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MANUAL

FOR

TRENCH ARTILLERY

UNITED STATES ARMY

(PROVISIONAL)

Part I

Trench Artillery

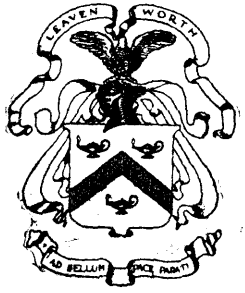
Reprint of pamphlet prepared at Headquarters American Expeditionary Forces, France, March, 1918

WAR PLANS DIVISION
JULY, 1918

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WAR DEPARTMENT,
WASHINGTON, *July 5, 1918.*

The following pamphlet, entitled "Manual for Trench Artillery United States Army (Provisional)—Part I, Trench Artillery," is published for the information and guidance of all concerned.

(062.1 A. G. O.)

BY ORDER OF THE SECRETARY OF WAR:

PEYTON C. MARCH,
General, Chief of Staff.

OFFICIAL:
H. P. McCAIN,
The Adjutant General.

MANUAL

FOR

TRENCH ARTILLERY

UNITED STATES ARMY

(*Provisional*)

Part I.—Trench artillery.
Part II.—Formations and maneuvers.
Part III.—6″ Newton trench mortar (British).
Part IV.—240 mm. trench mortar (French).
Part V.—58 No. 2 trench mortar (French).

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PART I

TRENCH ARTILLERY

CHAPTER I

HISTORICAL SKETCH

The earliest types of mortars of which we have a record were constructed of wooden blocks hollowed out and reinforced with iron bands, followed by types made of wood wrapped the entire length with wire. These mortars were about 10″ in caliber, 5 feet long, and fired a bomb made of wood. Ignition of the bursting charge in the bomb was accomplished by slow burning tape lighted by the propelling charge. Mortars made of metal next appeared. These were of various calibers and designs. Among them were the Coehorn Mortar and 10″ iron mortar used in the American civil war, 1861 to 1865.

At the beginning of the present war the Germans put into use their Minenwerfers, designed and built in 1911 and perhaps earlier, in anticipation of siege warfare. The weapons were highly developed as will be seen by reference to Chapter IX, Part I, of this series. To meet the condition imposed by trench warfare, development of types both by the French and English governments was rapid. The earliest types brought out by the French fired a projectile containing 13½ pounds of explosives and was easily manufactured. In December, 1914, the mortar known as the No. 1 *bis* was tested and in March, 1915, was sent to the front. At the same time came the 58 mm. No.2, which fired two bombs, a light one weighing 37 pounds having a range of 600 yards, and a heavy one weighing 77 pounds having a range of 350 yards. These mortars are still in use, the same as originally constructed, but many of them with improvements and modifications which enable them to be fired more rapidly and more accurately. Their efficiency as weapons has been much improved through the development of fuses, firing mechanism, etc.

The first English mortar was a 2″ smooth bore, firing a spherical shaped bomb having a cylindrical tail. The bomb weighed 51 pounds, contained 12½ pounds of high explosive, and had a range of 570 yards. Later came the 6″ Newton mortar firing a bomb with four vanes. It weighed 47 pounds and contained a 10 pound bursting charge. Many improvements have been made on the original type, and the latest weapon has a range of 1420 yards and can be fired at the rate of six rounds a minute under conditions which are only moderately favorable.

Both the French and the English governments developed larger and more powerful types of mortars during 1915, the

French type being known as the 240 mm. mortar and English type as the 9″.45 mortar. These types are very similar except that with the English 9″.45 mortar both the bomb and the charge are inserted at the muzzle, whereas with the French weapons the propelling charge is contained in a brass cartridge case which is inserted at the breech. These mortars have a range of 2,400 yards. In 1916, still a heavier mortar, 340 mm. in caliber, was developed and used to some extent. It fires a bomb weighing about 500 pounds containing approximately 220 pounds of explosive. Difficulty was experienced in getting a bomb of the proper design. This and the fact that this weapon is heavy and unwieldly have minimized its use until these difficulties are overcome. There have been various other types of mortars, such as the Van Deuren, the Doyen, the Fabry, etc., but none of these have yet come into extended use except perhaps the French 150 mm., which was used to some extent during 1916 and 1917.

Mention should be made of the English "Stokes" mortar. The ease with which this weapon, with its accessories, can be transferred from place to place, and its rapidity and accuracy of fire, have made it a very valuable weapon. The most advanced type of mortars in use at this date may be said to be the French 58 No. 2 (with possible addition of the new type of 150 mm. mortar) and the Newton 6″ as medium caliber weapons, and the English 9″.45 and French 240 mm. mortars as heaviest caliber weapons. The present tendency in further development of trench mortars lies in the improvement of platforms, bombs, and devices for pointing, by means of which greater accuracy and rapidity of fire can be obtained.

CHAPTER II

CHARACTERISTICS AND EMPLOYMENT OF TRENCH ARTILLERY

The trench mortar is essentially a trench artillery weapon of limited range which will render very efficient service only when properly emplaced and skillfully handled and served.

In normal trench warfare the role of trench artillery is to harrass the enemy by engaging living targets where opportunity offers, to attack and destroy enemy defensive works and obstacles within range limits, and to prevent the construction of new works.

The trench mortars are divided into three classes, light, medium, and heavy calibers.

The light trench mortar (3″ Stokes) forms a part of the equipment of the Headquarters company of each infantry regiment. There are 12 of these mortars to each infantry brigade, and 24 to each infantry division. They are under the tactical control of the regimental commanders.

The medium trench mortar (58 No. 2, French, and 6″ Newton, British) forms the equipment of the trench mortar battery of a division. There are 12 mortars to each battery. These batteries are manned by artillery troops and are under the tactical control of the artillery brigade commander of the division.

The heavy trench mortar (240 mm. French, and 9″.45 Newton, British) forms the equipment of the four batteries of the battalion of trench artillery assigned to a corps. Each battery is equipped with 6 pieces. These mortars are controlled tactically by the corps artillery commander.

The light trench mortar is very mobile. Its effect against materiel is inconsiderable, but it is particularly effective against massed troops, or troops driven into the open. Its rate of fire is very great.

The mediun trench mortar, with its range of approximately 1,200 meters and an explosive charge of from 6 to 10 kilos, is very effective against wire entanglements, machine gun shelters, strong points, trenches, and other similar objectives not too strongly protected.

The heavy trench mortar, with a range of approximately 2,400 meters and an explosive charge of 42 kilos, is designed for the attack of heavily protected shelters and dugouts, trenches, machine gun shelters and strong points. It may be used to supplement the fire of the medium caliber mortar. It is seldom used against wire because of the large crater formed by the explosion.

Medium and heavy trench mortars are included in the artillery plan for the organization of a sector. Owing to their limited ranges, and to the fact that emplacements are re-

quired for their installation and service, it is necessary that a thorough study be made, and a final decision be reached as to the targets to be attacked and the caliber of mortar to be assigned to each before it will be possible to determine the location of the batteries. This study will involve the questions of frontal, oblique and cross fires; concentration fire; flank protection; reserve batteries;. forward displacement for the medium caliber mortar; alternate emplacements; protection and camouflage; ammunition supply, and communications.

As soon as the battery commander is advised of his mission he proceeds to make a reconnaissance of his position for the purpose of locating his mortar emplacements; personnel and ammunition shelters; command and observation posts; communications, and ammunition supply.

Light mortars, as a rule, take little part in the preliminary bombardment, but are used to advantage to harrass the enemy in the final stages of the bombardment for which their rapidity of fire renders them particularly effective.

They are used to form a barrage behind the hostile line to prevent reserves and ammunition being brought up. Owing to their high mobility, limited only by the difficulty of ammunition supply, they are especially fitted to accompany the infantry as it advances, and are used to attack machine gun shelters and other points which have temporarily checked the forward movement of the infantry.

The medium trench mortars, not required for wire cutting, are usually not used until the last day of the bombardment, it being considered advisable to conceal them from the enemy as long as possible to prevent their possible destruction or neutralization. These mortars deal with all ordinary defenses which they can reach. They are especially effective against wire.

Once the assault has commenced the medium mortars are usually not required.

However, one or two mortars may be designated to follow up the attacking infantry to deal with objectives which the small caliber mortars cannot destroy, such as concrete machine gun nests and chevaux-de-frise. Owing to the weight of this mortar and its accessories, and the number of men required to handle them and ammunition, these mortars will seldom be able to go forward before dark. The battery commander should, however, make his reconnaissance by daylight to avoid confusion and delay later.

The heavy trench mortar takes part in the bombardment. Its fire is deliberate and must be continued until the targets have been demolished.

It is usually well to adjust the fire of these mortars during the first day or two of the bombardment, holding the fire for effect until the last possible day.

Because of the large area of explosive effect of the bomb used in this mortar, it will be seldom that its fire may be used to accompany infantry in the attack, while it will often be possible to use the medium mortar for this purpose.

The parts to be taken by the several calibers of trench mortars in the defense should be included in the artillery plan.

The light mortar should engage the enemy front trenches, sap heads, and other points at which he is likely to concentrate in order to isolate the attacking troops.

The medium mortar, with its slow rate of fire, will be of little assistance in breaking up the attacking forces, and if kept in too forward positions is liable to destruction or capture. They should, therefore, when not required forward for special mission, be kept in their permanent positions covering our first and second line fire trenches. From these positions they will be able to cover the hostile front and flanks and so engage the enemy during his attack. Should the enemy get a footing in our trenches, these mortars would be of great assistance in preventing him from consolidating the position, and they are also well placed to support our counter-attack.

The heavy mortar is designed for offensive work of destruction, and in case of an enemy attack may be used to bombard important points in his lines.

Too much stress can not be placed upon the problem of ammunition supply for the trench artillery. It is of great importance that a sufficient and steady flow of ammunition be arranged for in advance, and that it be maintained.

The duties of the trench artillery personnel is very trying and severe. They should be afforded all possible assistance in the construction of their emplacements and the supply of ammunition. Arrangements should be made for a portion of the men to be in rest until such time as all are required at the battery.

The trench artillery *is to remain in its position and fight its mortars* until receipt of orders to abandon the position. Should those orders come, mortars, ammunition and construction should be wrecked to avoid their use by the enemy.

CHAPTER III

BATTERY POSITIONS AND EMPLACEMENTS

The reconnaissance made by trench artillery officers should be preceded by a study of the map.

Within the limitations imposed by his mission, the battery commander is responsible for the proper selection of his battery positions. Wherever possible, the selection of sites should permit the arcs of fire of adjacent pieces to overlap; to allow the fire of several pieces or groups to be concentrated upon specially important points; and to make possible both cross and enfilade fire on such of our own trenches as might be carried by a hostile attack. Positions should be sufficiently far forward to allow of points in rear of the enemy first line being engaged without change of position, and yet so situated as not to interfere with the movement of our own troops in the trenches.

Positions may be prepared nearer the front line for the reception of the mortars, but not actually occupied until the situation requires the displacement. The subsequent advance in support of the infantry must always be kept in view.

In so far as possible care should be taken to avoid placing trench mortars close to important points in our own lines, as they usually draw the enemy fire as soon as discovered.

Observation posts should be provided in sufficient number to enable the battery commander to entirely cover the sector assigned to him. The location of these posts will depend largely upon the terrain. They are often combined with those of the infantry command, thus assuring a good field of view and a complete liaison.

The battery command post should provide a good field of view, sufficient cover, and be accessible.

The location of parks, ammunition dumps, temporary quarters, and the field kitchen is determined by the battery commander in his reconnaissance.

Experience has shown that about thirty days will be required to prepare positions for twelve medium or six heavy caliber trench mortars. This time may be reduced if conditions are favorable for construction.

In the selection of sites for temporary emplacements it should be remembered that those offering natural shelter or defilade are usually ones which are more or less prominent as landmarks, and have therefore been registered by the enemy.

All positions should be accurately located and marked on the map.

Positions are provided in order that the resources in personnel and materiel may be conserved and utilized. The elements of a position consist of:

(*a*) Emplacements.

(*b*) Magazines.
(*c*) Dugouts.
(*d*) Connecting trenches.
(*e*) Drainage system.
(*f*) Kitchen.
(*g*) Water supply.
(*h*) Latrines and lavatories.
(*i*) Communication system.
(*j*) Ammunition dumps.

Neither the exact layout nor the type of position can be stereotyped, since much will depend upon local conditions. In general, it may be said that an emplacement should be as small as possible while allowing a mortar its full field of fire. One which is too large means a sacrifice of valuable cover.

Type emplacements are shown in War department publications. [1]

Steady platforms are a matter of great importance, especially with medium and heavy mortars. The beds should be placed so that when centrally fixed the mortars cover the targets to be engaged or the center portion of the enemy front allotted to each.

The greatest care should be taken in digging-in the beds, as the accuracy of shooting depends on this. It is most important to guard against the bed, feet, etc., sinking sideways on firing. If this happens the mortar will be thrown off the line. The clinometer can be used to correct any sinkage.

Protection must be as thorough as possible. Concrete overhead cover gives security to the detachment and adds greatly to efficient service. Cover from aircraft observation must be provided.

Deep emplacements give better security, but revetting is necessary. With trenches 6 feet deep or more, cross-shoring is also required in addition to revetment. Emplacements should not be larger than will allow for the service of the gun and it should be possible to fire the mortar from under cover. The line of fire must clear the parapet at the lowest angle of elevation.

Ammunition stores must be separated by at least a traverse from the mortar and the very strongest possible protection should be provided against hostile fire.

Emplacements must be drained.

The construction of alternative emplacements for each mortar should be commenced as soon as the mortars are in the first position. Spare mortar beds should be kept in these emplacements to enable mortars which have to change position to open fire from the alternative emplacement without delay.

The depth of the excavation for emplacements is controlled by:

1. Defilade required.
2. Facilities for removing earth.

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[1] Notes on Field Fortifications.
Organization and Construction of Battery Emplacements.

3. Facilities for concealing earth removed.
4. Availability of revetting materiel.
5. Width of field of fire necessary.
6. Facilities for camouflaging finished position.

Aside from the overhead cover provided the best protection is:

1. Short straight routes to dug-outs.
2. Traverses and sinuous passages.

The former are desirable to provide quick entrance to shelter so as to avoid results of premature and other bursts.

The latter are necessary to localize effects of all bursts and enfilade fire. There are then conflicting requirements to be carefully weighed in selecting a trace.

All dug-outs should have two entrances, at least five meters apart, with a traverse between them. This requirement is easily met by constructing emplacements in pairs and using a common personnel shelter, and repeating the trace according to the number of mortars to be emplaced.

This construction is normally in keeping with local tactical conditions and at the same time facilitates communication when close together and minimizes effect of retaliation fire when separated.

While covered trenches afford protection against shell splinters, and conceal the movements of the personnel therein, it is evident that they will also form a concussion chamber in the event of a burst near either entrance, as well as increase the explosive effect of a shell which penetrates the cover.

Tactical conditions permitting the position selected should permit of drainage to contiguous ground. Otherwise, a system of interior drainage, with sumps at frequent intervals, must be provided. Lavatories, along with the drainage system, should be so constructed that seepage will not enter the dug-outs.

Kitchen and ammunition dumps always, and water generally, are necessarily at some distance from the emplacements and the selection of their location is a subordinate matter.

Telephone communication should be established between the observing stations and the emplacement and also between the battery commander and the officer under whose orders he is working.

Although the telephone is the normal method of communication, the wires are liable to be cut. Opportunity for visual signalling should therefore be fully exploited and provision made for courier service.

In computing dimension of ammunition shelters and niches, a cubic meter should be allowed for:

45 L. S. bombs,
25 D. L. S. bombs,
70 6″ Newton bombs,
16 240 mm. bombs.

The sap for the lodging of personnel should be at least 6 meters long. It will be advantageous to construct it with

nine instead of with seven frames. In hard ground there should be at least six, and in softer ground from eight to ten meters of head cover.

Bomb shelters with sap descent are effective in limiting the risks of explosion, but shelters of the open cut type are more quickly built when the head cover desired is small.

Bomb shelters with double galleries facilitate the sorting of bombs by types at the time of their arrival. A good timber frame, protected by fifty centimeters of virgin soil and a layer of logs, or two layers of logs separated by fifty centimeters of earth, constitute sufficient protection for an ammunition depot, and is effective against splinters and medium caliber shells. Further, in case of explosion of a large caliber shell with delay action fuse there is little compression, the gases finding a way out and the crushing of neighboring shelters is less to be feared.

When grand and major gallery frames cannot be obtained they can be made from logs, either on the spot, or cut in the rear of the line and prepared for assembling at the emplacements.

When it is not possible to work in the open or if sub-soil water does not allow the construction of saps, shelters can be quickly made by using arch iron elements.

The logs should be strongly tied together with wire or staple spikes.

It is advisable to give an inclination of about ten degrees to overhead covers in a manner that will cause ricochet of enemy shells.

The advanced location of the medium caliber batteries in the lines and the difficulties of transportation practically prevent the use of logs of more than 15 to 20 centimeter diameter and of I-beams and rails.

When time for the installation of the battery position is limited the laying out may be modified.

As soon as the ammunition shelters, the sap heads for men's shelters and the gun emplacements are finished, fire can be executed; but the entrances to personnel shelters are more vulnerable and greater losses are to be expected. To permanently occupy a position thus hastily constructed it is necessary to dig the personnel shelter between the two sap heads pushed to the necessary depth.

A communication trench between the two pieces can be dug at a later time.

In permanently occupied sectors mortars are continually removed from one position to another in order to deceive enemy observation, existing works being utilized whenever available.

With a "shell hole" disposition the personnel is little exposed, but service of the mortar and the construction of works are slow. Ammunition and personnel shelters should be dug six meters under ground and the excavated earth carried out through the passages. In order to effectively conceal the position the excavated earth should be wasted on the parapets of surrounding trenches.

The above applies more particularly to medium caliber trench mortars located near the front line of trenches. Heavy caliber trench mortars, being farther from the front lines, have better transportation facilities for emplacement materiel and may utilize heavy logs, I-beams and rails.

In the organization of a battery position for defense an obstacle is made by enclosing the battery with a low wire entanglement or abatis so made as not to attract enemy observation. Passages, necessary for the personnel and the bringing in of ammunition, materiel and supplies are left in the entanglement, but these passages must be enfiladed from adjacent trench elements.

Machine gun emplacements flanking the position are so built that they may be used against air, as well as against ground attack. Ammunition for machine guns, rifles and hand grenades are placed in damp proof niches.

The machine gun emplacements must be so located that the trench mortars can support them in resisting a surprise attack by infantry or tanks. A properly organized trench mortar position can at least hold the enemy until the counter-attack is organized, and may even break up the attack.

CHAPTER IV

AEROPLANE PHOTOGRAPHY AND CAMOUFLAGE

The study of aerial photography and camouflage is all important to the trench artillery officer. The former is necessary for the study of targets and the discovery of new targets and to show the nature and extent of concealment which must be provided for our own batteries, i.e., camouflage.

Since the advent of high altitude captive balloons and, above all, since the use of aerial observation and of aeroplane photography, defilade does not suffice to protect a position from view. It must be camouflaged. The general principles of camouflage apply, yet for trench artillery the problem has its peculiarities.

Aerial photography and camouflage are therefore closely allied and a proper study of the latter entails a study of the former.

Interpretation of Aeroplane Photographs

I.—General

1. The Examination of photographs.—Before beginning the examination of photographs, every opportunity should be taken for studying, on the ground, objects similar to those which may be required to be identified on a photograph. Thus, captured hostile trenches and positions should be visited until the different types of enemy works are well known.

The configuration and nature of the ground should be studied in order that a correct impression may be gained when siting these features on a photograph.

Every opportunity should also be taken of studying the ground from the air.

During the actual examination of a photograph the following points, placed in order of important, should be remembered:

(*a*) Study the best available map with great care, so that configuration of the ground and the salient details are thoroughly known. During the whole examination of the photograph keep the map with you for constant comparison with the photograph.

(*b*) Ascertain the direction of light.

(*c*) Concentrate your whole mind on the particular objects which you are seeking. Do not let your attention wander to subsidiary objectives. Follow every traverse and detail with a pointer in regular and logical order, but be careful not to mark the photograph.

(*d*) Examine the photograph as an item of independent evidence and then compare this evidence with reports of

visual observation, locations given in intelligence summaries, and evidence of reliable prisoners. Eliminate those portions of this evidence which are obviously wrong; consider the likely places for the objects referred to in the remainder, and verify them. Avoid "special pleadings" and do not allow yourself to read in a photograph what you *want* to see.

(*e*) Compare the photograph with earlier photographs of the same locality. It is from such comparisons that valuable results are obtained. This applies in particular to the appearance of objects on a photograph as affected by the changes of season.

(*f*) Be particularly careful to avoid obliterating detail when annoting or marking photographs.

2. Shadows.—Shadows play a most important part in the interpretation of photographs. It is essential to ascertain the direction of light in order to decide whether the point under observation is convex or concave, and in order to get an idea of the depth or height of cuttings and embankments by comparison with the length of the shadow cast by other objects.

3. Alterations in detail.—New photographs are useful in discovering alteration in old detail, as for instance, the comparison between an old cadastral plan and a recent photograph, showing how a road has been altered in the course of time.

4. Necessity for verifying doubtful points.—A great deal of patience and care taken in the study of aeroplane photographs is wasted unless verification of doubtful points is obtained from the inspection of captured trenches. It is not enough for a few people to view these points. A more practical and quite a simple way is to make a model of them before the machine guns and trench mortars have been removed and the emplacement dismantled.

II.—Machine Guns

1. Machine gun emplacement.—Emplacements for machine guns are either open or covered. Both types are difficult to locate with certainty. In examining photographs, special attention should be paid to any traverse, the size, shape or angle of which departs from the normal. Oblique photographs are a valuable aid in discovering machine gun emplacements.

2. The open emplacement takes the form of a square tray or concrete platform let into the parapet. It varies in appearance according to the altitude of the sun, and may show up either as a white mark with a dark edge or as a comparatively dark square. This latter is hard to distinguish from the many dark nicks in the parapet, which may be sentry posts or firing recesses.

3. The covered emplacement, which is concreted or otherwise strengthened, should be the object of particular attention, as it requires special treatment at the hands of our artillery and trench mortars, when once located. Though the use of covered emplacements is diminishing, a certain

number may be expected in each sector. Their sites are selected with a view to:

(*a*) A good field of fire (preferably enfilade).

(*b*) Concealment from direct observation from the immediate front.

(*c*) Rapid removal of the machine gun.

For the above reasons, they may be looked for:

(1) Where an angle occurs in the trench system within convenient reach of a communication trench, with dug-outs for the gun crew close at hand.

(2) Close to the base of a well protected sap, from the head of which a sentry can give warning and prevent the gun from being rushed.

(3) Occasionally behind the parados.

A covered emplacement may be discovered by a "V" shaped mark in the forward edge of the parapet, where the latter has been cut away to allow the gun to traverse. At the back of this "V," or close beside it in the trench, if the emplacement is entered from the side, may be found a dark nick similar to a dug-out entrance. Sometimes a very short trench is cut out to it.

At times a position of a covered emplacement is revealed by a square mark on the forward slope of the parapet. This occurs when the sun is shining at a slight angle behind the opening, but not at a sufficient angle to show up the "V."

III.—Trench Mortars

1. Types.—The Germans use various types of trench mortars, of which the regulation rifled patterns are light, medium and heavy.

2. Siting.—The following are likely sites for trench mortar emplacements:

(*a*) In the shallow disused trenches, which often exist behind the German fire trenches, a portion of which is deepened to take the mortar.

(*b*) Immediately in front of the parapet of a fire trench.

(*c*) By the side of a communication trench.

(*d*) Along or near the terminus of a trench tramway (especially in the case of heavy trench mortars).

Many trench mortar emplacements may be found by following the line drawn parallel to our own front line at a distance of about 500 meters. Others must be searched for anywhere up to about 700 meters from our front line.

3. Light trench mortar emplacements.—Light trench mortars are often fired from open emplacements to allow a rapid change of position, and it is difficult to distinguish their emplacements from latrines or store pits. One difference, which is by no means universal, is that trenches leading to trench mortar emplacements are more often zig-zagged or traversed than in the case of trenches leading to latrines. It is only by close co-operation with ground observers that these emplacements can be definitely located.

4. Medium and heavy trench mortar emplacements are casemated and much more conspicuous. They can gen-

erally be recognized by an almost square, darkish mark in the center of a mound or ring of earth. This square mark is the top of the funnel up which the mortars fire, and differs in appearance according to the angle of light; it may be black, diagonally black and grey, or grey with a short, oblong, dark slit.

IV.—Railways and Trench Tramways

Much information of tactical and strategical importance can be gained from a close study of railways and trench tramways.

1. Employment.—Besides the normal gauge lines, which were mostly built before the war, the Germans have made an extensive use of the light railway system in the occupied portions of France and Belgium and have extended this system near the front by new construction on a large scale. Personnel, stores and materiel are brought up by branch lines, which run to nearly all important points and villages in the front line system, and battery groups and single heavy batteries are almost entirely supplied by this method. Supply dumps will almost necessarily occur at the breaks of gauge, as well as at various points along the tracks.

2. New construction.—The light railway systems may be divided into three groups:

(*a*) 1.00 m. and 0.80 m. gauge, of which the former is the most common.

(*b*) 0.60 m. gauge.

(*c*) 0.40 m. gauge.

In the first of these groups, new work has consisted in extending the existing lines in operation before the war. The second and third groups have come into existence since the commencement of trench warfare and are found only in the forward areas.

As far as possible, 0.60 m. gauge has been used in all new work, as this standard lends itself for several reasons to the requirements of field warfare.

The metre gauge has, as a general rule, been used in new construction only where lines of that gauge already existed, and where the use of a different standard would cause needless transhipment. The use of 0.40 m. gauge is restricted to the more forward trench tramways where mechanical traction is rarely used.

The German forward railway systems are constantly being altered, especially during active operations. Light lines spring into being to serve a definite purpose, such as the construction of a new line of defence or the regrouping of artillery, and are taken up as soon as they are no longer required. The mark of the track remains for some time after the rails and sleepers have been removed and photographs of such areas should be carefully examined for signs of deterioration or disuse.

3. Characteristic appearance on a photograph.—*Light railways* (1.00, 0.80 and 0.60 m. gauge) can be distinguished on a photograph by:

(*a*) The straightness with which they run.

(*b*) The absence of any series of sharp curves.

(*c*) Embankments and cuttings at points in their construction.

(*d*) Bridges by which they cross streams and trenches.

They will also follow contours and defiladed ground.

Trench tramways (0.40 m. gauge) may be recognized by:

(*a*) The narrowness of the track, which shows as a fine line on the photograph, probably owing to the natural inclination of men to walk between the rails.

(*b*) Their sharper curves where they continue into the trench system.

(*c*) The absence of traverses in the trench in which they are laid.

Railways have a tendency to appear darker on a photograph than used roads or tracks.

V.—Tracks

Tracks form a valuable guide to the enemy's movements, but are sometimes neglected because they are obvious.

The clues which they afford deserve enumeration:

(1) They disclose routes from railhead to billets and from billets to trenches. Even after trenches are reached, the main communication trenches may be distinguished by tracks running along side, made by carrying parties at night, or by working parties employed in the upkeep of important trenches.

(2) They throw light on the limits of sectors, the study of which is important.

(3) They disclose dumps, battery positions; headquarters; wire which is otherwise invisible, and gaps through it; patrol paths; observation posts; fortified shell holes, and in suitable weather, when tracks show up immediately, the activity of working parties.

As in the case of railways, the traces of tracks remain for a long time, and photographs should be examined for signs of disuse, such as new and continuous wire, or broad and unbridged trenches passing across them.

The value of a combined study of tracks and railways in giving assistance to machine guns and artillery for indirect fire, especially at night, is obvious. When made special targets, during more important operations, the resulting confusion and disorganization of the enemy's system has proved very serious to him.

VI.—Buried Cables and Air Lines

1. The study of cable trenches and air lines.—It is important that buried cables and air lines should be marked down when fresh, as they tend to disappear quickly and in course of time become more and more invisible. They should be studied in conjunction with railways and tracks, as they all come under the heading of communications.

2. Cable trenches are a valuable aid in discovering the position of headquarters, telephone dug-outs, camouflaged batteries, observation posts and important centers. Where the buried cables end, the air line system can be picked up.

Cable trenches can be distinguished, when open, by their more or less straight course and narrow construction, and when filled in by their irregular definition and somewhat "woolly" appearance. Where they cross over other trenches a gap appears as the lines are passed under the trench flooring.

3. Air lines appear as a series of regular white dots, these being the displaced earth where the poles have been erected. These dots are connected by a thin track, which is made by the men walking from pole to pole putting up the wire or patrolling the line.

Air lines will sometimes come to life again on a photograph when the ground has been cultivated or ploughed, and they then show up as a succession of small dark islands, where the soil round the posts has not been disturbed. In clear photographs the shadows thrown by the poles can be seen.

VII.—Dug-outs and Mine Shafts

1. Dug-outs can be detected in several ways especially in a photograph taken while they are under construction. It is then possible to see the entrance to the shafts. These appear as black nicks, usually in the corners on either side of a traverse, where the maximum amount of protection from shell fire is afforded.

When dug-outs are made, a large amount of earth is thrown out which varies with their depth. This earth is apparent on older photographs.

Increasing care, however, is being taken to conceal defences, and the earth thrown out is frequently well scattered and quickly becomes difficult to trace.

If the photograph is sufficiently clear and the light falls favorably, it will still be possible to see the black nicks which represent the entrances. These are still clearer if the point where the fire step has been cut through can be seen.

In snow photographs, dug-outs under construction are very obvious.

2. Mine shafts show a similar black nick in the traverse, but their location is more difficult. The entrances are sometimes protected by splinter-proof cover built across the trench.

An indication of their presence is the large amount of spoil brought up from the galleries and wasted in the vicinity:

VIII.—Trench Construction and General Defensive System

Trench construction may be considered under the following headings:

(1) Stationary or trench warfare, with steady and methodical additions and improvements of defences.

(2) Special trench construction indicating that an attack is anticipated.

(3) Special trench construction indicating that an attack is intended.

(4) Construction of defences during a battle.

In case (1) photographs can be studied at length and more or less at leisure.

In cases (2) and (3) there will be at least a few days for study.

In case (4) only a rapid investigation of photographs is possible requiring a quick decision regarding an immediate dissemination of points of interest.

1. Stationary or trench warfare.—(*a*) General organization of a German position.

At least two, but more often three, successive positions or systems of defence are prepared, each position consisting of two or more continuous lines. These lines include strong points such as villages, farms or woods which may happen to be situated in the forward area. In fact, the normal procedure, when taking up a new position, is to fix on a general line of natural strong points and to prepare these for defence first and then to join them up by fire trenches. The first indication that a new line is being constructed is usually the appearance of trenches covering villages and woods.

Support and reserve lines usually include a number of closed works, heavily wired, full of dug-outs, and with a liberal supply of communication trenches to facilitate the speedy passage of the garrison to any threatened point.

(*b*) The determination of sector boundaries.

The divisions of a defensive system into sectors and subsectors affords a study of considerable importance. At intervals in the front line trench, short sections may be found where the amount of earth thrown up is noticeably small. These may indicate the permanent limits of a company sector. There is a natural tendency for a company to commence work about the centre of its sector, leaving the flanks until the last, so that any subsequent alteration in the sector limits would not result in another company enjoying the benefit of its labors.

Each sector is fed by several communication trenches, decreasing in number in proportion as the distance from the first line increases. Between the first trench, and the second and third trenches of the front-line position, there are many communication trenches. Between the front-line position and the second-line position there may be more, but scarcely ever less than two main feeders, an in-track and an out-track. There are generally two from the second-line position to the third-line position or to rest billets.

From a study of the map and photographs determine the two main communication trenches. Compare the latter with the tracks that branch off to the front-line trench. An examination of the points where the branch tracks end should give the approximate limit of the sector. Draw a pencil line through this point and proceed to construct the next sector. Three of these sectors will give the regimental bound areas of a division.

It will be found that each sector is like a human hand and arm, with the main arteries running down the arm and feed-

ing the spread fingers through the smaller veins which lead to the finger tips and return.

Topographical features, such as canals, rivers, main roads or railway lines, occasionally form natural divisions between sectors and enable one boundary to be determined.

2. Indications that an attack is anticipated.—The following are indications that an attack is anticipated:

(*a*) New lines of barbed wire, behind which occasional traverse and dug-outs appear, marking the trace of an intended new line.

(*b*) General strengthening and deepening of trenches.

(*c*) Addition to existing wire.

(*d*) Rapid construction of intermediate and switch lines.

(*e*) An increase in battery positions.

3. Indications that an attack is intended.—The following are indications that an attack is intended:

(*a*) A sudden increase of artillery activity or in the number of battery positions.

(*b*) An increase in the number of communication trenches.

(*c*) A series of saps pushed forward and hastily linked up.

(*d*) Possibly, in the case of small attacks, new assembly trenches in or behind the front-line trenches, or numerous small T-shaped trenches or recesses for holding extra groups of men belonging to the second wave of assault.

(*e*) A rapid increase in the number of light railways.

4. During a battle.—The conditions during a battle render the interpretation of aeroplane photographs far more difficult, for the following reasons:

(*a*) Artillery preparation and continuous bombardment cut up the ground and obliterate trenches and landmarks.

(*b*) Battery positions are destroyed or captured and new ones appear everywhere.

(*c*) New lines of defence may be scattered and may consist merely of a line of fortified shell holes. These may be either detached or improved and linked up to form part of a new defensive organization in conjunction with any available natural cover.

The following are some of the more important points which should be looked for:

(1) Tracks into shell holes which may contain detached parties or machine guns.

(2) Old battery positions, many of which are wired round and, when occupied by infantry, will form local strong points.

(3) Blocks and barricades across communication trenches.

(4) New tracks across country.

(5) New active battery positions.

IX.—Oblique Photographs

Oblique photographs give a view such as an observer from a hill is accustomed to see. Hence, though necessarily somewhat distorted, they convey more information to the unskilled student of air photographs than do vertical photographs.

They disclose details such as machine gun emplacements, otherwise hidden, identify individual trees of which only the tops can otherwise be seen and indicate the contours of the country.

They also give valuable assistance in working out the heights of embankments and the depths of sunken roads.

X.—Stereoscopic Effect with Air Photographs.

1. Method of use.—When any locality is photographed, two or more exposures are often made in order to ensure that one plate at least covers the area. Very often two or more of them do so and may give a stereoscopic effect if looked at through a stereoscopic viewer.

To obtain this effect, take the two photographs of the object (two copies of the same photograph will not do—a fact which is not always recognized, and place one photograph on the top of the other, so that the features of one coincide with the same feature of the other.

Draw the top photograph aside, keeping the features under examination parallel the whole time, until at about 2 inches apart the images will again fit, and houses and trees will stand up as in nature.

The photographs must be placed in the order in which they were taken, i. e., the left-hand picture on the left-hand side, as otherwise the features will appear reversed and houses will sink into holes, and cuttings will become embankments.

At first the number of images may be confusing, but a few minutes' practice will be enough to accustom the eyes to pick up the two required.

2. Value.—Stereoscopic photographs reveal, for example, depressions and slopes which are not distinguishable on a single vertical photograph.

By showing up objects in relief, they enable the artillery to estimate the amount of cover over emplacements and the nature of their protection, thus materially assisting them to determine what nature and caliber of gun is required to deal with them effectively.

Camouflage Applied to Trench Artillery

I.—Necessity for Camouflage

In the study of open warfare carried on by all the armies before this war the necessity of camouflage had not been felt. For their safety batteries depended solely on defilade. But the advent of trench warfare and, above all, the development of aeroplane observation and photography has made camouflage a necessity. The details of field works, of battery emplacements, etc., which could escape the eye of the observer will not escape the eye of the camera and, alone, a refined make up of positions or certain precautions, both of which constitute camouflage, will prevent the discovery of emplacements by the enemy.

As seen in the preceding paragraphs of this chapter aeroplane photographs reveal almost everything and the neces-

sity for clever camouflage is evident. It can be stated that *a battery seen is a battery lost.* The training of the officers and men of trench mortar batteries in the art of camouflage is indispensable.

Camouflage sections.—Camouflage sections exist on the front recruited mostly from among men specially fitted for that kind of work by their former calling (painters, sculptors, etc.). These sections supply army units with special devices and act as guides for officers desiring to do the work of camouflage in the best manner. It is always advisable to consult with them before commencing work.

Materiel for camouflaging.—The materiel is furnished to the divisions by the camouflage sections. The main items are:

Unbleached or green burlap.
Fish netting with knots of reeds.
Chicken wire with knots of reeds.
" " with knots made with strips of burlap.

These reeds are dyed to harmonize with the color of the background.

Tarpaulins of burlap painted with broken colors.

Natural camouflage.—Natural camouflage can be obtained by the proper use of sod, branches, trees, dead leaves, weeds, by the use of gardening, sowing of oats, by the careful selection of sites and the utilization of ruins, old earthworks, etc.

Principles of Camouflage.

The following principles govern the art of camouflage:

(1) **Hiding the batteries from direct observation.**—For this woods, abandoned fieldworks and ruins can be advantageously sought. But in the case of woods special care must be given to the conservation of trees as trees cut down carelessly will show position of battery.

(2) **Hiding position in shadow.**—This is obtained by screens and also by careful orientation. When over-head screens are used care will be taken that edge shadows of these screens are properly camouflaged.

(3) **Hide through color.**—On a dark color background tarpaulins or materiels painted in broken colors will not show. On a light background uniform colors should be used.

(4) **Restitution of ground and objects.**—This is in many cases the best method of camouflage. For this the site must be selected so that restitution is easily obtained.

Stages of Camouflaging

(1) **Camouflage of construction.**—When only night work is done, the construction is carefully camouflaged at day break with camouflage materiel. Care must be taken that earth from the excavations is not piled up too high so as not to have shadows. For day work screens are set up above excavations and work is done under them.

(2) **Camouflage of paths.**—Paths must be carefully camouflaged as they are the surest indication of the battery

position. When a path has to be made it must not stop at the battery but keep on until it meets another path or until it is some distance in the open. The best is not to make any tracks. This can be obtained by training the men in camouflage discipline. They must be taught not to take always the same track and not to follow one another in Indian file.

(3) **Camouflage of battery on completion.**—This is generally best done by the restitution of the ground but it must be done with great care and the result of the camouflage must not be different from the effect obtained from the camouflage made during the period of construction.

(4) **Camouflage of observation posts.**—The most important quality of an observation post lies in the fact that it is difficult for the enemy to locate. It is then necessary to camouflage observation posts in the best possible manner. The camouflage sections furnish very convenient devices, such as periscopic trees, camouflaged steel turrets, etc.

Good camouflage is, above all, a question of intelligence and in this officers must exert all their initiative and judgment.

CHAPTER V

BALLISTICS AND GUNNERY

Definitions

Trajectory.—The curve described by the center of gravity of the projectile in passing from the muzzle of the gun to the point of impact.

Elements at the beginning of the trajectory.

Origin.—The center of the muzzle.

Line of elevation.—The prolongation of the axis of the bore when the gun is laid. It is tangent to the trajectory at its origin.

Line of departure.—The prolongation of the axis of the bore at the instant the projectile leaves the muzzle; it is tangent to the trajectory at that point.

Plane of fire.—The vertical plane containing the line of departure. It is perpendicular to the plane of site.

Elevation.—The angle included between the line of elevation and the plane of site.

Angle of departure.—The angle included between the line of departure and the plane of site.

Quadrant elevation.—The angle included between the line of elevation and a horizontal plane through the muzzle.

Quadrant angle of departure.—The angle made by the line of departure with the horizontal.

Site.—The angle made with the horizontal by the plane of site. The site is positive for points above and negative for points below the muzzle.

Jump.—The angle included between the line of departure and the line of elevation. This angle is always small and is peculiar to the individual piece; it is also constant for that piece. It may be either positive or negative in value and is combined algebraically with the quadrant elevation.

Muzzle velocity.—The rate of travel in meters per second at which the projectile leaves the muzzle of the gun.

Elements at the end of the trajectory:

Point of fall.—The end of the trajectory considered.

Angle of fall.—The angle included between plane of site and the tangent to the trajectory at the point of fall.

Angle of impact.—The angle made by the tangent to the trajectory with the ground at the point of fall.

Angle of incidence.—The inclination of the tangent to the trajectory at point of impact to the normal to the surface hit.

Remaining elements of the trajectory:

Inclination of the trajectory.—The inclination of the trajectory at any point is the angle between the tangent to the trajectory at this point and the horizontal.

Summit.—The highest point of the trajectory.

Maximum ordinate.—The height of the summit above the line of site.

Ascending branch.—That part of the trajectory between the origin and the summit.

Descending branch.—That part of the trajectory between the summit and the point of fall.

Time of flight.—The number of seconds required for the projectile to travel from the origin to the point of fall.

Line of site.—The line through the point of fall and the muzzle.

It coincides with the chord of the trajectory.

Plane of site.—A plane containing the line of site and perpendicular to the plane of fire.

Range.—The horizontal distance in meters from the muzzle to the point of fall or to an objective.

Slant range.—The distance in meters to an objective or the point of fall, measured along the line of site.

For a complete description of the trajectory, angular units, the dispersion and probability of fire and for the use of firing tables, see Part I, Artillery Firing.

The ballistic properties of trench mortars are given in the tables at the end of this chapter (Table I).

Owing to the form of the head of the trench mortar projectile its dispersion is considerable; it is for this reason that every precaution should be taken during the fire for adjustment to prevent injury to our infantry. This is especially important when the enemy trenches are close to our own (Table II).

Table III shows the daily average expenditure for the medium and heavy calibers during an offensive.

Table IV gives, in a general way, the effect of trench mortar projectiles.

Table V shows the number of projectiles which will probably be required for the various works of destruction.

TABLE I.—Ballistic Properties of Trench Mortars

Motors				Ammunition											Remarks
				Projectiles									Charges	Fuses	
Caliber type	Elevation	Field of fire	Number of shots per minute	Type	Metal	Total weight	Weight of explosive	Muzzle velocity (1)	Maximum pressure (1)	Maximum range	Minimum range	Time of flight for maximum range			
						kgs.	kgs.	m/sec.	kgs.	met.	met.	sec.	Wt., Gr. and kind		(1)
58 mm. No. 2.	45° to 80°	60°	2 to 3	L. S. bombs six wings obturated stem	steel	18	5.350	102	1750	1250	120	17	60 85 110 160 185	I. T. mod. 1915 non-delay action fuse or	For the highest charge.
"	"	"	2	D.L.S. bombs six wings obturated stem,	steel	35	10	78	2500	670	100	11	60 85 110 135	R.Y. mod. 1917 non-delay action fuse or	
"	"	"	4	A.L.S. bombs hollow stem and circular tail	steel	20	6.400	"	"	1450	460	"	185 gr. 250 gr. bal. 12	P. R. mod. 1916 delay action fuse.	More details will be given when these bombs are definitely adopted.
"	"	"	4	S.W.D. bombs hollow stem six wings	steel	35	"	"	"	950	"	"	"	id.	
6 " Newton	47° to 77°	60°	6	Bomb made of toughened iron with four vanes	iron	(24)	10	"	"	1278	90	"	Gun cotton 1, 2, 3, or 4 oz. and 4 oz. Gun Cotton + 2½ oz. flaked cordite	Percussion fuse mod. 110	
240 mm.	45° to 75°	36°	½	T—bomb 4 vanes.	steel	83	42	150	260	2300	600	17	1250 gr. bal. 10 10 gr. F_3 800 gr. bal. 10 10 gr. F_3	P. R. mod. 1916 delay action fuse.	

TABLE II

Information on Dispersion of Trench Mortars

Materiel	Conditions of Fire				100% Zone of Dispersion		Remarks
	Projectiles	Charge	Elevation	Range	Width	Depth	
1	2	3	4	5	6	7	8
		Gr.	Deg.	Met.	Met.	Met.	
	L. S. bomb	60	75	120	15	20	(a) Very small
		85	45	490	59	79	
		110	45	700	85	112	
		160	45	980	118	157	
		185	45	1250	188	204	
58 No. 2 Mortar	D.L.S. bomb	60	75	100	12	16	
		85	45	370	45	60	
		110	45	540	65	87	
		135	45	670	80	108	
	A.L.S. bomb	185	75	460	10	80	
	S.W.D. bomb	250	45	1450	30	250	
		250	45	785	30	200	
6″ Newton	6″ Newton bomb	Gun cotton 1 oz.	68	700	(a)	60	
		2 oz.					
		3 oz.					
		4 oz.	67	1000	(a)	100	
		4 oz. + 2½ oz. flaked cordite					
240 mm. Mortar	T—bomb	800	75	600	30	60	
		"	65	1000	50	70	
		"	45	1500	70	140	
		1250	55	1900	80	160	

TABLE III

Average Daily Firing Capacity During Periods of Attacks

Caliber	Number of rounds per diem	Remarks
58 No. 2.	150	At this rate the personnel is not overworked.
6″ Newton	200	It is more a question of ammunition supply as the possible rate of fire greatly exceeds the figures given.
240 mm.	100	

TABLE IV

Effects of Trench Mortar Projectiles

Materiel	Projectiles	Dimensions of craters. Bombs fired with delay action fuse (hard clay soil)	Effects of projectiles on wire entanglements. Bombs fired with instantaneous fuse	Effects on personnel. Number of fragments going through 2 m. high panels placed on circle 10 m. in diameter. Instantaneous fuse	REMARKS
		meters	meters		
mm.	L.S., A.L.S. bombs carrying about 6 kgs. explosive	D = 1.50 to 3.0 d = 1.30 h = 0.80 to 1.0	Barbed wire cleared up in radius of 2.0. Half of the stakes broken down	About 160 fragments	
No. 2 mortar	D.L.S., S.W.D., bombs 10 kgs. of explosive	D = 4.0 to 4.5 d = 2.0 h = 1.0	Same as above except that radius = 3.50m.	Not used against personnel	
6″ Newton	52-lbs. bombs	D = 4.0 d = 1.0 h = 1.5	Same as small 58, No. 2 bomb	About 500 fragments	
250 mm. mortar	Bomb of 83 kgs. 42 kgs. of explosive	D = 6.0 to 10.0 d = 2.0 to 3.0 h = 1.50 to 3.0	Not used on wire.	Not used against personnel	

TABLE V

Average Number of Projectiles Needed for Various Works of Destruction

(a) Destruction of wire entanglements

Ranges	Calibre	Nature of ground	Ammunition and fuse	Number of rounds required for passage meters
meters 0 to 550	58 No. 2	Any kind	D.L.S. or S.W.D. bombs	10 × 40
			I.T. or R.Y. fuses	80 to 100
500 to 1000			L.S. bombs	
			I.T. or R.Y. fuses	200
0 to 1278	6″ Newton	"	Ammonal bombs	200

(b) Destruction of shelters, magazines, blockhouses, etc.

Ranges	Calibre	Light and Medium Shelters	Heavy Shelters	Fuse	Number of Bombs Required
meters 0 to 500	58 No. 2	D. L. S. bombs	38 k. bombs	Delay action fuse	80
		L. S. bombs	"		
500 to 900	240 mm.	"	"	Id.	100
800 to 2300				Id.	70 to 80

(c) Destruction of trenches

With 58.2—80 to 100 bombs on most important point and 1 bomb to the running meter between two important points.

6″—The same as above.

240 mm.—80 bombs for communication trenches crossing.

Enfilade fire—300 L.S. bombs.

150 D.L.S. bombs per 100 m. of enfiladed trench and the 6″ Newton mortar.

CHAPTER VI

PRINCIPLES AND METHODS OF FIRE

For a complete discussion of the principles and methods of fire see Part V, *Artillery Firing*.

The role of artillery in war is to destroy the enemy. Destruction being impossible, the artillery will attempt to neutralize the enemy by causing a cessation, or at least an abatement of his activity.

To successfully accomplish the destruction precision fire is necessary and to do this artillery fire must be adjusted on the objective.

In general, all fire consists of *fire for adjustment* and *fire for effect*. Fire for adjustment, if complete, consists of *trial fire* and *improvement fire*.

Trial fire places the zone of dispersion of a single elevation so as to include the objective, while improvement fire places the center of this zone on the objective.

In certain cases, fire for adjustment is carried only to the point of obtaining a bracket, which is called *bracket adjustment*.

Fire for effect is classified as *precision* or *zone fire*. In the former the object is to keep the center of impact of each piece on the objective; in the latter it is to distribute the shots in a more or less regular manner about the target.

A *salvo* is a series of one shot per piece fired at regular intervals from one flank of the battery to the other. A *volley* is a series of one or more rounds per piece fired as rapidly as the materiel permits. Each piece is served separately.

It is usual to adjust first for deflection then for range.

In trench artillery two methods are used to adjust the fire:

(1) Bracket adjustment, when only the sense of the deviations are known.

(2) Adjustment by means of the measured deviations (successive approximations).

Fire for adjustment, first method:

Trial fire: The object is to *bracket* the objective between two verified elevations differing by *one fork* (6 tabular probable errors or 4 field probable errors), one of the elevations being over and the other short.

Improvement fire: The object is to find an elevation giving substantially as many observations short as over. With the trial elevation fire six shots. If there is not an equality of overs and shorts, modify the elevation by as many *sixths* of a fork as there are shots to be changed in sense to obtain this

equality. The angle thus obtained is called the *adjusted elevation*.

Fire for adjustment, second method.

In the employment of this method, conditions for the observation of fire must be good.

The first shot from a trench mortar is usually called a drying shot. In what follows the first shot is the second shot from the same piece.

The deviations observed for the drying shot are disregarded, except for deflection.

Lay the mortar for the first shot with the elevation and deflection corrected for the daily message.

Lay the mortar for the second shot corrected for the *full* value of the deviations of the first shot.

Correct the laying of the third shot from that of the second by *one-half* of the deviations of the second.

Correct the laying of the fourth shot from that of the third by *one-third* of the deviations of the third shot.

Generally, correct the laying of $(n+1)$ shot from the laying of the *nth* shot by $1/n$ of the deviations of the *nth* shot.

This method of adjustment should be used only when the rate of fire is sufficiently rapid to insure the series being fired under the same atmospheric conditions.

Following the fire for adjustment is the fire for effect. It is usually executed in salvos of twelve shots.

Ordinarily the fire of each piece is adjusted separately.

Observation

Due to the difficulty of discerning targets, which are well camouflaged, the task of observation is not an easy one. A part of the trench artillery personnel should be specially trained for this work. Daily and continuous observation of the terrain, frequent conversation with the occupants of the sector (infantrymen in listening posts and advance machine gunners), minute study of aeroplane photographs and a study of the daily intelligence reports are of the utmost importance.

The position of the observation post is determined by the nature of the terrain and must afford a clear view of the target. It is generally located in a front line trench, but occasionally there may be an elevated position at the side or in the rear of the mortar that will afford the best observation. It may be possible to use infantry or field artillery observation posts which are already constructed.

Observation posts are located either (1), on the line of fire (2), on a line perpendicular to the line of fire (3), on a line oblique to the line of fire.

(1) With the observation post on the line of fire, the first method of fire adjustment is used for range and the second method for direction (axial observation).

(2) With the observation post on a line perpendicular to the line of fire the second method is used for range and the first method for direction (flank observation).

(3) With the observation post on a line oblique to the line of fire, a combination of the two methods is used, making allowance for the angle between the line of observation and the line of fire (lateral observation).

In some cases it is possible to locate observation posts on opposite sides of the line of fire and thus obtain cross observation and an accurate plotting of the shots (bilateral observation).

If the target cannot be seen from an observation post or trench, aerial observation or an auxiliary target must be used.

Determination of Initial Firing Data

The initial firing data should be determined with all possible accuracy as this governs the rapidity with which fire adjustment is executed and therefore the amount of ammunition required. The data to be determined includes:

(*a*) Deflection.
(*b*) Charge.
(*c*) Elevation.
(*d*) Fuse.
(*e*) Bomb.

The selection of the fuse and bomb are taken up elsewhere and will not be considered here.

(*a*) **Deflection.**—If the gun has not already fired, in its present location, it is laid in the proper direction by one of the methods described for the particular mortar. After adjusting the fire the zero line of the mortar will be known and carefully noted on the battle map. For subsequent firing the proper deflection is determined by measuring on the battle map the angle between the zero line and the mortar-target line.

(*b*) **Charge.**—The map range is measured and the corresponding elevation is read from the range table. It sometimes happens that a range can be obtained by using two or more different charges. For example, if firing with the 240 mm. trench mortar at a range of 1200 meters, the range tables give:

Charge No. 1. Elevation 73¼°. Range 1,200 meters.
Charge No. 2. Elevation 61°. Range 1,200 meters.

In a case of this kind, the following considerations obtain: (1) that charge is chosen which allows a sufficient margin for correction in elevation without necessitating a change in powder charge (2) high angles of elevation should be avoided as the strain on the materiel and the influence of wind on the flight of the projectile is greater than at the low angles.

Thus, in the above examples, charge No. 2 is selected.

(*c*) **Elevation.**—The elevation is determined by measuring on the map the range of the target and correcting for site.

(Height of site is the difference in altitude between the target and mortar.) Special site tables give corrected elevations for various heights of site. If there is no site table at hand, the right elevation may be calculated by correcting the map range by one-half the difference of altitude, expressed in meters, remembering that, if the target is higher than the gun, the range is to be increased.

Coefficient of control: Due to the error of the day and the peculiarities of the particular gun, it is found that the range corresponding to the actual elevation used to place the center of impact on the target is not the same as the map range. The ratio between the range corresponding to the elevation used and the map range is called the coefficient of control. The first range must be reduced to zero height of site. Fire having been adjusted on a certain target, a shift may be made to another target by applying this coefficient, keeping in mind that the powder charge must be the same for both targets.

Use of Auxiliary Target

The two following methods are used for shifting fire from an auxiliary target to the real objective:

(*a*) **Approximate method.**—This may be used when the auxiliary target and the real objective are at practically the same altitude and require the same charge. It is illustrated by the following example:

Result of fire control on auxiliary target "A"

58-2 T. M.—Bomb L.S.—Charge 120 grams B. C. powder.
Elevation required to reach target . . 68¾°.
Corresponding range . . . . . 500 meters
Map range . . . . . 520 "
Correction . . . . . .500—520=20 meters.

Calculation of firing data for real target "B"

Map range . . . . . 580 meters.
Correction . . . . . 20 "

Corrected range . . . . . 560 "
Corresponding elevation 65¾°.

The direction is changed by the angle made by the two lines, real-objective-mortar and auxiliary target-mortar and the firing data are:

Bomb L. S. Charge 120 gr. B. C. powder.
Elevation 65¾°.

(*b*) **Regular method.**—This is longer but much more accurate and may be used when the auxiliary and real targets are not more than 250 mils or 160 decigrades apart and when the two targets can be reached by using the same charge. The method is shown in the following example:

Map range to auxiliary target "A" . . . . . 1560 meters

Height of site . . . . . 62.5 " $= \frac{62.5}{1.56} = 40$ mils.

Map range to real target "B" 1720 "

Height of site . . . . . 105.0 " $= \frac{105}{1.72} = 60$ mils.

Result of Fire Adjustment on Auxiliary Target "A."

Elevation required to reach target . . . . . 66½°
Corrected elevation (reduced to zero height of site) . . . . . 67°
Corresponding range . . . . . 1540 meters
Map range . . . . . 1560 "
Coefficient of control . . . . . $\frac{1540}{1560} = 0.987$

Calculation of the Firing Data for Target "B."

Map range . . . . . 1720 meters
Map range corrected by coefficient of control . . . . . 1700 " (1720×0.987)
Corresponding elevation . . . . 63½°
Elevation corrected for height of site . . . . . 62½°

Thus the elements of fire for effect on real target B will be 240 mm. T. M., charge No. 1, elevation 62½°. The direction is modified in the usual way.

CHAPTER VII

BATTLE MAPS

For a complete description and use of maps and battle maps see Appendix X, *Artillery Firing*. Certain parts which follow have been selected therefrom.

The battle map issued to trench artillery officers is the 1/5000. This map shows in detail the organization of the enemy first lines, to a depth of about 2 kilometers, and contains all necessary information for the preparation of fire. It also shows our own trench system to a depth of about one

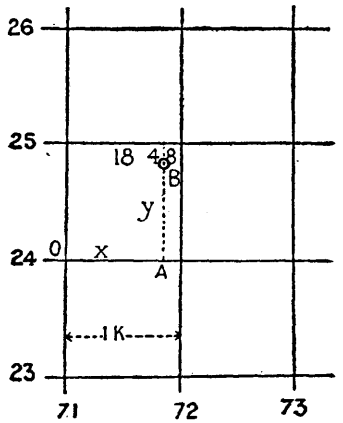


Figure 1.

kilometer. It must not be permitted to fall into the hands of the enemy.

The colors used on battle maps are:

Black or gray, details of the terrain, such as water courses, roads, cultivation, and buildings.

Brown, the form of the terrain, by contours at 5 or 10 meters vertical interval.

Blue, enemy works.

Red, friendly works, or simply the line of the front.

The contour interval of the 1/5000 battle map is 5 meters.

All maps used in firing are provided with kilometer squares, called *Lambert squares*, which are numbered on the margin and sometimes at the intersections.

A point is defined by its x and y coordinates, which are the distances of the point from the X and Y axes, respectively, of the map.

The Lambert, or *Y-north*, is the direction of the vertical lines of the map squares, from bottom to top, using the Lambert system of projection.

A point on the map may be designated by a number of 4 or 6 figures, the first two or three figures give the abscissa to the nearest hectometer and the last two or three the ordinate.

In the figure, OA is 851 meters and AB is 825 meters. The complete coordinates of B are,

$$x = 71.851 \qquad y = 24.825.$$

The numerical designation of this point would be,

718.248 or 18.48

The complete coordinates are to be used for the accurate definition of a position and in artillery computations.

The *Y-azimuth* of O B in the above figure is the angle between it and the *Y-line* measured from the north from 0 to 6400 mils, or 0 to 4000 decigrades, and in a clockwise direction.

The preparation of fire and the organization of observation involve the following topographical operations:

(*a*) Determination of a line.
(*b*) Location of a point.
(*c*) Determination of the altitude of a point.

A line may be determined by the following methods:

(*a*) Using a declinated instrument.
(*b*) Using an undeclinated instrument.
(*c*) By the use of two known points.
  (*a*) Graphically.
  (*b*) By calculation.
(*d*) By astronomical observation.

A point may be located:

(*a*) By a declinated plane table.
  (*a*) Requiring only sights for direction.
    (*a*) Intersection.
    (*b*) Three point.
    (*c*) Resection.
  (*b*) Requiring distance measurement also.
    (*a*) Direction and distance.
    (*b*) Traversing.
(*b*) By use of a declinated theodolite (as above).
(*c*) By use of an undeclinated goniometer (as above).

The altitude of a point may be determined:

(*a*) By reading directly from the battle map by means of the contours.
(*b*) Levelling by a theodolite.
(*c*) Levelling with a barometer.

The above methods are given in Appendix XI, *Artillery Firing*, and in *The Artillery Reconnaissance Officer*.

All trench artillery officers should be familiar with all the above methods and should be able to use the declinated plane table.

CHAPTER VIII

GERMAN TRENCH ARTILLERY MINENWERFERS

It is especially necessary for trench artillery officers to study weapons of trench artillery used by the Germans in order to be acquainted with their construction, their projectiles and their maneuver, thus being able, if occasion presents itself, to turn them against their makers.

German minenwerfers are divided into two kinds:

(*a*) Auxiliary minenwerfer.

(*b*) Minenwerfer properly called.

Auxiliary Minenwerfer

Though these minenwerfers have been greatly improved, they still remain characteristically improvised weapons and some of them are now little used. The principal auxiliary minenwerfers are:

(*a*) Light minenwerfer Lanz. Range: 25 to 450 meters.

(*b*) Light minenwerfer Mauser. Range: 150 to 270 meters.

(*c*) Light minenwerfer "F." Range: 60 to 300 meters.

(*d*) Light minenwerfer "D." Range: 60 to 400 meters.

(*e*) Light ladungswerfer Erhardt. Range: 35 to 150 meters.

(*f*) Heavy ladungswerfer Erhardt. Range: 20 to 265 meters.

(*g*) Erdmörser and mortars Albrecht. Range: 35 to 600 meters.

(*h*) 18 cm. minenwerfer. Range not known.

A.—Minenwerfer "Lanz"

This minenwerfer is composed of a steel tube of diameter of 91 mm. 3 (3.09 inch) resting on a four branched stand which can be folded for transportation through the trenches. When firing the stand is placed on a wooden platform consisting of 9 boards reinforced and held together by means of 2 angle irons. The stand, serving as a carriage, is fastened to the platform by means of a connecting key.

Direction is given to the mortar by traversing the whole mortar and platform and elevation is given to the mortar by means of a pendulum hanging in front of a graduated dial.

Projectiles.—Two kinds of projectiles are used with this mortar. They are both tubes of cast iron 91 mm. (3″.58) in diameter and filled with an explosive of the astralit type, the ingredients being about

Ammonium nitrate	80%
Tolite	12.5
Nitro-glycerin	4.5
Saw dust	3

One of them weighs 4 kgs. (8.8 lbs.) and contains 375 gr.

(13.25 oz.) of explosive. The explosion is obtained by means of a Bickford fuse lighted by the flash of the propelling charge. The second projectile weighs 3 kg. 8 (8.36 lbs.) and contains 360 gr. (12.70 oz.) of explosive. The explosion is obtained by means of a fuse called "Lanz" fuse which acts whatever may be the position in which the projectile strikes the ground.

This mortar also throws a gas bomb weighing 2 kgs. (4.4 lbs.) and containing 1 kg. 5 (3.3 lbs.) of liquid.

Charges.—Both bombs may be fired with two charges, 35 gr. and 7 gr. The mortar is loaded by the muzzle for the projectile and by the breech for the charge. The primer is a rifle cartridge and the firing mechanism is a rifle breech. 20 gr. and 35 gr. charges of black powder may also be used. In this case a Bickford fuse is used as a primer.

Ranges.—Projectile with Bickford fuse:

Smokeless powder from	75 to 400 meters
Black powder	100 to 365 "

Projectile with fuse:

Smokeless powder from	125 to 450 m.
Black powder	150 to 415 "

Weights of materiel.

Minenwerfer	60 kgs.	132 lbs.
Platform	45 "	99 "
Total		231 lbs

B.—MINENWERFER "MAUSER"

This minenwerfer is almost the same as the "Lanz," same construction, same diameter, and same elevation sight. The breech block is different. It is a steel cylinder in which is bored a powder chamber. It slides inside the barrel and is easily taken out by means of a handle. When firing it is held in place in the barrel by a strong pin 2 cm. 5 (1 inch) in diameter, which runs through both the barrel and breech block. A vent is pierced through the breech block.

The propelling charge is contained in a small silk bag fitted with a Bickford fuse. To load the charge the breech block is removed and the charge placed in the powder chamber the fuse running through the vent.

Projectiles.—The projectile called the "stove pipe" is a cylinder made of an iron sheet and closed on both ends by wooden blocks. The bottom block is pierced with a hole which receives the detonator and time fuse. A washer made of greased felt acts as an obturator. The projectile weighs 3 kg. 35 (7.37 lbs.) and contains 2 kgs. (4.4 lbs.) of explosive (Romgarit Donartod) compound of ammonium nitrate. The projectile is loaded by the breech end and pushed gently a little way into the barrel and the charge is then placed in so that it pushes the projectile forward.

Charges.—20 and 25 gr. black powder.

Ranges.—From 150 to 270 meters.

Weights.

Minenwerfer	46 kgs.	101.2 lbs.
Platform	27 "	59.4 "
Total		160.6 lbs.

C.—Minenwerfer, "F" and "D"

These are made by the armies themselves and are very rudimentary. They consist simply of an emptied shell fitted with a wooden sole and pierced with a hole at the bottom. The powder is placed down the shell, a Bickford fuse placed through the vent and the projectile put into the shell.

These minenwerfers are no longer used to any great extent.

D.—Light Ladungswerfer "Erhardt"

This minenwerfer (literally, charge thrower) consists of two cylinders screwed onto one another and closed at both ends thus forming a pump, inside of which can run a piston. The rod of the piston is fitted at the top end with a claw which holds the charge. Near the base is a hole in which is screwed a friction primer.

About half way up the cylinder is pierced with holes through which the gas escapes. The cylinder is fixed to a metallic platform resting on a wooden platform which can be traversed around a pivot.

The platform has a graduated scale running from —14 to + 14, each division being worth 20 mils.

The elevation sight is the same as that of the "Lanz" mortar.

Projectiles and charges.—The projectiles are sheet iron cylinders filled with explosive. The earlier projectiles weighed 3, 4 and 5 kgs. (6.6, 8.8, 11 lbs.) and were thrown to ranges of 50, 37.5 and 35 meters simply by the friction primer. Now they have been reduced to 2.5, 3.5, 4.5 (5.5, 7.7, 9.9 lbs.). The smallest bomb is thrown to a range of 70 meters by the friction primer and 150 meters by the friction primer +5 gr. black powder.

This Ladungswerfer may also be used as a minenwerfer. In this case the upper tube is unscrewed and the piston removed. The diameter of the barrel is 91 cm. 3 (3.09 inch).

It can use the bomb of the "Lanz" mortar.

(*a*) The bomb with Bickford fuse at a range of 190 meters.

(*b*) The bomb with Lanz fuse at a range of 210 meters.

The propelling charge consists of the friction primer + 5 gr. black powder.

Weights.

Total	49 k. 5	108.9 lbs.
Lower tube and platform	39 k. 5	86.9 "

E.—Heavy Ladungswerfer "Erhardt"

This Ladungswerfer consists of three parts:

(*a*) Barrel.

(*b*) Carriage.

(*c*) Platform.

Barrel.—The barrel is a steel tube about 75 cm. (30 inch) in length and 24 cm. 5 (9.65 inch) in diameter. The breech end is fitted with two trunnions. A powder chamber is bored in the breech end which is pierced with a vent into which a friction primer is screwed. On the right side of the barrel is a pinion moved by a handle and running on a semi-circular rack fixed to the carriage. The barrel is locked at a proper elevation by means of a handlock. A bracket on the right side of the barrel holds the elevation sight which is the same as that of the 7 cm. 6 minenwerfer.

Carriage.—The carriage is made of steel and has two trunnions which are connected to those of the barrel by means of an axle with a key. By removing the key the rack can be lowered to a travelling position.

The carriage also has a pivot and a wing nut to lock it in the desired direction.

Platform.—The platform is made of wood and reinforced with sheet iron. Its dimensions are: 59 × 115 cm. (23.23 × 45.28 inch). It has a socket for the pivot of the carriage, a semi-circular racer in which runs the screw of the traversing locking nut of the carriage and has a graduation for the direction.

Projectiles.—The projectile is a sheet iron cylinder (1 mm. 55 thick), to which is welded a hemispherical top. The diameter of the cylinders is 240 mm. (9.45 inch) and the total length 31 cm. (12.20 inch). A wooden circular piece is screwed at the bottom of the projectile and acts as an obturator. The top part of the bomb is threaded and a fuse socket containing 270 gr. (9.52 oz.) of trotol is screwed in.

Three kinds of projectiles are used:

(*a*) Length 31 cm. (12.20 inch), weight 20 kgs. (44 lbs.), Expl. 14 kgs. (30.8 lbs.).

(*b*) Length 40 cm. (15.74 inch), weight 30 kgs. (66 lbs.), Expl. 23 kgs. (50.6 lbs.).

(*c*) Length 66.5 cm. (26.18 inch), weight 40 kgs. (88 lbs.), Expl. 32 kgs. 5 (71.5 lbs.).

The bursting charge is of the astralit type.

Charges.—The charges are of 30, 60, 90 grammes (1.05, 2.11, 3.17 ounces) of black powder.

Ranges.—The ranges obtained are:

20 kgs. (44 lbs.)	from 35	to 265 meters
30 kgs. (66 lbs.)	" 25	to 190 "
40 kgs. (88 lbs.)	" 20	to 160 "

Fuse.—The fuse used is a time fuse acting from 4 to 15 seconds after the bomb is fired.

F.—Erdmörser

The Erdmörser or "buried mortar" is made of a wooden cylinder reinforced with wire. The inside diameter is 25 cm. The mortar is buried in the "parados" and the bottom of the trench and the projectile slides along a wooden racer 2 m. 40 (7 feet 10 inches) in length, semi-circular in cross section and resting on the parapet with an inclination of 45°.

Projectile.—The French call the projectile the "coal bucket" type. It is a cylinder made of sheet iron 3 mm. 5 (1.37 inch), 25 cm. (9.82 inch) in diameter and 38 cm. (14.96 inch) in height. The cylinder is closed at both ends by wooden blocks, one having a handle for transporting the projectile and the other being pierced with a hole in which to place the Bickford fuse. This fuse is lighted by the flash of the charge.

The projectile weighs 23.5 kgs. (51.7 lbs.) and contains 12 kgs. (26.4 lbs.) of explosive containing 1 kg. (2.2 lbs.) of iron bits.

A smaller model is also used.

This projectile has simply been improved, the bottom being reinforced with an iron sheet and the top being fitted with a metallic cone which gives a better stability to the projectile.

G.—"Albrecht" Mortar

This mortar is a wooden tube 2 meters (6 ft. 8 in.) in length and 25 cm. (9.84 in.) in diameter, reinforced with wire.

The bottom of the barrel rests on a wooden block. A metallic stand supports the barrel and a handwheel screw elevates and depresses the barrel.

This mortar uses the same projectile as the Erdmörser at ranges varying from 35 to 600 meters with charges varying from 50 to 700 gr. (1.76 to 24.68 ounces).

Weights of materiel.

Barrel	162.5 kgs.	358 lbs.
Wooden Block	56 "	123.5 "
Metallic stand	70.5 "	155 "
Total		636.5 lbs.

Besides this mortar there are two other mortars of the same pattern:

(*a*) Diam. 35 cm. (13.78 in.). Projectile 100 kgs. (220 lbs.) Expl. 60 kgs. (132 lbs.).

(*b*) Diam. 45 cm. (17.71 in.). Projectile 200 kgs. (441 lbs.) Expl. 117 kgs. (257.5 lbs.).

H.—18 cm. (7.08 Inch) Minenwerfer

This minenwerfer is not included in minenwerfer batteries and it seems that its use is not general and that it is to be classified as an auxiliary minenwerfer.

It consists of three parts:

(*a*) Barrel.

(*b*) Carriage.

(*c*) Platform.

Barrel.—The barrel is made of brass and is 18 cm. (7.08 inch) in diameter. It has a smooth bore and no recoil system.

A powder chamber, of a smaller diameter than the barrel, is bored in the breech end which is pierced with a vent in which is screwed a friction primer.

The barrel is connected to the carriage by means of an axle.

Carriage.—The carriage is made of steel, has two sockets for the axle, and a pivot which goes in the platform.

Platform.—The platform is made of steel and is 140 cm. (4 feet 8 in.) in length, 75 cm. (28½ in.) wide.

The bottom of the platform is reinforced with angle irons acting as spades, three of them parallel to the long side of the platform, two diagonally located and one parallel to the short side.

The socket for the pivot is at the center of the platform.

A racer placed at the front is graduated from 0 to 600 mils.

An axle is fixed to the platform for transporting on wheels.

Manning party is 1 N. C. O., and 4 cannoneers.

The elevation is obtained by means of the same sight as for the 7 cm. 6 minenwerfer, and a double telescopic screw.

Direction is given by means of a double screw fixed on one side to the platform and on the other side to the carriage.

Projectile.—The projectile is made of steel with a welded bottom.

Length 40.8 cm. (16 inch), diameter 17.7 cm. (6.95 inch).

Weights 27.3 kgs. (60 lbs. and contains 9.4 kgs.) (20.68 lbs. of explosive).

Charges.—Four packages of propelling charges are fastened together. By removing 1, 2 or 3 the following charges are obtained:

No. 1	17 gr.	0.60 oz.
No. 2	31 gr.	1.10 oz.
No. 3	46 gr.	1.34 oz.
No. 4	67 gr.	2.27 oz.

Ranges.—Not known. Maximum range is between 500 and 600 meters.

Weights of Materiel.

Barrel	141 kgs.	310.5 lbs.
Carriage	72.5 "	159.5 "
Platform	236.5 "	520.5 "
Total		990.5 lbs.
Wheels 40 kgs. 88 lbs. ×2		176 lbs.
Shaft 10 kgs		22 "
Weight on wheels		1188.5 lbs.

MINENWERFERS, PROPERLY CALLED

There are four sizes:

(*a*) 25 cm. (9.84 inch) rifled.
(*b*) 24 cm. (9.45 inch) smooth bore.
(*c*) 17 cm. (6.69 inch) rifled.
(*d*) 7.6 cm. (2.99 inch) rifled.

A.—25 CM. (9.84 INCH. HEAVY) MINENWERFER (Fig. 3.)

This mortar consists of four main parts:

(*a*) Barrel.
(*b*) Jacket with recoil cylinder.
(*c*) Carriage.
(*d*) Platform.

The barrel is a steel tube whose caliber is 25 cm. (9.84 in.).

Its weight is 145 kgs. (320 lbs.) and it is grooved with six riflings turning to the right. This mortar is muzzle loading for the charge as well as for the bomb. There is at the bottom of the barrel a special chamber of a diameter smaller than that of the tube and which receives the propelling charge. The barrel slides inside a jacket or sleeve and is, for that purpose, fitted with two shoulders sliding inside two guides grooved in the jacket.

The jacket or sleeve consists of a tube with trunnions and of two recoil cylinders. The tube and the cylinders are cast together and the whole is connected to the barrel by means of two shoulders which are on the barrel on the upper and under side of the breech and which are attached to the piston rods of the cylinders.

Each recoil cylinder contains a piston, a recoil spring, and is filled with a practically incompressible mixture of 59 parts of glycerin and 41 parts of water.

The recoil of the tube draws the pistons backwards, thus compressing the springs and the mixture runs from one side of the piston to the other through throttling grooves in the walls of the cylinder. The grooves are large at the front end of the cylinder and decrease to almost zero at the rear end. This construction permits rapid movement in recoil at first and practically no movement at the end. The recoil being stopped, the compressed spring brings the tube back to its former position. The strength of the spring is to be carefully measured to make certain that, when firing with the heaviest charge, the recoil does not exceed 25 cm., the length of the grooves. An indicator is attached to the piston of the upper cylinder and shows the amount of recoil. It has to be carefully watched when firing. The carriage is composed of two sheet steel flanges joined by two cross bars. The front cross bar has a socket for the traversing pivot and two clips which run inside the guides of the platform. The rear cross bar also acts as sole plate and there is an opening cut into it into which the barrel moves in recoil. It has a traversing worm wheel for laying the gun in direction. The right flange has a plumb line for use in installing the platform at the proper inclination.

The platform, 80 cm. by 160 cm. (31½ to 63 inches) is composed of a steel plate reinforced in front and rear with timber. The steadiness of the platform is secured by two lateral and one central spade and at the rear by a slightly tilted spade which acts perpendicularly to the direction of fire. On the top of the platform there are two front racers, one pivot, an opening for the barrel to recoil, a traversing rack, two rear racers and two traversing spring studs.

To put the platform into position for firing, the emplacement must be dug just deep enough so that the top of the platform will be at the level of the ground when in position. The rear of the excavation is to be higher than the front end so that the inclination of the platform towards the front will be from 5 to 10 degrees to allow for settling of the platform when the mortar is fired.

Projectiles.—This mortar fires two types of projectiles, both being shells:

(*a*) Long projectile, 1.02 m. (40.15 inch) in length, weighs 207 lbs. and contains 103 lbs. of explosive. The 1911 regulation (this mortar was made in 1911) said that the projectiles were filled with trotol. They are now filled with astralit.

The projectile is painted yellow gray and has a black circle on the ogive to indicate the correct loading of the projectile in the barrel.

(*b*) Short projectile, 0.59 m. (23.20 inch) in length, weighs 139 lbs., contains 57 lbs. of nitrolit, with a central priming charge of picric acid. Nitrolit is a compound of:

60% Trinitranisol,
40% Ammonium nitrate.

Trinitranisol is a methylated ether of picric acid.

The projectile is painted grey.

Both bombs are fitted with a band with six shoulders running in the grooves (rifling) of the barrel.

Fuses.—Two kinds of fuses are used, one which can be used only with the heavy bomb (Zs W. M. 1913) and one which can be used on both bombs (Zs u. m. W. M. 1915). They are double action non-delay fuses with a percussion system which works regardless of which end (nose or bottom) hits the ground.

Charges.—The charges are made of thin round pieces of smokeless powder of nitroglycerin base. They are tied up in four packages, each numbered. The heaviest charge is composed of the four packages. At the top of the package is a cardboard washer acting as obturator. No. 4 being at the bottom, by removing charge No. 4, No. 3 is uncovered and so on.

Charges.	No. 1	100 gr.	(3.53 oz.)
"	No. 2	130 "	(4.58 ")
"	No. 3	155 "	(5.47 ")
"	No. 4	185 "	(6.52 ")

are used with the heavy bombs and ranges from 220 to 600 meters are obtained. According to the regulations of 1911, charges No. 1 and No. 3 only were to be used. Charges No. 1, No. 2 and No. 3 are used with the short bombs and ranges thus obtained vary from 490 to 900 yards.

The charge is placed in the chamber by hand and firmly pressed down by means of a rammer. According to the regulation of 1911, the mortar was to be fired by electric primer. The Germans now use a friction primer which is screwed into the breech of the mortar and contains fulminate of mercury and a boosting charge of black powder.

The manning detail of the mortar is:

1 non-commissioned officer,
6 cannoneers.

The gun is laid in direction by means of periscopic sight and a battery telescope.

The gun is traversed by means of the traversing worm wheel which runs on the rack of the platform. There is a graduation on the platform which runs from —180 to +180

mils. The elevation is given to the mortar by means of an elevating rack which is fixed to the left trunnion and an elevating gear fixed to the carriage. To the elevating gear is fixed a semi-circular graduated dial on which runs a periscope socket fitted with a reading window. This socket is moved by means of a thumb screw which acts on a rack placed on the left side of the dial. Another thumb screw permits the whole dial and periscope socket to be moved on a line perpendicular to the line of fire in order to place the socket perpendicular. The periscope socket has two bubbles perpendicular to each other by means of which vertical position of the sight is checked, a condition necessary to insure the correct elevation of the mortar.

Transportation.—An axle is fixed to the platform. Two wheels can be put to that axle and the mortar pulled by 4 men.

Projectiles are carried in wicker baskets with handles and a special wooden bottom which protects the band of the shell. They are loaded in the mortar by means of a special loading apparatus.

Weights of different parts of materiel are:

	kgs.	lbs.
Barrel	147.5	325
Jacket and recoil cylinder full of glycerin	133.5	295
Carriage	96	211
Platform	224.5	494
Sights	18	40
Total weight in battery	619.5	1365
Wheels 94½×2	43	189
Pole	10.5	23
Weight on wheels	716	1577

A new 25 cm. (9.84 in.) 1916 pattern heavy minenwerfer, slightly different from the old pattern (longer barrel), has ranges from 545 to 1095 yards and uses both delay and non-delay action fuses.

B.—24 CM. (9.45 INCH.) HEAVY FLÜGELMINENWERFER (Figs. 4 and 5.)

This is a new pattern minenwerfer which was brought out in 1916 and looks very much like the French 240. It consists of three main parts, i.e., gun, carriage and wooden platform.

The gun consists of:

(*a*) The breech piece.
(*b*) The gun proper.
(*c*) The elevating collar.
(*d*) The sight bracket.

The gun is a smooth bore steel tube of a diameter of 240 cm. The carriage consists of an upper carriage which is a rotating plate and an under carriage which is a steel platform. The wooden platform is made of ten cross sleepers laid side by side on top of eight longitudinal bearers, the whole resting on two cross sole plates. The recoil is taken by a plate riveted to the platform by three traverse cheeks and 24 iron shoes.

The gun is laid in direction by means of a traversing block coupled to the upper carriage by two tie rods. This block slides in a U-shaped traversing arc and can be clamped by means of a handwheel. The traversing arc is graduated from —50 to +50, each graduation being 10 mils. The sight consists of a graduated arc, level pointer and open sight. The whole is placed in the sight bracket which is on the right side of the barrel near the muzzle. This minenwerfer uses a heavy bomb fitted with four vanes like the French 240 mm. bombs. This bomb weighs 100 kgs. (220 lbs.) and contains 42 kgs. (92.5 lbs.) of explosive.

There are two charges, a full charge, 800 gr. (1.76 lbs.) contained in two bags, the larger of which 500 gr. (1.1 lb.) is used as charge No. 2. The ranges obtained vary from 490 to 1310 yards, with elevation varying from 50° to 75°.

The fuse is a delay or non-delay percussion fuse, very dangerous to manipulate when the safety pin is removed. The manning party for the mortar is 1 N. C. O. and 5 cannoneers.

C.—17 CM. (6.69 INCH.) MEDIUM MINENWERFER (Fig. 6.)

This minenwerfer is of the same design as the 25 cm. minenwerfer except for a difference in the traversing gear.

The traversing arc is graduated from 0 to 440 mils, each division being 5 mils.

Laying and firing systems are the same as for the 25 cm. mortar. The manning party, 1 N. C. O., and 4 cannoneers.

Projectiles.—The explosive projectile is of the same kind as the 25 cm. It is 0.635 m. (2½ inch) in height, weighs 49 kgs. 500 (109 lbs.) and contains 12 kgs. (26.4 lbs.) of explosive of the astralit type.

This mortar also uses a gas shell weighing 42 kgs. (92.6 lbs.) and containing 10 to 11 kgs. (22 to 24.2 lbs.) of asphyxiating liquid (chloroformiate of chlorated methyl) or lachrymogen liquid (bromoethylethylceton) and an incendiary shell containing sulphur and metallic oxides and weighing about 37 kgs. 5 (82.5 lbs.).

The explosive bomb is painted red brown, the asphyxiating bomb light grey with 2 yellow or white circles painted on the ogive, the "weeping" bomb light grey without any circle and the incendiary bomb blue.

Charges.—The charges are made like those of the 25 cm. but are composed of six packages with which 6 charges are obtained.

No. 1	44	gr.	(1.5 ounces)
No. 2	66	"	(2.25 ")
No. 3	88	"	(3.10 ")
No. 4	110	"	(3.88 ")
No. 5	132	"	(4.65 ")
No. 6	154	"	(5.45 ")

with which the following ranges are obtained:

Medium explosive bomb, 165 to 985 yards.
" gas shell, 330 to 1095 "

Ranges obtained with the incendiary bomb are not accurately known.

The maximum recoil of this gun is 27 cm. and the accuracy is said to be good. 50% of the shots may be placed in a rectangle 9×3 meters.

Weights of materiel.

	Kgs.	Lbs.
Barrel	122	268.5
Jacket and recoil cylinder	84	185
Carriage	86	189
Sights	13	28.5
Total		671
Wheels 40 (88)×2		176
Pole	10.500	23
Weight on wheels		870

A new 1916 pattern differs but slightly from the old pattern. It throws the explosive bomb to ranges varying from 330 to 1260 yards and the gas bomb from 435 to 1750 yards.

D.—7 CM. 6 (2.99 INCH.) LIGHT MINENWERFER (Fig. 7.)

This mortar consists of:

(*a*) Barrel.
(*b*) Jacket.
(*c*) Platform.

The barrel, a steel tube with six grooves (the width of the groove is equal to the width of the interval between two grooves) slides in a jacket fitted with one recoil cylinder on each side and one recuperator cylinder on the top. The jacket and cylinders are made of bronze. The three pistons of the cylinders are connected with the barrel by means of three shoulders. Two flanges which are part of the jacket are connected to the platform by means of an axle. There is an indicator for the recoil which is normally 17 cm. but which may attain a maximum of 18.5. The support consists of two platforms, a moving platform which is made of brass and a fixed platform made of steel. The latter has a pivot

and two semi-circular racers. Underneath the platform is a space parallel to the long side of the platform.

The moving platform, which in fact is the carriage, can be traversed around the platform pivot and rests on the two semi-circular racers of the platform.

The front semi-circular racer has a radius of 20 cm. and the rear one a radius of 40 cm. The latter is graduated into 40 divisions, each worth 10 mils.

The platform has an axle fitted underneath upon which wheels can be put and the mortar wheeled by means of two shafts.

Normally one non-commissioned officer and 2 cannoneers serve the mortar but if there is an important firing to be performed 6 cannoneers instead of 2 serve the mortar.

The elevation is given to the mortar by means of a telescopic screw moved by a handwheel. The direction is given by a screw attached to the carriage and running through a bolt placed on the platform and which can turn around a vertical pivot.

There is a panoramic sight for laying the gun in direction. Usually the mortar is laid without that sight by means of the graduated arc. The elevation is given to the mortar by means of a special sight fixed to the jacket and consisting of a dial divided into four parts corresponding to the four charges. A pointer runs along this dial and is fitted with an indicator which is placed on the desired range in the column corresponding to the charge used. There are two bubble levels, one to check the horizontality of the platform, the other to give the mortar the correct elevation. There is also, on the side of the dial, a graduation in degrees.

Projectiles.—The projectile used is a bomb in which the ogive is screwed into the body of the shell. It is 28 cm. (11 inch) in height, weighs 4 kgs. 500 (9.9 lbs.) and contains 0.560 kg. (1.23 lbs.) of explosive (astralit type). There is also a gas bomb weighing 4 kgs. 500 (9.9 lbs.) and containing 0.800 kg. (1.76 lbs.) of liquid. The band is fitted with six shoulders.

The bottom of the shell is hollow and holds the charge. This powder chamber is 1 cm. deep and 5.8 cm. (2 inch) in diameter. The charge is made of four packages of thin circular pieces of powder weighing altogether 15 grammes (0.53 oz.). The charge can be reduced by removing one or more packages.

The following charges are used:

No. 1	6 gr.	(0.21 oz.)	with which ranges from 330 to 1095 yards are obtained.
No. 2	9 "	(0.32 ")	
No. 3	12 "	(0.42 ")	
No. 4	15 "	(0.53 ")	

The powder chamber is closed by the bottom of the shell which is screwed to the base of the bomb and is fitted with a primer. This bottom has four holes which are covered by a thin copper disc. This copper disc is also pierced with four round holes 4 mm. in diameter, covered by an oil canvas to

protect the charge from dampness. When the powder is ignited by the primer the pressure tears the copper disc and the gas runs through the holes into the barrel. The copper disc is torn by a very small pressure thus insuring a special uniformity of bore pressure.

The percussion primer is fired by a striker which is operated by a lanyard.

Fuse.—The fuse used is a double acting, delay or non-delay action fuse, marked L. W. M. Z. dr. 1915.

Weights of the different parts:

Barrel	22 kgs.	48.4 lbs.
Jacket	23 "	50.6 "
Brass plat.	20 "	44 "
Steel plat.	25 "	55 "
Total		198 lbs.
Weight 5 kgs. (11 lbs.)		22 "
Weight on wheels		220 lbs.

New Pattern 7.6 mm. (2.99 in.) Light Minenwerfer 1916. (Fig. 8.)

This minenwerfer consists of three parts:

(*a*) Barrel.
(*b*) Jacket.
(*c*) Platform.

The barrel and the jacket are made on the same design as the old pattern but are reinforced.

Platform.—Two platforms, one movable and one fixed platform. The fixed platform is made of a sheet iron plate semi-circular at the front and rectangular at the rear. It is fitted with a pivot, two axle trees for the wheels, a circular racer and is graduated with 64 divisions each worth 10 mils.

The moving platform is a circular plate with a socket for the pivot and two trunnions to which the jacket is connected by means of an angle. There is also a reference mark for laying the gun in direction. The platform can be revolved through a complete circle on the pivot and is stopped by means of a screw acting on the racer. When the platform is stopped by the screw it can still be slightly transversed by means of a handwheel screw running through a bolt which is tightened by the traversing locking screw.

The elevation sight is the same as for the old pattern 76 cm. mortar.

Projectile and charges.—This mortar uses the same charges as the old 7 cm. mortar and throws the same projectile to the same ranges. It also uses a new pattern bomb of the same weight and containing the same amount of explosive and a gas bomb, and attains ranges varying from 330 to 1420 yards.

The fuse and the firing mechanism are the same.

Weights of different parts are:

Barrel and jacket	54 kgs.	119 lbs.
Moving platform	24 "	53 "
Fixed platform	64 "	140.50 "
Total		312.50 lbs.
Wheels 7 kgs. (15.5 lbs.)×2		31
Weight on wheels		343.50 lbs.

General Organization

Auxiliary minenwerfers are served by the infantry. An officer is assigned to the command of the minenwerfers in each battalion. The composition of the manning squad varies from one battalion to another. Besides the auxiliary minenwerfers, they also serve the light 7.6 cm. minenwerfer. The other minenwerfer personnel are formed into minenwerfer companies. As a rule there is one minenwerfer company per division whose normal equipment consists of four heavy and eight medium mortars. It belongs to the pioneer battalions of the division. Mountain minenwerfer companies supplied with mountain transport and pack animals have an equipment of four medium and eight light minenwerfers. They are allotted to certain divisions as required. Besides these companies, there are minenwerfers battalions at the disposal of the general headquarters which are employed at important points as required. Each battalion consists of six companies each of six heavy and four light minenwerfers.

Tactical use.—The tactical use of minenwerfers is exactly that of trench mortars as used in the allied armies.

Conclusion

In 1914 the Germans had 150 minenwerfers (40 heavy, 40 medium and 70 light) and in June, 1917, 1196 heavy, 1904 medium and 8656 light minenwerfers. At the present time (February, 1918), they have about the same number of heavy and medium minenwerfers and 17056 light minenwerfers.

NUMBER OF ROUNDS REQUIRED TO DESTROY A GIVEN TARGET

(BASED ON THE LAWS OF PROBABILITY.)

Notation:

Let N = number of rounds fired for effect.
n = number of rounds used in ranging.
X = total number of rounds required.
y = depth of target, in meters.
x = width of target, in meters.
P = probable error in range.
P′ = probable error in direction.
a = destructive area of one bomb.

Case I. x, not greater than 2P′; y, not greater than 2P (Fig. 9).

$$X = N + n = \frac{16\ PP'}{a} + n.$$

Derivation:

Consider center of impact on center of target, or the target anywhere wholly within the 25% rectangle.

xy = area of target.
4 PP′ = area of 25% rectangle.
$\frac{N}{4}$ = number of rounds falling in 25% rectangle.

Let t = number of rounds hitting target.

Then, $t : \frac{N}{4} = xy : 4\ PP'$, assuming that the shots are evenly distributed over 25% rectangle. The flatness of the probability curve in the vicinity of its median makes the above assumption sufficiently approximate for an ammunition estimate.

$$t = \frac{Nxy}{16\ PP'}$$

$\frac{xy}{a}$ = number of hits on target necessary to destroy it.

$$\frac{Nxy'}{16\ PP} = \frac{xy}{a} \text{ or } N = \frac{16\ PP'}{a} \text{ and } X = \frac{16\ PP'}{a} + n.$$

It will be observed that Case I reduces to the number of rounds necessary to destroy the total 25% rectangle. The case is applicable to emplacements, dugouts, machine-guns, etc., as targets. For very small targets, the lessened chance of direct hits is somewhat compensated for by the closer grouping of shots near the center of impact.

Case II. x, not greater than 2 P′; y, greater than 2 P and not greater than 4 P (Fig. 10).

(*a*) Center of impact adjusted on center of target.

In this case only 16/25 as many shots fall on the zones of the target, outside the 25% rectangle, as on the inside.

$$\therefore \frac{16}{25} \times \frac{N}{4} \times \frac{xy}{4\ PP'} = \frac{xy}{a} \text{ or } N = \frac{25\ PP'}{a}$$

$$\text{and } X = \frac{25\ PP'}{a} + n.$$

(*b*) (Fig. 11) Adjust center of impact one probable error from near edge of target and for N/2 rounds. Then increase range by 2 P′ and fire N/2 rounds. It will be seen from the figure that 16% (approximately 1/6 of the shots) is the lowest for any zone of the target.

$$\therefore \frac{N}{6} \times \frac{xy}{4\ PP'} = \frac{xy}{a} \text{ or } N = \frac{24\ PP'}{a}$$

$$\text{and } X = \frac{24\ PP'}{a} + n.$$

Case II is applicable to barbed wire entanglements, communication trenches or other trenches on which enfilade fire can be obtained, as targets. It will be observed that little advantage in number of rounds required is obtained by shifting center of impact, hence case II*b* will seldom be used except in cases where observation can be had only on one edge of the target.

Case III. x, not greater than 2 P′; y, greater than 4 P and not greater than 6 P (Fig. 11).

Center of impact is adjusted one probable error from near edge of target and N/2 rounds fired. Then the range is increased by 4 P and N/2 rounds fired.

From the figure, it will be seen that 11½ per cent., or approximately 1/8 of shots, is the lowest for any zone of the target.

$$\therefore \frac{N}{8} \times \frac{xy}{4\ PP'} = \frac{xy}{a} \text{ or } N = \frac{32\ PP'}{a}$$

$$\text{and } X = \frac{32\ PP'}{a} + n.$$

This case is applicable to enfilade fire on trenches, or attack on barbed wire entanglements.

Case IV. x, greater than 4 P′ and not greater than 6 P′; y not greater than 2 P (Fig. 12).

Adjust the center of impact on center of right (left) flank of target and employ fire as in Case III; shifting center of impact 4 P′ left (right) instead of in range.

In the same manner as in Case III: $X = \frac{32\ PP'}{a} + n.$

This case is applicable to direct fire on trenches or to cutting wide breaches through barbed wire entanglements.

Case V. x, greater than 4 P′ and not greater than 6 P′; y, greater than 4 P and not greater than 6 P.

This is a combination of III and IV.

Apply case III to right (left) flank of target, then shift 4 P′ left (right) and repeat.

In the same manner as in case III:

$$\frac{N}{16} \times \frac{xy}{4\ PP'} \quad \frac{xy}{a} \text{ or } N = \frac{64\ PP'}{a}$$

$$\text{and } X = \frac{64\ PP'}{a} + n.$$

It will seldom be found necessary or advisable to use Case V. The element of time would, as a rule, prevent such employment of a single mortar.

The above formulas involve only the probable error of a materiel and the destructive area of the bomb used and are therefore general for all armament and applicable as soon as range tables are established.

While not strictly exact, they will be found sufficiently accurate to estimate the ammunition required for a given mission and to aid in determining the duration of fire when proper observation cannot be obtained. Whenever possible, the result must be determined by observation.

APPENDIX

TABLE VI

Manoeuvring Possibilities of Trench Mortars.

Dimensions of materiel and transportation of same:

Type of Mortar	Dimensions of Platforms in Gun Pit			Weight		Transportation of Materiel	
	Width	Length	Height	Total (Not Counting Tool Chest)	Of Heaviest Part	Number of men necessary to carry gun complete with tool Chest	Conveyances
58 No. 2	meters 1.80	meters 1.64	meters 1.05	Kgs. 853	Kgs. 75	29	2 park wagons can carry 3 mortars complete 1 light two-wheeled cart will carry 1 gun and platform 1 tool box 1 charge chest 2 fuse boxes
6″ Newton	0.70	1.07	1.5	189	115.4	12 when using light sub-bed	
240 mm.	4.00	2.60	2.45	3500	345		1 gun is transported on 4 light two-wheeled carts: 1 gun barrel cart 1 gun carriage cart 1 gun bedplate cart 1 service box cart

TABLE VII.

LENGTH OF TRENCH MORTAR COLUMNS IN MARCHING ORDER ON THE ROAD.

Formation	Battery	Combat train	Total length
	meters	meters	meters
Battalion H. Q.	——	——	70
Batteries of 58 No. 2.	260	70	330
of 6″	"	"	"
of 240 mm.	210	70	330

TABLE VIII.

TRANSPORTATION OF AMMUNITION WITHIN THE BATTERY.

Weight per round: Inclusive of bomb, charge, primer, fuse and crates:

58.2 . . . . . LS Bomb . . . . . 28 kg.
DLS Bomb . . . . . 53 kg.
6″ Newton . . . . . .
240 mm. . . . . 100 kg.

Type of gun	Transport by hand	Transport by cart	Transport by wagon (crated)
58 No. 2	1 man can carry 2 small bombs 1 large bomb	On bomb cart 16 small bombs 10 large bombs	50 small 30 large
6″	1 man can carry: 2 bombs	1 bomb is transported in a box 8″ × 8″ × 26″	
240 mm.	With bomb carrier 2 men can carry 1 bomb	On bomb cart 4 bombs	12 bombs

TABLE IX.

Bomb Carrying Capacity of Motor Trucks.

Type of Ammunition	5 Ton Trucks	4 Ton Trucks	3½ Ton Trucks	3 Ton Trucks	2½ Ton Trucks
58. 2 light bombs	170	140	120	105	85
heavy bombs	90	70	60	50	40
6 Newton	200	160	140	120	100
240 mm	50	40	35	30	25

TABLE X.

Bomb Carrying Capacity of Narrow Gauge and Normal Gauge Railway Cars.

Type of Ammunition	Narrow Gauge Car	French Railroad Box Car
58–2 light bomb	150	200
heavy bomb	70	60
6″ Newton	250	1000
240 mm	70	100

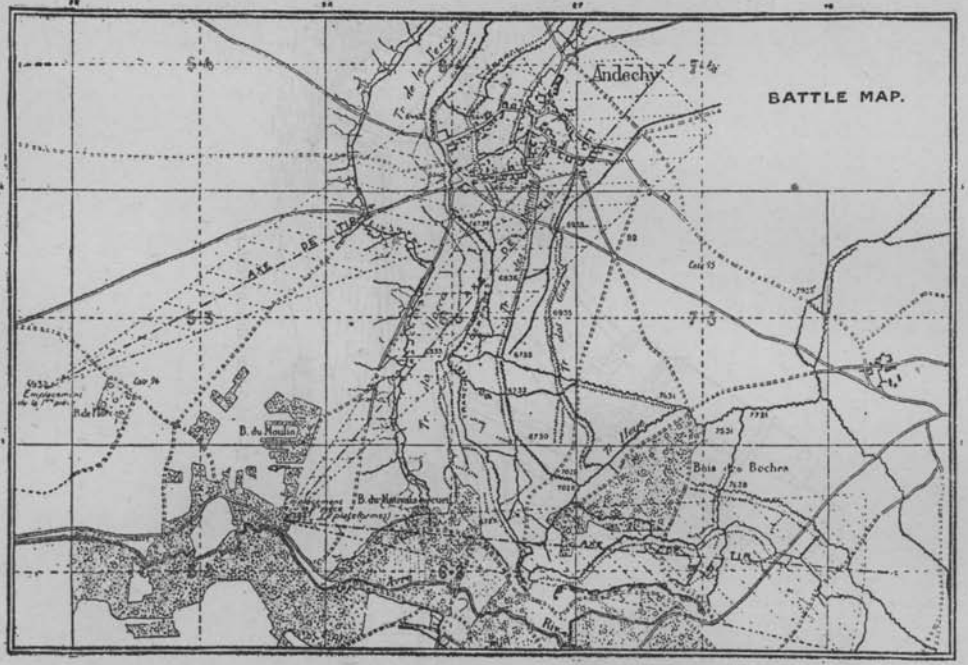
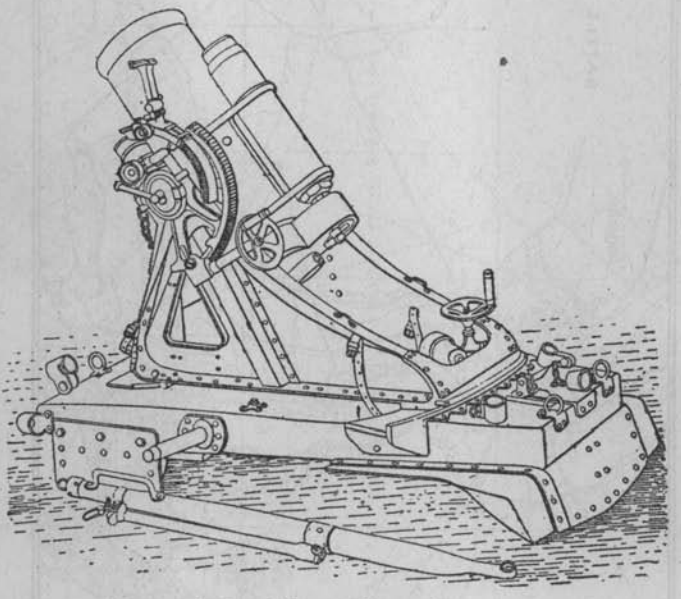


Fig. 2.



Fig, 3. — 24.5 mm. Minenwerfer.

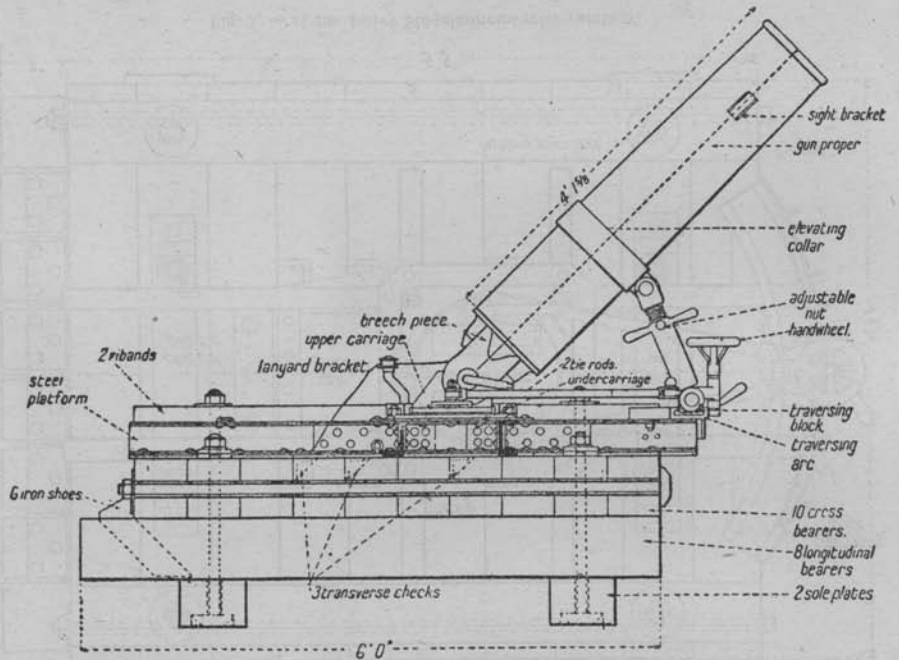


Fig. 4. — 24 cm. heavy Flügelminenwerfer.

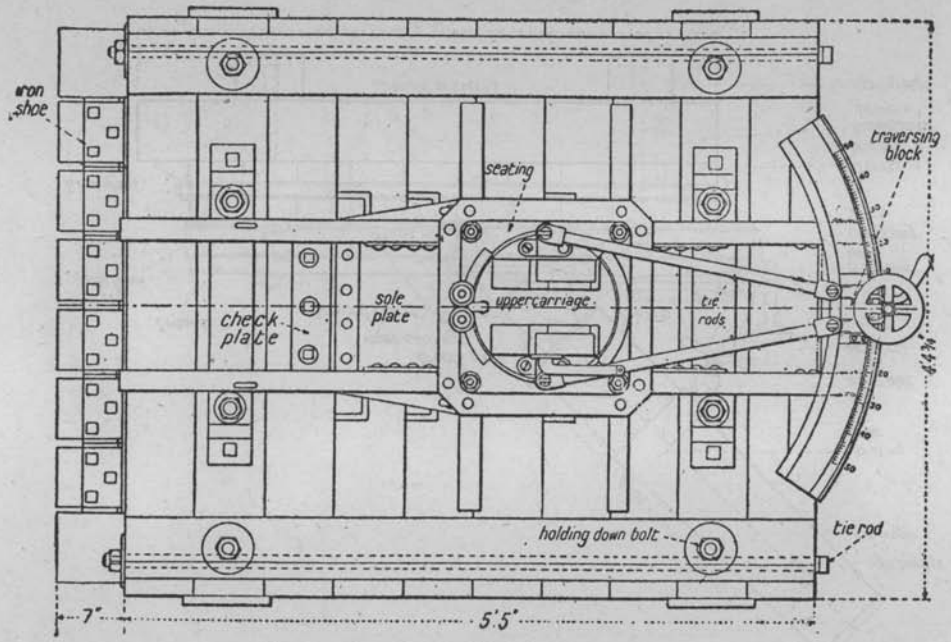


Fig. 5. — 24 cm. heavy Flügelminenwerfer carriage.

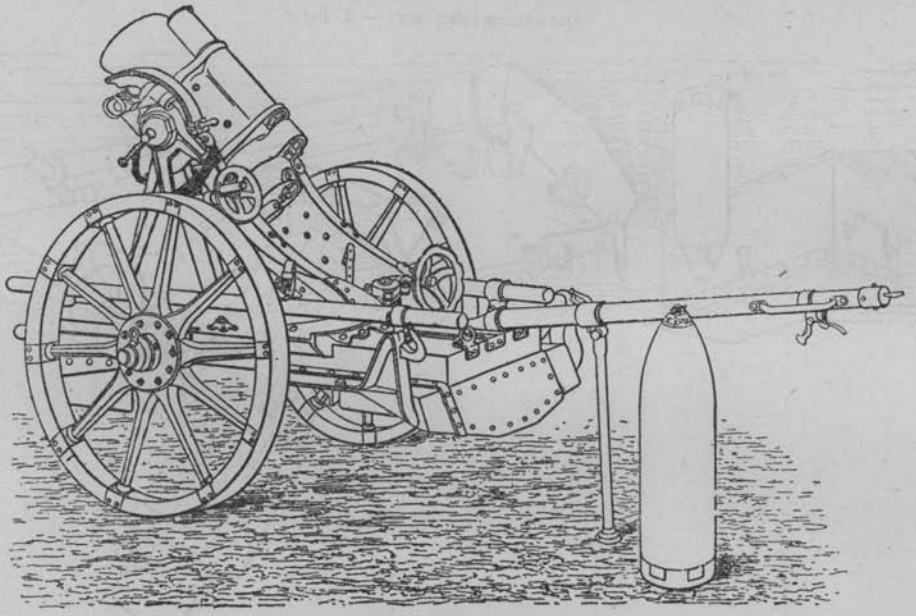


Fig. 6. —17 cm. medium Minenwerfer.

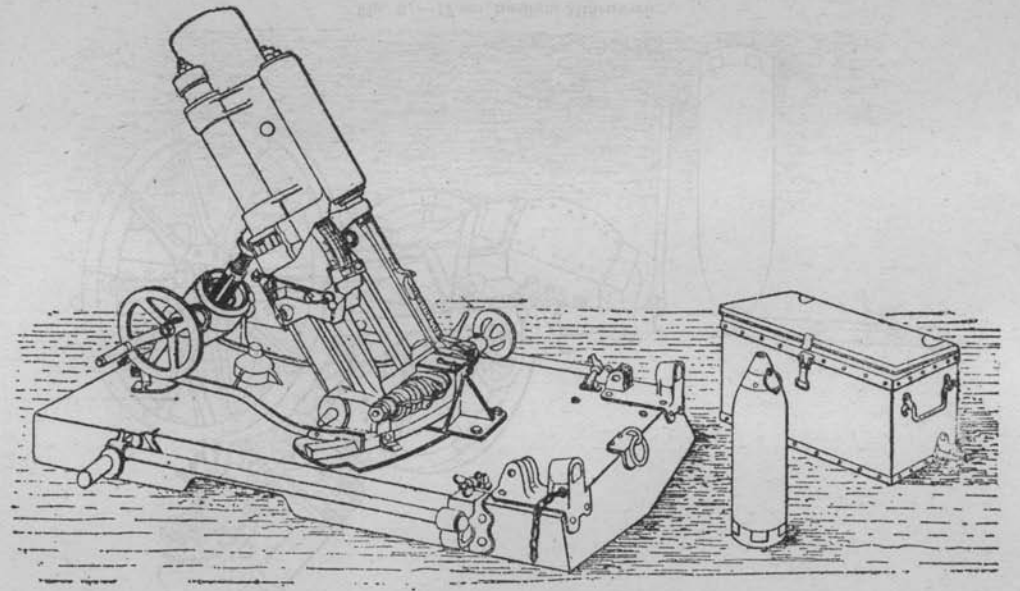


Fig. 7. — 7 cm. Light Minenwerfer.

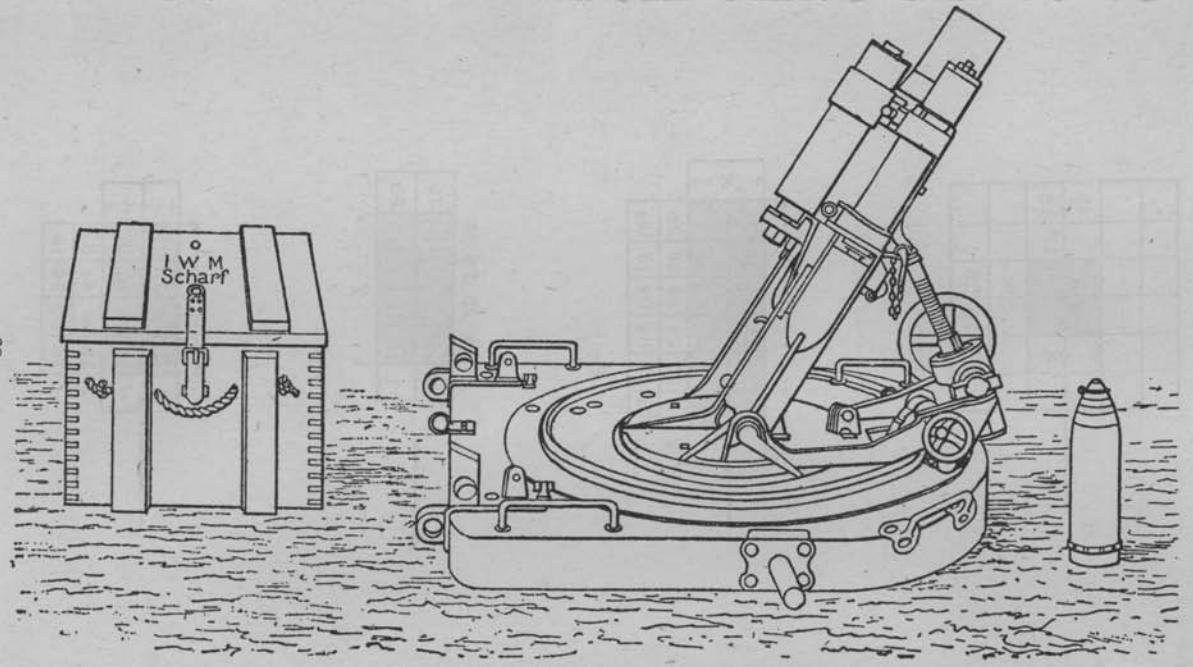


Fig. 8.—7.6 mm. Light Minenwerfer, Model 1916.

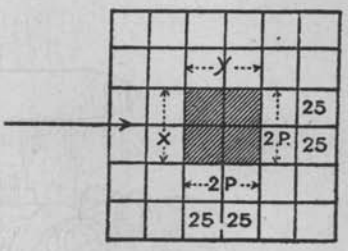


Fig. 9.

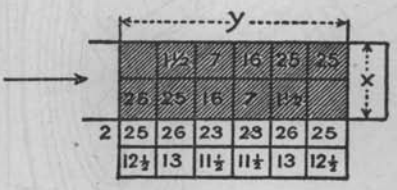


Fig. 10.

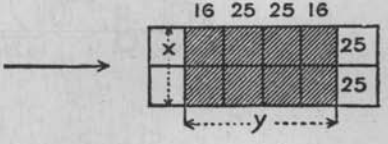


Fig. 11.

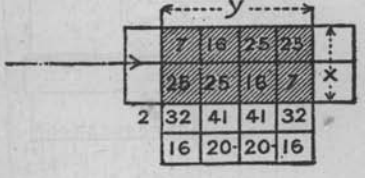


Fig. 12.

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