bottle breaks and liberates the FS, marking the spot where the bomb struck by a cloud of smoke.

Longitudinal Section of Bomb
Practice 100-lb.,M38A2

As the above described bombs are not fitted with fuzes they cannot provide training in the operation of bomb racks, a training which experience has shown to be very necessary. To provide this training the bomb, practice, 100-lb., M38A2 was designed. This bomb embodies a number of slight structural changes from the M38, and in addition is provided with a sleeve in the rear end to receive the spotting charge assembly M1A1.

This assembly consists of a can containing 2-1/2 pounds of black powder to which a simple arming pin type fuze is attached. The M38A2 practice bomb weighs approximately 95 pounds when loaded with dry sand, and tests indicate that it gives excellent results.

Longitudinal Section of Bomb, Practice, 17-lb. M37.

The 100-pound practice bomb fills the needs of the Air Corps for practice bombs for high altitude, but there remains a requirement for a practice bomb for use by attack aviation. The bomb, practice, 17-pound, M37, is supplied for this purpose and appears to be quite satisfactory.

It is obvious that means for training inexperienced personnel in the loading of bombs onto aircraft without endangering the lives of such personnel must be provided. This is done by issuing standard bombs and fuzes which are loaded to weight with inert material in place of explosives. These inert loaded bombs can, of course, be used repeatedly.

The types of practice bombs which have just been described provide materiel for preliminary training in all phases of the gunnery of bombing, the final training, however, must be obtained with live bombs, and for this the standard service bombs and fuzes will be issued.

Bomb Fuzes.

The earlier post-war demolition bombs are usually equipped with both nose and tail fuzes in order to insure certainty of functioning. The Nose Bomb Fuze, Mk. VIIMII has been standard for some time, for demolition bombs of the Mk. III and modified Mk. I types, together with the Tail Fuze, Mk. VMI. With these fuzes, primer detonators of the Mk. IIB type are employed, either the Instantaneous or the 0.1 Second Delay being used with the nose fuze. Only the short delay (0.1 Sec.) primer detonator is used with the tail fuzes, since the purpose of the latter is only to insure detonation in case of failure of the nose fuze.

Slide No. N-9
(Ordnance Photo No. 8144)
Fuze, Bomb, Nose, Mk. VIIMII, and
Primer Detonator

Both of these fuzes are equipped with safety features to prevent functioning until the bomb has fallen a very short distance from the airplane, and also to permit dropping the bombs with fuzes unarmed so that no detonation will occur on impact. This is desirable in case it becomes necessary to release bombs over friendly territory due to plane trouble. Another fuze, the Mk. XIV, quite similar to the Mk. VII fuze in design, but of smaller size and lighter construction, is employed with the standard fragmentation bomb.

Slide No. N-10
(Ordnance Photo No. 8145)
Fuze, Bomb, Tail, Mk. VIII, and
Primer Detonator

These fuzes require that the booster be assembled to the bomb when it is loaded. This causes trouble and expense if the bursting charge should exude. They also make use of a separate primer detonator which makes the fuzing of the bombs a more or less hazardous operation. These and other minor undesirable features have made it desirable to develop new fuzes to take their place.

One of these is the Nose Fuze, M103, which is designed for use in all sizes of bombs of the cylindrical type. It contains a selective instantaneous or 0.1 second delay feature, eliminating the separate loading primer detonator employed with the Mk. VII type of fuze, which has always constituted somewhat of a hazard with the latter type. The new fuze contains the booster as a component part, and also the detonator-safe feature is incorporated, which means that the firing pin is not in line with the primer and the detonator not in line with the booster until the fuze is actually armed. This fuze has been standardized. It also provides for a much longer delay in arming than the Mk VII MII type.

Slide No. N-11
Section of Fuze Bomb, Nose, M103

The companion to the nose fuze M103 is the tail fuze, M100, M101, or M102. The designations M100, M101, and M102 merely indicate three different lengths of fuze stem required to permit its use with the various sizes of bombs, the fuze being identical in all other respects for all bombs from the

100-pound to the 2000-pound, that is, all sizes of bombs of the cylindrical type. It provides for only one setting, 0.1-second delay, like the Mark V fuze which it is intended to replace, and eliminates a separate primer detonator employed with the latter. It also provides for a much longer delay in arming than the MkV MI type.

Slide No. N.-12 ,3125
(Ordnance Photo No. ~~2129~~)
Fuze, Bomb, Tail, M100, M101 & M102.

Future Development.

A joint Army and Navy Committee has unanimously agreed that the present standard army 600 pound and 1100 pound bomb cases and the navy 500 pound and 1000 pound cases be replaced in both services by newly designed 500-pound and 1000 pound cases. The proposed designs, which were prepared in the Ordnance Office have outside dimentions and wall thicknesses corresponding to standard tube and pipe sizes. The Ordnance Department is changing the design of its present 100 pound and 300 pound bomb cases so that standard tubing to correspond to standard sizes of pipe and tubing may be used in their manufacture; therefore, all standard demolition bombs in our army, except the 2000 pound, will be so designed.

It has also been agreed that the suspension lugs of all demolition bombs, manufactured in the future by both army and navy be of such design that complete rounds of army and navy bombs could be carried interchangeably on army and navy bomb racks.

SECTION O

PYROTECHNICS

Use of the art of pyrotechny in war has pursued a devious course through many centuries. Although known from very early times, far antedating the development of gunpowder, the musket, and cannon, pyrotechny fell from the position of high importance, which it occupied in Asiatic and Greek warfare, practically into oblivion. Modern chemistry and the stimulus of the last war, which established a great need for pyrotechnics for visual signaling and illumination, have resulted in not only setting up military requirements for pyrotechnic signals and illuminating flares, but have permitted considerable progress in this art.

Flares.

The development of military aviation has demonstrated the need for flares for use in night operation. Up to the present time requirements for four (4) types of aircraft flares have been established. These types are:

(a) The Landing Flare, for illuminating the ground in case of a forced landing outside an airdrome or in case of a landing on an airdrome where ground illumination is not provided.

(b) The Reconnaissance Flare, for use in illuminating the ground for a short time with sufficient light to enable the observer to judge whether a closer examination is necessary.

(c) The Observation Flare, for use in making a detailed examination of the ground being reconnoitered.

(d) The Bombardment Flare, for illuminating targets that are being attacked by bombardment from high altitudes.

Landing Flares

This was the first type of flare whose development was undertaken. The first model to be adopted for service use was the Mark I, of which a large number were actually used by the Air Corps. Experience with this first model indicated a number of improvements that could be made and the Aircraft Parachute Flare, M3, was developed to embody these improvements. This flare was used in large numbers with good success, not only by the Air Corps but also by the old Air Mail Service. Experience again showed up defects and advances in the art indicated that improvements could be made.

Developments resulted in the M8 Flare which is a self-contained unit, and met the requirements of the Air Corps for a high-powered long-burning flare that may be carried on, and released from either special flare adapters provided by the Air Corps, and which carry the flare vertically inside the airplane structure, or from standard bomb racks or special horizontal suspension type flare racks installed either outside or inside the airplane. It provides illumination of 300,000 candlepower for 3 minutes, the most effective illumination being obtained when released at altitudes of between 1500 and 2000 feet.

The M8 Flare, as originally adopted, was intended only for use as a landing flare, and consequently, not designed to withstand release at high speeds. Subsequently the Air Corps requested that all airplane flares furnished in future be able to withstand release at the highest speeds of which their airplanes were capable. Recent modifications to the parachute connections have made it possible to secure reliable functioning at air speeds of 210 miles per hour.

Further improvements of the flare have been made. Certain new illuminant compositions, designated W2 and W5, emit a soft yellow light which is unusually efficient in revealing fine detail, and which also penetrates the smoke of the flare and thus corrects the dark spots in the illumination which were formerly caused by the smoke. The W2 composition, when loaded into the candle case of the M8 flare, has a candlepower of about 800,000 and a burning time of about two minutes, while the W5 composition in the same loading gives a candlepower of about 430,000 and a burning time of three minutes.

A number of the recent improvements have been adopted for production lots of flares. Among these are a metallic sheathing for the flare (to increase its serviceability and its life in storage), a shock absorber and cotton shroud lines of 100-pound strength for the parachute, and an illuminant of the W5 composition. The improved flare is designated M8A1.

Slide No. 0-1
(Ordnance Photo No. ~~8162~~ 1326)
Flare, Aircraft, Parachute, M8A1

Reconnaissance Flares.

To meet the requirement for a flare to give, for a short time, illumination sufficient to enable the observer to distinguish the general festures of the ground under him, Flare, Aircraft, Parachute, M9, has been developed. This flare gives about 80,000 candlepower for about one minute. It weighs only about 2 pounds, and is fired from the Pistol, Pyrotechnic, M2, which is described later. (Both the projector and flare are shown on Slide No. 0-5.) These festures enable a comparatively large number of flares to be carried for preliminary reconnaissance in addition to the larter observation flares required for the detailed reconnaissance, and which must be carried on special racks installed on the airplane.

Efforts are being made toward increasing the candlepower of this flare, while maintaining the present time of burning of one minute. The use of a composition, which emits a yellowish white light on burning will be investigated. The use of this composition will increase the candlepower from 80,000 to about 125,000.

Observation Flares.

For the more detailed reconnaissance there has been developed the Flare, Aircraft, Parachute, Observation, T6. This flare is identical with the M8 Landing Type Flare, with the exception of the illuminating composition which is designed to produce approximately one million candlepower for about one and one-quarter minutes. The weight is about the same as that of the M8 Flare; i.e., 17-lbs.

Bombardment Flares.

For tactical reasons it is desirable to illuminate a target being attacked by bombardment from high altitude by a flare dropped from a plane in the bombardment formation. Since the intensity of light on the ground varies inversely as the square of the altitude of the light source, it is necessary to place the flare near the ground while the plane which releases it may be at a height of 10,000 feet or more. To accomplish this, the Aircraft Parachute Flare, T3, has been developed. It is equipped with a time fuze which functions at a predetermined time after release of the flare from the plane.

The fuze is usually set to function when the flare has fallen to an altitude of about 3000 feet above the ground. When the fuze functions the parachute opens and suspends the flare and at the same time the candle is ignited. The candle develops about one million candlepower and burns for about two minutes.

Slide No. C-2
(Ordnance Photo No. 8131)
Flare, Aircraft, Parachute, T3.

Two types of time fuzes are available for use with this flare; i.e.

(a) The Time Fuze, T9, which is a modification of the 21-second Artillery type powder train fuze. It provides for settings of from about 7 to 20 seconds, thus permitting a fall of approximately 800 to 7000 feet before functioning the flare to which it may be fitted. It is now used for training only, since a mechanical fuze, believed desirable for such application, is still under development. This fuze will permit the use of the flare from much higher altitudes.

Slide No. 0-3
Fuze, Flare and Bomb, T9

(b) The Mechanical Time Fuze, T-10, which is constructed by modifying an obsolete type 75-second artillery fuze of Waltham design.

Slide No. 0-4
(Ordnance Drg. No. P-20046)
Fuze, Mechanical, Flare and Bomb, T-10

A pilot flying over water can distinguish no fixed features of the surface from which he can estimate his drift. To provide him with the means of putting down such a point at will, a drift signal is supplied. When this signal strikes the water the fuze is functioned, and the signal, floating at the surface, emits a dense smoke.

Pyrotechnic Signals.

During the World War the principal items of materiel used for pyrotechnic signalling were rockets, V. B. Cartridges and the Very Pistol and its signal cartridges. These war-time pyrotechnics were essentially "fireworks" insofar as their quality was concerned, and it is not surprising that under the conditions of military service they proved to be insufficiently reliable for such service.

The rockets could of course be used only by ground troops and in such use were found to be cumbersome and to have the disadvantage that they disclosed the position from which they were sent up. The Very Pistols and Cartridges were used both by ground troops and aircraft. They were found to be unsatisfactory for both uses because of their low light intensity, developing only some 200 to 300 candlepower. Furthermore, for satisfactory use from the ground their height of projection was not sufficient and the hangfires which were of common occurrence made their use in airplanes dangerous. Since the War a large amount of work has been done to develop pyrotechnic signalling materiel to the same standards of reliability of functioning, safety and stability in storage as are required of military ammunition.

Early in this work it was thought that signal cartridges could be developed which could be used both for projection from aircraft and for projection from the ground with only minor modifications to fit them to the appropriate projectors. It was, however, soon found that there were certain peculiar requirements to be met in these two conditions of service which were so different that the use of identical materiel would not be made to serve for both. This has resulted in the development of two different types of materiel.

Pyrotechnic Signalling Materiel for Aircraft Use.

The distinguishing requirements for pyrotechnic signalling materiel for aircraft are:

(a) The signals need only to be projected to a distance great enough to clear the airplane itself.

(b) The materiel must be such that in case of malfunctioning there will be no danger of setting fire to the airplane or its occupants.

(c) It must be capable of being operated in the dark with one hand which is inclosed in a heavy flying mitten or glove. These characteristics are possessed to a high degree by the pyrotechnic signalling materiel which has been adopted for aircraft use. This materiel consists of the Pistol, Pyrotechnic, M2, and the signal and flare cartridges which are fired from it. These items are shown on Slide No. O-5.

Slide No. O-5
(Ordnance Photo No. 8147)
Pistol, Pyrotechnic, M2. Signal, Aircraft, Parachute, M10. Flare Aircraft, Parachute, M9.

Pyrotechnic Projector for Aircraft Use.

The Pistol, Pyrotechnic, M2, has a barrel with a bore 1-1/2 inches in diameter and 2-1/4 inches long. It has no trigger guard and pressure on the trigger both cocks and fires the piece. The signal cartridge which contains the propelling charge and primer and the signal itself, fits loosely into the barrel of the discharger and is held in place by a simple latch which can be released by pressure of the thumb on a button on the outside near the top of the grip. The cartridge extends beyond the end of the barrel of the projector as much as may be necessary. The cartridges are carried in racks mounted in the plane with their bases exposed and are loaded into the pistol by simply placing the barrel over the exposed base. The signal is then discharged over the side of the cockpit. In case of malfunctioning of the signal the whole cartridge can be dropped overboard by simply pressing on the release button already mentioned, thus eliminating any danger to the operator or the plane.

Signal Cartridges for Aircraft Use.

At present two types of air-signal cartridges are standard for use, the Signal, Aircraft, White Star, Parachute, M-10, and the Red Star, M-11. These signals burn for about 35 seconds, with a candlepower of 20 to 30 thousand and are visible under good atmospheric conditions for a range of several miles.

Pyrotechnic Signalling Materiel for Ground Use.

The distinguishing requirements for pyrotechnic signalling materiel for ground use are:

(a) The height of projection must be great enough to permit the signal to be seen by observers

Slide No. O-6
(Ordnance Drg. No. 78-2-119)
Projector, Signal, Ground, M1.

Signal Cartridges for Ground Use.

Three types of signals for ground use have been adopted, the Signal, Ground, White Star, Parachute, M-5; Red Star Cluster, M-6, and Red Chain, Parachute, M-7. The Yellow Smoke, Parachute, and the Red Star, Parachute, types have been service tested with good results. These signals when projected to a height of 400 feet furnish good visibility over moderate ranges. The construction of all these signals is identical with the exception of the pyrotechnic element itself, which of course varies with the kind of signal it is desired to produce. A typical construction is shown on Slide No. O-7.

A great amount of research, experimenting, and testing have been done in the effort to supply a greater variety of signals, employing different colors and signals differing in character as well as color, such as blinkers, clusters, etc. This work is still in progress.

Slide No. 0-7
(Ordnance Photo No. 8128)

Signal, Yellow Smoke, Parachute, Ground, T1.

SF 6507

SECTION P

AUTOMOTIVE

GENERAL REMARKS

The delivery in quantity to the using arms during the past two years of tanks and combat cars has placed in their hands the necessary tools for testing the old and formulating new tactical doctrines covering the employment of modern high speed combat vehicles. This they have done to the maximum extent possible to date, both by routine use and by participation in extensive maneuvers. These major maneuvers, combined with numerous local problems and exercises are rapidly disclosing the capabilities and limitations inherent in these new weapons, and it is possible some radical changes in tactical conceptions will occur. Such changes will result in new engineering requirements, since in the present vehicle the characteristic of high speed has directly determined the use of components of light weight and minimum factor of safety. Information gained by experience has to some extent resulted in changes being incorporated in vehicles to better adapt them to tactical requirements. The need for considerably heavier armor, which is gradually crystallizing, will result in heavier suspensions and tracks, at some sacrifice in speed.

The present review gives information on the vehicles constructed to date; from these the tendencies which have thus far been governing can be seen. As to the steps which have so far been taken to provide heavier armor, the light tanks manufactured in the fiscal year 1938 are provided with thicker plate, and the Medium Tank T5, now under development, is designed with adequate factors of safety to permit a decided increase in armor thickness without altering the basic design.

RECONNAISSANCE VEHICLES

Slide No. 8410

Scout Car M1

Slide No. 10652
Scout Car M2

Slide No.11844
Scout Car M3

Slide No. 11810

Scout Car T13

For certain tactical uses there is a very definite requirement for automotive vehicles capable of travelling over bad roads and occasionally over rough country. Such a vehicle would be demanded for some reconnaissance missions, for communication purposes and for numerous other uses. Early developments in vehicles for such uses were based on light commerical passenger cars equipped with large section balloon tires. Development of this type has been turned over to the Quartermaster Corps by order of the War Department. The latter types of cars developed are Scout Cars M1, M2 and M3.

The Scout Car M1, is a 1-1/2-ton 4-wheel, 4-wheel drive commercial truck chassis with a radiator guard of 1/4" armor plate, body of 1/4" armor plate, and windshield of 1/2" armor plate. The body is open at the top and extends to a height slightly above the shoulders of the men seated in the car. A ground type caliber .50 machine gun, for use by the man seated to the right of the driver, is mounted with a pedestal mount on the right running board and provision is made for using the right front door as a shield when operating this gun. Bracket mounts are located on the two rear doors to provide for firing caliber .30 ground type machine guns against either ground or airplane targets. A bracket mount, centrally located on the rear body plate, provides for firing either the caliber .30 or caliber .50 gun to the rear. A trunk at the rear of the vehicle is used for the transportation of the necessary equipment. A light, quickly removable canvas top, with side curtains, is provided. The weight of the vehicle loaded is about 9,000 pounds.

A later design standardized as the M2 was further modified and designated M2A1. Further improvement of the design resulted in the present standard M3 Car.

In the later cars, provision has been made for carrying the fuel outside the car body in armor protected tanks. The armament is carried on mounts which run on a track mounted inside the hull plates near the top and extending entirely around the tonneau. The forward position is raised to provide for firing forward. This arrangement provides for movement of the mounts to any desired position and clamping them in place during firing. The gross weight is about 9650 pounds. These later types less armament are also being used as personnel carriers and as the basis of 4.2" mortar motor carriages.

Scout Car T13 is generally similar to the M3 Car. It is based on a lighter 4 x 4 chassis, utilizes soft steel in place of armour plate for body plates, is equipped with the same type of guns and mounts to provide for all around fire as in the case of the standard cars issued to the regular Army. This vehicle is provided for National Guard use only, primarily for training purposes.

Slide No. 10645

Light Tank M2A2

Light Tank M2A2E2

Slide M2A3

The light tank M2 is the result of development carried on with the Light tanks of series T1 to T6, inclusive, and T2 with the controlled differential steering system and volute spring suspension system. The power plant of the Light Tank M2 is a radial aircooled engine of 267 brake horsepower selected as a result of test conducted with this type of engine in the Combat Car T2.

The armament of this vehicle consists of a caliber .30 machine gun and caliber .50 machine gun in a combination mount in a single turret, and a caliber .30 machine gun in the bow plate; or two turrets, one mounting a caliber .50 machine gun and the other a caliber .30, and the bow gun as before. The single turret model was standardized as Light Tank M2A1, and the dual turret design was standardized as Light Tank M2A2. The tanks produced in the fiscal year 1938 of the dual turret type are an improved model of this type, designated M2A3. This model has heavier armor, longer track, more favorable weight distribution and better accessibility to engine compartment and to track adjusting mechanism.

Three production light tanks, M2A2, powered with the Guiberson 1020 radial Diesel engine, were tested at Fort Benning, Ga. with highly satisfactory results. As a result of these tests and the recommendation of the Chief of Infantry, a limited number of tanks and combat cars with furhter development of the Guiberson Engine are being procured this fiscal year for further service test.

The design and manufacture of the Pilot Light Tank M2A2E2 has been completed and the vehicle is now undergoing proving ground test. This tank has incorporated in it many improvements over the production light tank M2A2, the most important of these being: (a) New outboard steering brakes, not located in the transmission case, (b) New suspension units, and (c) Heavier armor. It is believed that these major changes will be successful, though some minor changes will be required.

Slide No. 10692

Light Tank T3

Though called a light tank, this is an original design, quite different from anything else in our service. It weighs 3-1/2-tons, less than one-half as much as our other light tanks. It is a two-man tank of extremely low silhouette, very fast and maneuverable. It is equipped with one machine gun in a ball mount, which can fire in only a limited field to the front. Except for the absence of a turret, this tank is generally similar in construction to the M2 series of light tanks or the M1 series of combat cars. It can be given either a volute spring suspension or a rubber torsion suspension. Its engine, a Ford V-8, is a high production, easily procurable automobile engine instead of a radial aircraft engine of limited production.

Slide No. 6380

Armored Car M1.

The Armored Car M1 is a 6-wheel, 4-wheel drive vehicle, the design of which was based on several years of development work and experience with several types of cars. It embodies a new principle in armored car construction, that of the use of the structural strength of the armor plate hull to replace the normal chassis frame. This construction is advantageous in two ways - it reduces the weight of the vehicle materially, and results in a low silhouette conforming more nearly to the ideal specification in this respect. The principal mechanical units are of commercial manufacture, and the ratio of power to weight is considered extremely good. Disadvantages brought out by test are lack of traction in front wheels and obstruction of driver's vision by the long and relatively high armor plate hood. Twenty of these vehicles are in service. The armament consists of a caliber .30 machine gun and a caliber .50 machine gun in a combination mount in the turret and a single caliber .30 machine gun in the front plate to be operated by the man at the right of the driver. The car is equipped with a powerful radio set for both sending and receiving.

The mechanical brakes with which these vehicles were equipped having proved unsatisfactory, hydraulic brakes have been installed in all the vehicles in service.

Slide No. 10649

Armored Car T11E1

Slide No. 10783
Armored Car T11E2

As a result of technical and tactical tests of the Armored Car M1, a 4-wheel, 4-wheel drive design, known as the Armored Car T11, was developed. The principles of using the structural strength of the armor plate body, in place of a chassis frame, and of incorporating in the design the maximum proportion of commercial units, are employed in this design as in the Armored Car M1. The armor plate protection and the armament are equivalent to those provided in the M1 design. The driver has been located in the front of the vehicle and 4 wheels, all driving, are used instead of 6 wheels, 4 driving, as requested by the using service. This design was satisfactory for the Cavalry and a total of seven T11E1 Cars were procured for issue.

One Car, T11E2, incorporating several changes and improvements was procured for test after further development work at the Aberdeen Proving Ground. This car uses a heavy duty commercial engine and is equipped with turret similar to those used on Cavalry combat cars.

After thorough tests, the use of Scout Cars in lieu of armored cars has been recommended by the Chief of Cavalry and approved by the War Department for both the mechanized Cavalry and the horsed Cavalry Division. The requirement for armored cars, therefore, no longer exists.

Slide No. 10691

Combat Car M1

Pilot Combat Cars of convertible or full track types were developed concurrently. Tests of these pilots resulted in the selection and standardization of the full track type as Combar Car M1.

The armament consists of 1 caliber .50 and 2 caliber .30 machine guns, one of the caliber .30 guns being mounted in the front plate of the car and operated by the man sitting at the right of the driver. An improved type for 1938 fiscal year production is designated Combat Car M1A1. Improvements in this model include provision for better armor protection, increased length of track and better location of center of gravity, more accessible engine and track adjusting mechanism, and more stable gun platform. In addition, three production Combat Cars M1 were manufactured, using the Guiberson 1020 radial Diesel engine in place of the Continental R-670 radial gasoline engine, for service test. These vehicles are designated Combat Car M1E1. Various other models of this series represent development projects in improved suspensions and Diesel drive.

Combat Car T7

Although the full track type combat car was standardized, the development of the convertible type has been continued and the design and manufacture of a Pilot Combat Car T7 has been completed. This design is based on a hull structure substantially identical with that used in the Combat Car M1: the use of the same power plant and transmission system with the addition of the elements necessary to provide for driving the rear wheels when operating as a wheeled vehicle; and the application of a suspension system suitable for a convertible vehicle. An interesting feature of this pilot is the use of pneumatic tires in place of the solid or cushion tires employed in earlier models.

MEDIUM TANKS

Slide No. 8406

Medium Tank T3E2

The Medium Tank T3E2 is a convertible vehicle and is the result of experience had with the Medium Tank T3 (Christie). The vehicle weighs 15 tons fully equipped and is powered by a Curtis D12 engine which, as modified, delivers about 450 brake horsepower. It is designed for use where greater offensive power than that of the light tank is required. Its armament consists of a 37 m/m Gun, Model 1916, and Caliber .30 Machine Gun in a combination mount in the front of the turret, 3 Caliber .30 Machine

Guns in the rear part of the turret and an additional Caliber .30 Machine Gun in the right side of the bow plate. This type is now undergoing extended service test at Fort Benning.

Slide No. 10646

Medium Tank T4

Slide No. 10982

Medium Tank T4E1

This vehicle was developed originally as the Combat Car T4, and then taken over by the Infantry, with a few minor changes, as the Medium Tank T4. In test and in service, these vehicles developed defects in road brakes and in tracks, and studies are in progress on designs for correcting these.

Three (3) Medium Tanks T4E1 have been manufactured at Rock Island Arsenal and shipped to Fort Benning. This tank is the same as Medium Tank T4 except that the revolving turret of the latter is replaced with a barbette turret containing 1 Caliber .50 and 4 Caliber .30 Machine Guns.

Since the fire power, crew, and protection afforded by the T4 type of tank are no greater than those of the Light Tank M2A2 (with its decreased weight and cost) the Infantry has recommended that no further vehicles of this type be manufactured.

<u>Slide No. 11932</u>

<u>Medium Tank T5</u>

This is a new design of a full track medium tank of 15 tons approximate weight. The power train is generally similar to that of the Light Tank M2, and the running gear is also similar except that three bogies are used instead of two. A pilot vehicle has been tested at the Aberdeen Proving Ground and by the Infantry Board. The pilot tank was enthusiastically received by the Infantry Board and the Chief of Infantry recommended its standardization. The development of this type is being pushed with the view to supplying the higher performance characteristics and heavier armor protection which the using arm consider necessary in this type of tank. The production vehicles for fiscal year 1939 will be designated Medium Tank M3.

TANK TRAINERS

Tank Trainer T1

There is under manufacture two machines to be used for the training of drivers and gunners of tanks and combat cars. This trainer consists of a foundation upon which a framework is mounted in such manner that it may be caused to pitch and roll to simulate the motions of a tank travelling across country, the pitch and roll being controlled by the instructor. On this framework is mounted a hull simulating that of the tank or combat car, including the proper turret or turrets, suitable for training a combat vehicle crew. A Ford V-8, 60 horsepower engine is mounted in the rear of the body structure and connected with clutch and transmission as used in light tanks and combat cars. Provision is made for applying load to the power train under the control of the instructor.

TRACKLAYING TRACTORS

Slide No. 11763

Light Tractor M2

Commercial tractor manufacturers are continuing to supply tractors for test as new models or major improvements develop. As the result of these tests the Caterpillar 25, the Cletrac 25, the International Harvester T-20, and the Allis-Chalmers Model M, Light Tractor, all of about 25 horsepower, have been listed as suitable to fill the requirement for light military tractors. In the medium tractor field the Caterpillar RD6, Allis-Chalmers 35, Cletrac 35, and International

Harvester TA-40 TracTractor have been listed as satisfactory for military purposes. In the heavy class the Caterpillar RD7, Allis-Chalmers Model L, and Cletrac Model 80 are listed as satisfactory. The maximum speed of these tractors has been increased so that the high gear ratios now provide for speeds in the neighborhood of 8 miles per hour.

<u>Marmon-Herrington Tractor</u>

<u>Model TA-30</u>

Marmon-Herrington Tractor

Model TA-20

The Ordnance Department has procured and subjected to proving ground test two light tractors made by the Marmon-Herrington Company, the Model TA-20 and the Model TA-30. These small, light, high speed tractors use Ford V-8 engines of 60 and 85 horsepower, respectively, and have Goodrich continuous rubber band tracks. These are being investigated to determine their suitability for towing loads such as the 75 m/m Howitzer, or commercial pneumatic tired trailers for the transportation of such military loads as mortars, machine guns, and ammunition. They also appear generally suitable for the draft of antitank guns. Wheeled tractors of comparable power have also been investigated.

<u>Medium Tractor M1</u>

<u>Slide No. 6877</u>

Four (4) Medium Tractors M1 have been procured and issued to the Coast Artillery. This vehicle is the standard Caterpillar RD6 Diesel Engine Tractor with the addition of military accessories. They are the first Diesel powered tractors issued to the regular army and are strictly in accordance with the U. S. Army Specification for Medium Tractor M1, except as to top speed requirements.

<u>Slide No. 8325</u>

<u>Heavy Tractor M1</u>

The Caterpillar Tractor Company has submitted for test an RD7 Diesel engined tractor meeting every requirement of the U. S. Army specification for Heavy

Tractor M1. This test demonstrated conclusively that heavy commercial tractors can be easily modified so as to meet all the requirements of the present specification. This vehicle has been listed as satisfactory under current U. S. Army specifications for heavy military tractors.

Light Tractor T3E4

The Light Tractor T3, series weight approximately 3-1/2 tons, is an Ordnance Department development to satisfy a request of the Chief of Field Artillery for a modern high speed light tractor for use as a prime mover with divisional artillery. Various modifications of the tractor, principally in the track and suspension, resulted in the T3E1, T3E2, T3E3, and T3E4 models. The performance of these tractors in proving ground and service tests at speeds up to 25 miles per hour has been excellent, and indications are that this design, which follows the Ordnance Department policy of using the maximum of available commercial components, such as engines, transmissions, final drives, etc. will be successful.

At the present time six of the T3E4 model are undergoing service test.

<u>Slide No. 10887</u>

<u>Light Tractor T5</u>

One (1) Light Tractor T5 was manufactured at Rock Island Arsenal for the Air Corps, and is now in use at Wright Field, Dayton, Ohio. This vehicle weighs 2600 pounds and can be transported in the bomb bay of certain bombing planes. Provision was made for adding sand ballast of 1300 pounds, making a total weight of 3900 pounds. It is powered with a Ford V-8 engine, 85 horsepower, has a rubber suspension and continuous rubber band tracks. It has given very satisfactory performance.

Slide No. 10781

Medium Tractor T1.

The Medium Tractor T1, gross weight 16,000 pounds, is in general similar in construction to the light tractor T3E1. It is powered with a General Motors 707 engine. The gross weight is 16,000 pounds including a pay load of 2000 pounds. This tractor tows a 10,000 pound load at speeds up to 30 miles per hour. A unique feature, included as the result of experience with high speed track-laying tractors provides for selective independent control of the brakes on the towed load, by the tractor driver, when required by operating conditions.

This tractor has passed arsenal and proving ground tests, and is now undergoing service test under the Field Artillery Board at Fort Bragg, North Carolina.

Slide No. 11739

Heavy Tractor T1

The Heavy Tractor T1 is a coordinated design of the Caterpillar Tractor Company and the Ordnance

Department. It consists of a Diesel power plant as regularly used in the Caterpillar RD-7 tractor, mounted in a special frame designed for the adaptation of the standard volute suspension, idlers and tracks used on production light tanks M2A2. The tractor weighs 21,000 pounds and special gearing gives it a top speed of 21 miles per hour. It is also undergoing service tests by the Field Artillery Board. The remarks concerning the air brake system of the Medium Tractor also apply here.

MACHINE GUN CARRIERS

Slide No. 6974

Half Track Car T1E1

In connection with the mechanization of Cavalry regiments a need has developed for a vehicle which can travel on roads at speeds up to 35 miles per hour or across country at speeds up to 18 miles per hour, and be able to perform both these functions without the loss of time involved in changing the running gear. To meet this requirement a Half Track Car T1E1 was produced which consists of a special chassis and body powered by a Cadillac V-8 engine and a half track mechanism developed by the Cunningham Company. This vehicle is based on the Half Track Car developed in France by Citroën. These cars were supplied in limited quantity for extended service test in mechanized cavalry organizations.

Numerous types of joints have been tried on the rubber block track used and the effort to improve its performance is continuing. A rubber band type of track which is produced by the Goodrich Rubber Company has also been tested. This type is very interesting because of its substantially less resistance to traction than any jointed type so far tested, but it affords less traction on soft ground.

LIGHT CARGO CARRIERS

Slide No. 9695

Light Cargo Carrier T2

This vehicle, shown on the above slide, after undergoing service test at Fort Benning competed in tests conducted by the Infantry Board to determine a suitable carrier for that service. It is based on the tracklaying chassis of the Light Tank M2 or Combat Car M1. A body suitable for cross-country transportation of such cargo as ammunition, fuel oil, and some types of armament is used instead of a tank hull.

Slide No. 12002

Light Cargo Carrier T5

The Light Cargo Carrier T5 (sometimes called the Light Infantry Carrier T5) is based on the chassis of the Light Tank T3E1, using parts originally manufactured for that vehicle, such as power plant, transmission, final drive, suspension, tracks, controls, and the lower part of the hull, the only new part being a cargo body. It was designed for transportation on the battle field of infantry combat loads, but may also be used as a light tractor. An unusual feature is its power plant, a 4-cylinder Menasco Model C-4 aircooled aircraft engine of 125 horsepower.

<u>Personnel Carrier, Half Track, T7</u>

The Scout Car M2 less armament has been used to some extent as a personnel carrier. One of these vehicles is being modified by the application of a half track mechanism to provide an armored vehicle for transporting machine gun squads and equipment. This pilot is designated Personnel Carrier, Half Track, T7.

MORTAR MOTOR CARRIAGES

Slide No. 8941

4.2" Mortar Motor Carriage T2

This vehicle, which is of the full track type and mounts the 4.2" chemical mortar, performed very well for an entirely new design. The pilot has been delivered to the Chemical Warfare Service for test.

Slide No. 10784

4.2" Mortar Motor Carriage T5

This motor carriage is a 1-1/2-ton light 4 x 4 chassis with a body to transport the 4.2" chemical mortar and special mount, 4 men, 46 rounds of mortar ammunition, and 1 machine gun and mount for protection against ground troops and aircraft. The mortar carriage is designed to provide for changing from travelling position in the body to firing position on the ground in one minute.

4.2" Mortar Motor Carriage T5E1

The T5E1 Mortar Motor Carriage is a vehicle based on the Scout Car M2A1. In other respects it is much the same as the T5.

The wide diversity of types at present under test in this class of vehicles is notable.

HALF TRACK TRUCKS

Slide No. 7132

Half Track Truck T1

The Half Track Truck T1 is the first of a considerable line of vehicles embodying the application of the track and suspension principles to truck chassis. This is a commercial standard truck chassis of about two tons cargo capacity intended to provide a light prime mover of the half track class for divisional artillery. The vehicle is commercial standard throughout except for the rear axle which is made especially to provide a final drive of suitable design and ratio for propulsion of this type of vehicle. In the pilot an attempt was made to use substantially the same track and suspension as employed in the half track car, but test showed that a track of more substantial design was required.

HALF TRACK TRUCK T2

Slide No. 7103

The Half Track Truck T2 is very similar in design to the T1, except that it is based on a Ford truck chassis which is equipped with a Ford V-8 engine. This vehicle was developed by the Cunningham Company and submitted to the Proving Ground for a brief intensive test. Its performance, considering the size and power, was considered very satisfactory. The Cunningham track supplied was one of the first to give a really long life, perhaps 5,000 miles.

Slide No. 7989

Half Track Truck T3

The Half Track Truck T3 is a commercial vehicle developed by the Linn Manufacturing Corporation. It is far greater in size and power than the T1 and T2, since it wieghs 25,000 pounds and is powered by an American-LaFrance 240 horsepower V-12 engine. The test of this vehicle at the Proving Ground indicates that it is capable of handling heavy artillery loads under practically any terrain conditions likely to be encountered with this type of equipment. The vehicle is rugged, capable of transporting up to 10 tons of cargo and at the same time of towing a heavy load under favorable road or terrain conditions. For military test it is rated as a 6-ton cargo vehicle when towing heavy artillery loads. It is capable of speeds up to 15 miles an hour fully loaded on favorable terrain. Six (6) trucks of this model have been given a service test as prime movers for the 155 m/m Gun - 8" Howitzer Carriage. Service tests have shown that this commercial item is not particularly well adapted for use as a prime mover for heavy artillery.

Slide No. 10651

Half Track Truck T6

A slightly lighter and somewhat less powerful vehicle otherwise similar to the T3 was tested. It is designated Half Track Truck T6.

Slide No. 8411

Half Track Truck T4

The Half Track Truck T4 (wire laying) is essentially the same as the Half Track Truck T1 except for necessary body modifications to adapt it to the requirements of the Signal Corps.

Slide No. 9061

Half Track Truck T5

The Half Track Truck T5 is a somewhat larger and more powerful vehicle than any of the preceding pilots. It was designed to provide for transportation of the Field Artillery equipment attached to the mechanized Cavalry but is rather heavy for use with 75 m/m materiel. It is a very rugged and powerful vehicle, equipped with a General Motors 400 cu. in. engine of about 120 h.p. and having an allowable speed of 38 miles per hour.

Considerable trouble was experienced with rapid wear of tracks. This was partially corrected by the use of tracks 10" wide instead of 8" but complete correction of the trouble was not attained until the width of bogies and track rollers was also increased. The vehicle as improved is designated T5E2. Its only defects now appear to be insufficient ground clearance and absence of front wheel drive.

Slide No. 12668

Half Track Truck T9

The Half Track Truck T9 is an attempt to provide a light, readily procurable half track truck. Its principal features are the Ford V-8 engine, the provision of a front wheel drive, high ground clearance, and Goodrich rubber band tracks. These tracks give minimum rolling resistance which is necessitated by the small engine used, but their traction on soft ground is inferior to that of jointed track. The basis of the truck is the Marmon-Herrington 4-wheel drive 1-1/2 ton chassis.

Slide No. 11748

Half Track Truck T9E1

Two (2) Half Track Trucks T9E1 have also been procured. These are identical with the Half Track Trucks T9 except that 2-wheel bogies are installed instead of 4-wheel bogies. These two T9E1 trucks, with two T9 trucks, are now undergoing service test at Fort Knox, Ky.

MAINTENANCE VEHICLES

Slide No. 12613
Machine Shop Truck M2

Slide No. 12615
Tool and Bench Truck M1

Slide No. 12614

Welding Truck M1

The Machine Shop Truck M2 was developed to provide a suitable repair vehicle for use in mechanized organizations. This vehicle is based on a 4-wheel 4-wheel drive chassis rated at a carrying capacity of 2½ tons, and the vehicle gross weight is limited to 15,000 pounds. The body provides a floor area 10 feet long, 7 ft. wide, which is increased by sides and tail gate 24 inches high which are so designed that when the vehicle is in use these are lowered to form extensions of the floor. The sidewalls and rear end of the body are deisgned to be raised to form a shelter for the working platform. The machine tool and hand tool equipment for this vehicle were determined by service test. It is somewhat along the lines of the old Light Machine Shop Truck M1 which was in general used by the Army, for many years, but especially selected for the maintenance of Ordnance materiel in the field.

Companion vehicles are the Tool and Bench Truck M1 and the Welding Truck M1, built on the same chassis. The Bench truck is equipped with necessary accessories for bench operations and for the transportation of hand tools and supplies. The welding truck carries a 300 amps. gasoline electric welding set and oxy. acetylene welding equipment. This truck is also provided with bench facilities and portable electric tools.

<u>Slide No. 12463</u>
<u>Heavy Wrecking Truck M1</u>

A Heavy Wrecking Truck M1 has also been standardized. This is a 6-wheel 6-wheel drive truck capable of carrying an additional pay load of 1 ton. Mounted on the frame is a 5 ton power crane having 100% overload capacity with an integral winch of 7-1/2 tons single line capacity holding 600 feet of 1/2 inch cable. Sideboards are provided for the platform body for carrying large tools or parts taken from disabled vehicles. Tool boxes are provided under the body at the sides of the vehicle for hand tools. A portable acetylene-oxygen welding outfit is carried and flood lights are mounted on the frame of the crane for night work. A pintle is also provided for towing service. Detachable tracks are provided for the rear bogie and the front wheels, enabling the vehicle to go any place other vehicles might go.

This truck is the result of extensive use of a similar vehicle known as the Experimental Wrecking Truck which has been in service at Fort Knox for some time and has been of great value in repairing disabled automotive vehicles or artillery in the field.

Slide No. 12611

Emergency Repair Truck M1

The Emergency Repair Truck is a 1/2-ton 4 x 4 truck with light repair truck body. Due to its light weight and large section tire equipment this vehicle has exceptional cross-country mobility.

Small Arms Repair Truck T7

The Small Arms Repair Truck T7 is made up of a 1-1/2-ton 4 x 4 chassis mounting a special type body, low type mounting with wheel wells. It is equipped with 1-1/4 K.W. generator set, work benches, drawers, cabinets, etc., a small bench grinder, a 1/4" portable electric drill with stand, and necessary small hand tools. The gross weight is limited to 5 tons.

Slide No. 12612

Spare Parts Truck T1

This vehicle is a $1\frac{1}{2}$-ton 4 x 4 truck chassis with special body of Ordnance design for the transportation of spare parts required for maintenance of Ordnance materiel in the field.

The body sides and the tail gate may be lowered to form a working platform and the side covers may be raised to form a protective covering. These side members when locked in the closed position retain parts in their proper compartments and prevent loss by theft. Space in the center of the truck between the storage bins is available for transportation of larger parts or bulky equipment.

Slide No. 12577

Tractor Crane 1 Ton T4

The Tractor Crane 1 Ton T4 is a tracklaying tractor carrying a crane. Its purpose is to facilitate handling of large bombs. The lift is 1 ton at 8 feet radius, and the boom is 16 feet long and has a swing of 260°. Hoisting speed is 45 feet per minute.

Slide No. 12491

Bomb Trailer T 14

Slide No. 12489

Saginaw 3 Wheel Bomb Trailer

The Bomb Trailer T14, a number of which have also been furnished the Ordnance companies serving Air Corps units, is intended for the transportation of a 1-ton load of bombs. It is a commercial trailer with platform body 4 ft. x 9 ft., 24 in. above the ground. It is also used for the road transportation of the light tractor T6.

Slide No. 12490

Light Tractor T6

The light tractor T6 is a commercial wheeled tractor of about 2 tons weight. It must be capable of towing the bomb trailer with a 1 ton load of bombs and of being transported over roads by the bomb trailer which in turn, is towed by a $1\frac{1}{2}$-ton truck.